An Innovative of Pyramid-Based Fusion for Generating the HDR Images in Common Display Devices

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Abstract

In this paper, a method for generating the HDR images in the common devices is introduced. It can be done without computing the step of tone mapping compression. By using the dodge and burn technique with the pyramid-based technique, the resulted image can achieve both in global and local information. Firstly, a set of different exposed images in each pixel is measured for representing the well-exposed value. Then, the high intensity of the input images with dramatically changing values during the sequence of image will be reverted the occurrence, white becomes dark. Then, the pyramid-based blending technique is applied to fuse and reconstruct the set of input images. During the fusion step, the selection between inputA and inputB are used to improve the local information and avoid the visible seam. Finally, the HDR image is generated to show in the common devices. The superior of the algorithm is it does not require any information of camera response or the exposure values. Our experiments show the efficient results comparing to the existing methods.

1 Introduction

In the past decades, high dynamic range (HDR) technique has been one of significant techniques for expanding the range of the luminance levels. By following the acquisition pipeline of HDR image, a set of different exposed images, from the darkest to the brightest, is used to combine and capture the detail. It also required the function of camera response and the information of exposure values to linear the intensity of each exposed image. Anyway, most of the obtained results still have the wider dynamic range than the common devices. In the other word, it cannot directly display the HDR images in the common devices [1]. To overcome the problem, various tone mapping techniques have been implemented for compressing the dynamic range to match the ranges of display devices.

In stead of compressing the dynamic range, several researchers try to skip the step of computing the tone mapping operators. It can be done by measuring the salient areas or the pixels along the sequence of input images and merge them together. These kinds of techniques are called as the image fusion. Goshtasby et al. and Varkonyi-Koczy et al. proposed the block-based approach with the same size to measure and select the most salient areas along the sequence of input images [2],[3]. The performance of algorithm depends on the size of the block and the width of blending function. Jo et al. and his colleagues presented the cluster-based method with arbitrary shape areas with the bilateral filter [4]. The algorithm can achieve the high quality image. On the contrary, the computational time is very high due to the computational cost of bilateral filter. Mertens et al. created the quality measurements based on the global function represent as the weighted map. Then, the pyramid-based is used to fuse and reconstruct the resulted image [5]. The algorithm can immediately produce a well-exposed image for displaying in common devices. However, it cannot achieve the local information due to the limitation of pyramid-based fusion at the high levels of pyramid. In this paper, the proposed algorithm is also based on multi-scale of pyramid-based decomposition approach. The high luminance value which it has lots of change in the sequence of input images will be converted from white to black using dodge and burn techniques. The effect in each level of pyramid is also considered in this approach in order to retrieve the local information without constructing the seam boundary and halo effects.

The context of paper is organized as follows. the algorithm description is given in section 2. The result and discussion are provided in section 3. and the section 4 shows the conclusion of this paper.

2 Algorithm description

In this paper, the proposed method is based on Merten et al.'s work which it used the pyramide-based technique for fusing the set of images. The pyramid-based is a technique to to decomposed the image into various spatially scales of image based on interpolation and extrapolation methods. Normally, the pyramid-based can decompose the image into 2 types; gaussian pyramid and laplacian pyramid which represent the spatially low-passed scales and spatially band-passed scales of the image respectively.

To form the gaussian pyramid, the 2-D gaussian low-passed filter is applied to the input image G_0. Then, the low-passed image is sub-sampled using the interpolation methods. Finally, the reduced image G_1 is obtained. By repeating the steps, various scales of Gaussian pyramid are obtained as $G_0, G_1, G_2, ..., G_N$

$$G_k = S \downarrow (G_{k-1} * LP_k), \quad k = 1, 2, ...N \tag{1}$$

In case of laplacian pyramid, the extrapolation methods are used. By extrapolating the image G_N to G_{N-1} and subtracting it together,the band-passed image L_N occurs.

$$L_k = \begin{cases} G_k - S \uparrow (G_{k+1}), & k = 0, 1, 2, ...N-1 \\ G_k, & k = N \end{cases} \tag{2}$$

