Detail-Enhanced Weighted Guided Image Filter Based Multi-scale Exposure Fusion

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ABSTRACT

Multi-scale exposure fusion is an image enhancement technique for high dynamic range (HDR) visualization that is presented to fuse multiple images with different exposure times of the same HDR scene into a good quality low dynamic range (LDR) image. Two algorithms called weighted guided image filter (WGIF) based Multi-scale exposure fusion and Detail-Enhanced exposure fusion are proposed for increased fusion of different exposed LDR images. The WGIF based multi-scale exposure fusion algorithm is proposed to merge the differently exposed LDR images of a high dynamic range scene individually. WGIF is used to smooth the Gaussian pyramid of weight map for all LDR images. The relative brightness is protected by the proposed WGIF based multi-scale exposure fusion algorithm. To increase the quality of fused image, a fast detail layer extraction algorithm is proposed. Further to design a detail extracted layer, the two detail layers of dark and bright images are calculated. The proposed algorithm has been introduced mainly to protect the details in the darkest and brightest regions, as well as to avoid appearing in images related to blurred artifacts.

Index terms :- Exposure fusion, Weighted guided image filter, Detail extracted layer.

1.INTRODUCTION

The scenes which are visible to human eye have a large dynamic range which is not possible to capture with a digital camera in one shot. Cameras can capture either darkest regions or brightest regions of an image. The cameras and sensors which are embedded in mobiles have less capacity to capture lights of different ranges. So combining multiple low dynamic range (LDR) images of a same scene with different exposure times is a best way to overcome this limitation. Dynamic range is the ratio between maximum and minimum luminance intensity values of an image. The images which are less than or equal to the dynamic range 1000:1 are considered as LDR images.

There are two techniques for combining LDR images, one is HDR imaging and another is exposure fusion. In HDR imaging set of LDR images are combined to form an HDR image and then by applying tone mapping algorithms in [3], a HDR image is converted into LDR image to view image on LDR display devices. Exposure fusion is an algorithm in which a high quality LDR image is directly produced from the set of LDR images. Three quality measures are there to know how much the given pixel will match with the final produced image [4]. The set of LDR images forms a pyramid of several down-sampled layers using the Laplacian pyramid [6]. Finally all the images in the set of LDR images were combined at various scales using an approach called pyramidal image decomposition. The image fusion using guided image filtering was proposed in [7].

Multi-scale exposure fusion [1] is a popular and effective technique in which images at different levels are formed in a pyramid format by using Gaussian and Laplacian pyramid techniques. A guided filter is used to smooth the edges of pyramids. This technique does not require any knowledge about exposure time and lighting conditions of a scene. These fusion techniques in [1], [4] and [7] cannot preserve color information in the thickest and darkest parts of a HDR scene. To overcome this drawback a detail layer extraction concept is introduced in [5]. Based on observation the algorithm in [4] gives best results and the second best is the algorithm in [5]. One algorithm can preserve color information in the thickest and/or darkest parts of a scene and another one can preserve the relative brightness between the different parts of an image. But unfortunately, there is no algorithm can preserve both relative brightness and color information in the darkest and/or thickest parts of a scene.

So to overcome this insufficiency Detail-enhanced WGIF based multi-scale exposure fusion is introduced in this paper. WGIF based multi-scale exposure fusion algorithm is introduced to combine set of LDR images by using a filter WGIF to produce intermediate fused image. Detail-enhanced multi-scale exposure fusion extracts detailed layer from the input images. Finally detailed layer will add to the intermediate fused image to produce high quality LDR image. The proposed algorithm produces good quality LDR image directly without forming an intermediate HDR image. In this paper the set of LDR images are three images. One is under exposure image and the second is normal exposure image and the third is over exposure image. The luminance of the inputs and pyramids serves as the guide images.

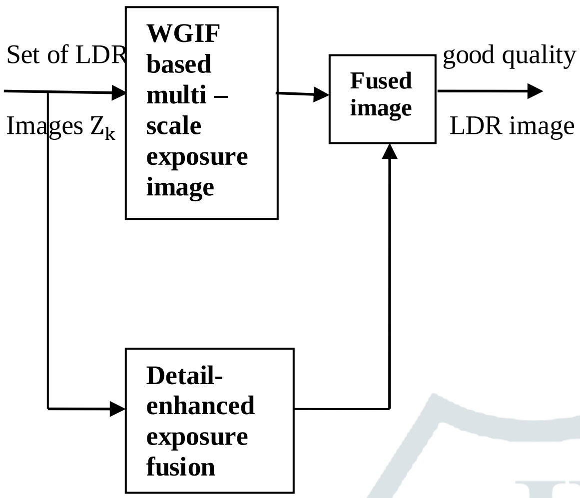


Fig. 1: Flow chart of the proposed method

2. WEIGHTED GUIDED IMAGE FILTER

In the fields of photography and image processing a lot of applications require image smoothing that can preserve edges. The weights of the edges are incorporating into the existing guided image filter (GIF) [8] to form WGIF. The WGIF in [9] is a local linear model between guide image and input image which has to be smoothed. Both GIF and WGIF are the image filters which are used for edge preserving and smoothing of an image. Both image filters can transfer structures from guide image to filtered output.