To reconstruct the resulted image, the sum of extrapolation of laplacian pyramids can be expressed as:

$$G_0 = L_0 + \sum_k S \uparrow (L_{k+1}), \quad k = 0, 1, 2, ...N-1 \tag{3}$$

The pyramid-based is a wisely technique for applying in the image processing [6]. Its approach can be applied to estimate the missing information by reconstructing extrapolated pyramid. It is also applied into image fusion or merging techniques in order to preserve the local information and keep the seamless of the boundary as following expression:

$$L\{R\}_k = \sum_{m=1}^{S} G\left\{\dot{W}\right\}_k^m L\{I\}_k^m \tag{4}$$

Where $L\{I\}_m^k$ is the laplacian pyramid of a set of input images, and $G\{W\}_m^k$ is the gaussian pyramid of a set of weighted map. Finally, $L\{R\}^k$ is reconstructed using eq.3 to get the resulted image.

The Merten et al's algorithm is very effective. Anyway, it still has the problem if the set of images contain small local details. The algorithm cannot retrieve those information nicely, some details may overexposed and become white color as shown in Fig. 1. In fact, the problem on the small local areas come from the step of interpolation and extrapolation methods. When the image is sub-sampled to lower scale, the neighbor pixels are used to estimate the sub-sampling pixel. By Repeating the step til the smallest size of image, it can notice that the information of local detail of the images may change due to the effect of interpolation.

For example, Let define the Fig. 2 as a weighted map which represent the quality of measurement of the image, from low to high [0,1]. In this case, the weight map image represents the low quality of measurement in the local details (circle mark). Then, the gaussian pyramid of weighted map is sub-sampled its image from original size, from level to level, until it reaches the smallest size (2x1). If the smallest size of weight map is extrapolated as same as the original image G_0, it can notice that the details on local area is changed from dark to gray. It means the quality of measurement is changed from low to high. when the guassian pyramid is applied into fusing equation, eq.4). The value of unwanted pixel will change. Moreover, if the information of high level of pyramid is changed, it will effect to other levels of pyramid when it come through the step of reconstruction pyramid. Finally,

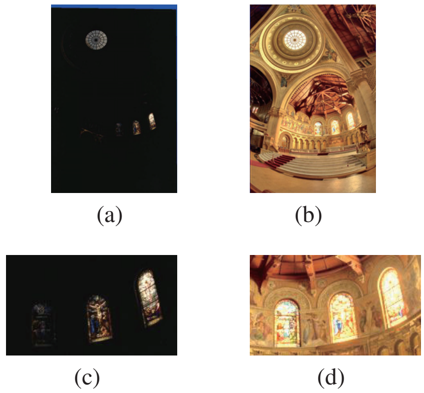

Figure 1: A Comparison between Merten's et al. and source of input images. (a) One of input images. (b) The resulted image generated by Merten's et al. with σ equal to 0.2 [5]. (c) and (d) Zoom versions of (a) and (b). Image courtesy of Paul Debevec.

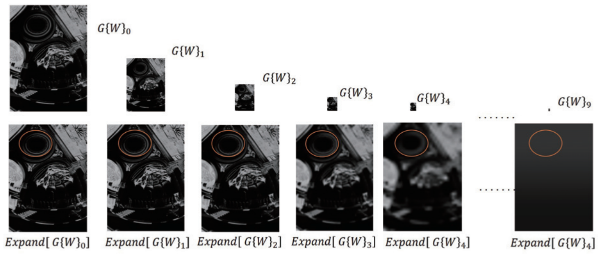

Figure 2: Multiresolution interpolation. Top row: an example of Gaussian pyramid generates from level $G\{W\}_0$ to $G\{W\}_9$. Bottom row: the extrapolation to the same size of G_0

the local detail will disappear because the local information values is exceed than one (white color). This issue is considered to be inherent limitation of pyramid-based technique.

To overcome the problem, a new framework, Fig.3 , using the dodge and burn technique with pyramid-based technique are introduced. The main ideas come from the property of Gaussian function which it is used to measure the quality of the pixel. Based on the symmetric property of Gaussian function, it can say that the best quality of the pixel is located on the middle of the graph, 0.5, where the worst quality of the pixels are located on the left and the right of the graph, 0 and 1, or, black and white. In stead of changing the value in high level of Gaussian pyramid. The dodge and burn technique is applied into set of input images to the high intensity pixels. The targeted pixel will be compressed from high intensity to low intensity in order to compensate the values in the step of fusion image at the high level of pyramid. Finally, the resulted image which preserve the small local area will obtain.