Algorithm: Guided Image Filter

Input : The input image I, guide image g, radius r, regularization parameter λ.

Output : filtered output o.

1. $\text{mean}_g = f_{\text{mean}}(g)$
   $\text{mean}_I = f_{\text{mean}}(I)$
   $\text{corr}_g = f_{\text{mean}}(g.* g)$
   $\text{corr}_{gI} = f_{\text{mean}}(g.* I)$
2. $\text{var}_g = \text{corr}_g - \text{mean}_g.* \text{mean}_g$
   $\text{cov}_{gi} = \text{corr}_{gi}\text{mean}_g.* \text{mean}_p$
3. $a = \text{cov}_{gI}./(\text{var}_g + \text{eps})$
   $b = \text{mean}_I - a.* \text{mean}_g$
4. $\text{mean}_a = f_{\text{mean}}(a)$
   $\text{mean}_b = f_{\text{mean}}(b)$
5. $o = \text{mean}_a.* g + \text{mean}_b$

where f_{mean} is a mean filter.

The weights of the edges incorporate into GIF to form WGIF. The weights of edges are defined using local variances of 3 x 3 windows of all pixels is given in the below equation :

$$\Gamma_g(p') = \frac{1}{N}\sum_{p=1}^{N}\frac{\sigma_{g,1}^2(p')+\varepsilon}{\sigma_{g,1}^2(p)+\varepsilon}, \qquad (1)$$

Where g be a guide image, ε is a small constant and its value as $(0.001*L)^2$ while L is the dynamic range of an input image and $\sigma_{g,1}^2(p')$ be the variance of g in the 3 x 3 window. If the value of $\Gamma_g(p')$ is greater than 1 then pixel p' is at an edge of an image and less than 1 then the pixel p' is in a smooth region.

3. WEIGHTED GUIDED IMAGE FILTER BASED MULTI-SCALE EXPOSURE FUSION

Let Z_k ($1 \leq k \leq 3$) be the set of LDR images with different exposure times. The set of three input images are under exposure image, normal exposure image and over exposure image. The luminance of the image Z_k is Y_k . The luminance of the image Z_k is calculated by converting RGB image into Ycbcr image and extracting Y component from Ycbcr image. There are three quality metrics in [4]. They are contrast, saturation and well-exposedness. The contrast of the image Z_k is calculated by applying a Laplacian filter to the gray-scale version of each input LDR image. The saturation is obtained by calculating the standard deviation within the red, green and blue channels of an image. The well-exposedness can be attained by applying a gauss curve to red, green and blue channels separately. The results of contrast, saturation and well-exposedness are multiplied and their product is noted as $\acute{W}_k(p)$. By using this product $\acute{W}_k(p)$ the weight map was constructed.

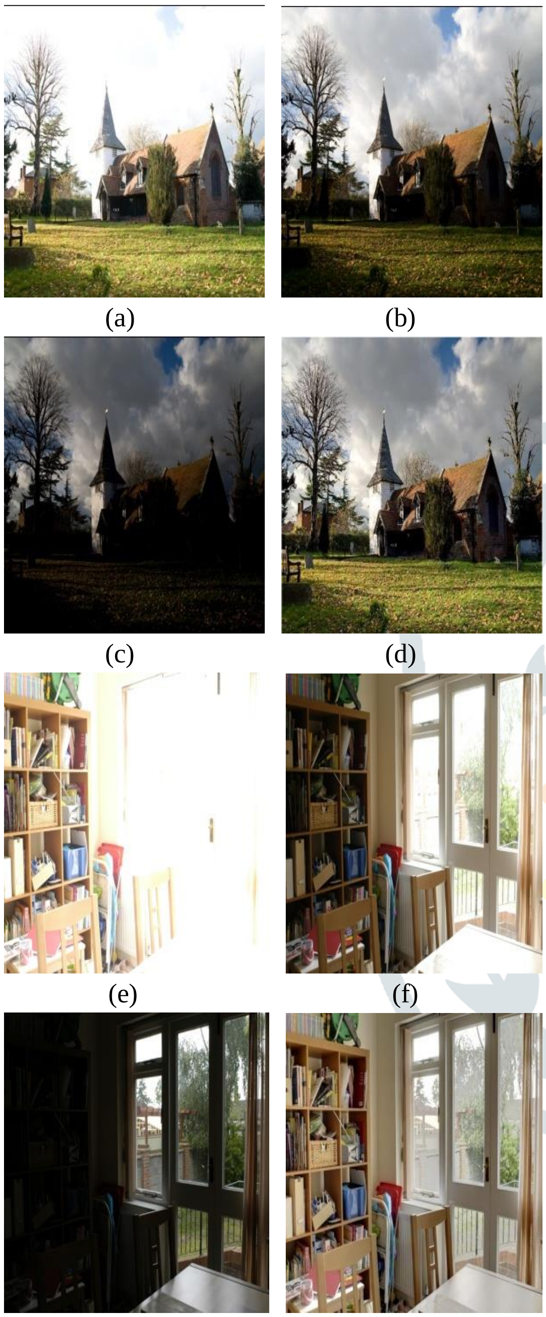
The weight map of the quality metrics is denoted as