2.1 Quality measurement

In an image, it consists of several information which contain a good-looking areas, colorless or vivid regions depends on the exposure values of photograph. However, only the attractive areas should be preserved. To satisfy the assumption, the pixel in each color channel is measured using the Gaussian function separately

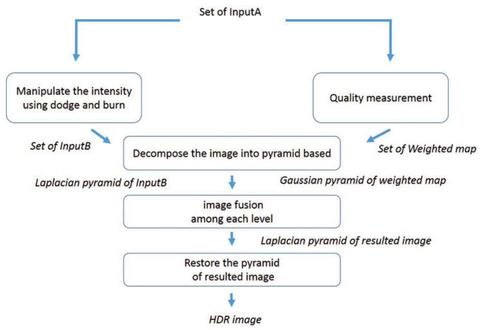

Figure 3: The overview of algorithm.

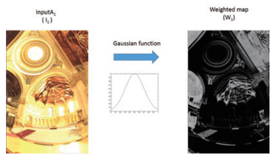

Figure 4: An example of quality measure using Gaussian function for generating weighted map image.

and multiply each channel to get the weighted map W. The mid-tone of intensity is assumed to be the highest quality for selecting the pixels while the bright and dark tone pixels are assumed to be the low quality. In this case, σ is set equal to 0.2.

$$W_m(i,j) = e^{-\frac{(R_m(i,j)-0.5)^2}{2\sigma^2}} \times e^{-\frac{(G_m(i,j)-0.5)^2}{2\sigma^2}} \times e^{-\frac{(B_m(i,j)-0.5)^2}{2\sigma^2}} \tag{5}$$

Finally, the normalzation technique is used to adjust the values from the different scales into the unit scale, 0 to 1 as shown in Fig. 4 .

$$\dot{W}_m(i,j) = \frac{W_m(i,j)}{\sum_{m=1}^{S} W_m(i,j)} \tag{6}$$

2.2 Manipulate the intensity using dodge and burn technique

As mentioned in section 2, the limitation of pyramid-based technique could make the some losses on the local areas. For this reason, it is necessary to decrease the high intensity pixel, from high to low to compensate the value when it come through the step of image fusion. To handle the problem, the dodge and burn technique is used. For this implementation, the value that exceed 90% of the maximum pixel, α, and also has the differentiation between maximum and minimum along a set of images more than 70%, β, is considered to be burnt out. The set of images after manipulate the intensity are shown in Fig. 5.

$$I_{B,m}(i,j) = I_{A,m}(i,j) \times B_m(i,j) \tag{7}$$

$$B_m(i,j) = \frac{I_{A,m}(i,j)}{I_{A,m}(i,j) + \delta_m(i,j)} \tag{8}$$

$$\delta_m(i,j) = \begin{cases} 1, & \begin{cases} I_{A,m}(i,j) \geq \alpha \\ max([I_A(i,j)]) - min([I_A(i,j)]) \geq \beta \end{cases} \\ 0, & Otherwise \end{cases} \tag{9}$$

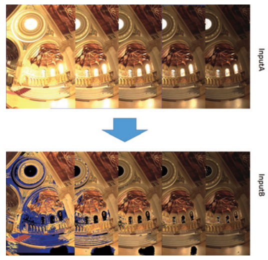

Figure 5: An example of Manipulate the intensity using dodge and burn technique. The high intensity pixels with large dramatically changed along the sequence are burnt out.

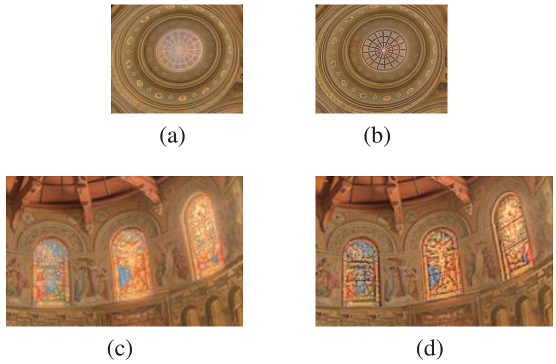

Figure 6: An example of image fusion. (a) The resulted image using only a set of $InputB$. (b) The resulted image using the combination between set of $InputA$ and $InputB$. The boundary of the small local areas can be recovered. (c) and (d) Zoom versions of (a) and (b).

2.3 Image fusion

After manipulate the high intensity value, the set of $InputB$ is occurred which it is ready to apply into the pyramid-based fusion as shown in eq. 4). However, using only the set of $InputB$ may not enough to recover the boundary of the small local areas. This problem comes from the burn out effect in subsection 2.2 which may burn some parts of boundary away as shown in Fig. 6. To recover the boundary transition, the first level of Laplacian pyramid is replaced by the set of $InputA$ instead of $InputB$.

$$L\{R\}_1 = \sum_{m=1}^{S} G\left\{\dot{W}\right\}_1^m L\{I_A\}_1^m$$

3 Result and discussion

In the experiment, various kinds of image are tested for measuring the performance of algorithm. In a set, the number of input image are varied from 3 up to 16, from over-exposed to under-exposed images. No requirement on the camera response, shutter speed, or the exposure value of the input images. The algorithm is operated under MATLAB $x64$ bits with Intel core I5-3210M CPU at 2.5 GHz. The proposed results are compared with several methods such as the original

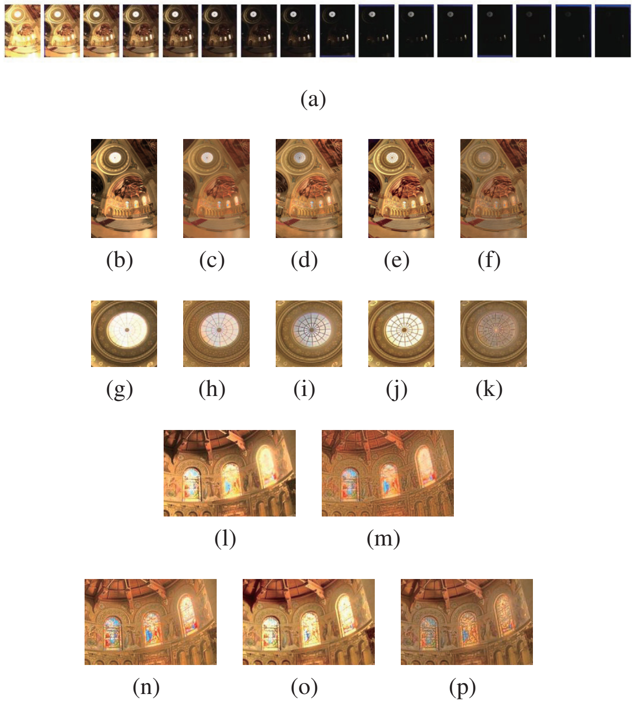

Figure 7: The result of proposed HDR image compare to other techniques. (a) Source of the input images. (b) - (f) The resulted HDR images from Ward et al. [8], Tumblin and Turk et al. [9], Fattal et al. [10], Mertens et al.[8], and the proposed method respectively. (g) - (k) Zoom versions of (b) - (f) spot at windows. (l)-(p) Zoom versions of (b) - (f) spot at the roof. Image courtesy of Paul Debevec.

method from Merten's et al.[5], and the tone mapping compression from several works [7].

In term of quantity, the proposed method is very effective. It can retrieve most of information, including the small local information as shown in Fig 7. Compare to other methods, the proposed method can achieve the better information such as the detail roof, walls, and especially in the windows of the church.

In term of quality, using just only the well-exposed from the intensity values make the resulted images look a bit darkens when compare to the others. Moreover, in some case, the resulted image can generate an unnatural looking image which come from the effect of dodge and burn. In fact, in the certain areas of the images, the various exposures will vary against them, from over to under-exposed. However, the effect of burn out make the certain area lost the high values from the over-exposed areas. Compare the targeted area with the neighborhood, the certain areas could look a bit darker and make the unnatural images.

4 Conclusion

The technique to retrieve the local information using pyramid-based technique has been introduced. Instead of compressing the dynamic range, the method to find the well-exposed pixel is used to make the HDR image can monitor in the common devices. With the proposed method, it does not need any information of the camera.

The proposed technique based on reducing the high intensity values, from white to dark, in order to compensate the changed value at the step of image fusion at the high level of pyramid. The proposed results show that the algorithm can handle the problem very well. However, due to the effect of dodge and burn, the resulted image have a chance to generate the unnatural image too.

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