$$W_k(p) = \frac{\acute{W}_k(p)}{\sum_{j=1}^{N}\acute{W}_j(p)} \qquad (2)$$

The Gaussian pyramids of luminance Y_k and weight map $\acute{W}_k$ are $G\{Y_k\}^{(l)}$ and $G\{w_k\}^{(l)}$ respectively. The Gaussian pyramid $G\{Y_k\}^{(l)}$ is acts as a guidance pyramid and the Gaussian pyramid $G\{w_k\}^{(l)}$ is a pyramid to be smoothed. The number of layers in a pyramid is calculated using the equation as follows

$$l = \lfloor log_2 \min(w,h) \rfloor - 2 \qquad (3)$$

Where $\lfloor x \rfloor$ denotes the biggest integer which is not larger than x, w denotes the width of the input image and h denotes the height of the input image. WGIF is a filter which is used to smooth the Gaussian pyramids of the set of LDR images is introduced. Here WGIF based pyramid is to combine the images



(a) (b) (c) (d) (e) (f) (g) (h)

Fig. 1: The Weighted guided image filter (WGIF) based multi-scale exposure fusion. (a)-(c), (e)-(g) are input images. (a), (e) is the over exposure image, (b), (f) is the normal exposure image and (c), (g) is the under exposure image and (d), (h) is the intermediate fused image by the proposed algorithm.

of different exposure times. To this WGIF pyramid the Gaussian pyramid of luminance $G\{Y_k\}^{(l)}$ is acts as guidance pyramid and the Gaussian pyramid of weight map $G\{w_k\}^{(l)}$ acts as an input which has to be smoothed. Assume the coefficients of the WGIF as $\{a_i\}^k$ and $\{b_i\}^k$ and these coefficients are calculated by using the method in [4]. The radius r was fixed at 4 and the regularization parameter λ have been fixed at 1/1024. The WGIF based pyramid is formed by using the equation as follows

$$\{\acute{W}_k\}^{(l)} = \{a_i\}^k \{Y_i\}^{(l)} + \{b_i\}^k \; ; 1 \leq l \leq k. \quad (4)$$

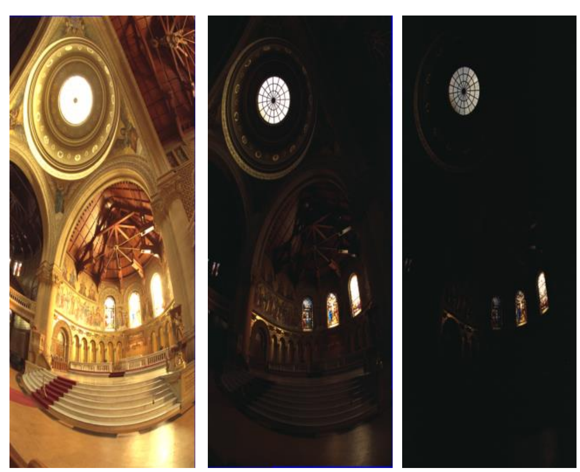
The Laplacian pyramid of all the input images are formed and it is denoted as $L\{Z_{k,j}\}^{(l)}$. The images Z_k $(1 \leq k \leq N)$ are blended at the different pyramid levels of Laplacian pyramid. The Laplacian pyramid of the intermediate fused image $L\{Z_j^{int}\}^{(l)}$ is formed as

$$L\{Z_j^{int}\}^{(l)} = \sum_{k=1}^{N} [L\{Z_{k,j}\}^{(l)} \{\acute{W}_k\}^{(l)}]; j \in \{r, g, b\} (5)$$

The Laplacian pyramid $L\{Z_j^{int}\}^{(l)}$ of the intermediate fused image is decomposed to produce the intermediate fused image. The proposed WGIF based multi-scale exposure fusion preserves brightness among the pixels very well.

4. DETAIL-ENHANCED EXPOSURE FUSION

A detail layer extracted from the input images can be added to the intermediate fused image to improve the quality of images. The main drawback of the proposed WGIF based multi-scale exposure fusion is that it cannot preserve fine details in the darkest and thickest regions of a HDR scene. To overcome this drawback a detailed layer is extracted from input images and adding detailed layer to the intermediate fused image. In the proposed approach 2 detail layers are extracting from the input images, one is detailed layer of the darkest regions and another is a detailed layer of the thickest regions. The detailed layer of the darkest regions can be extracted from the over exposure image because over exposure images can preserve fine details in the darkest regions and the detailed layer of the thickest regions can be extracted from the under exposure images because the under exposure images can preserve fine details in the thickest regions.

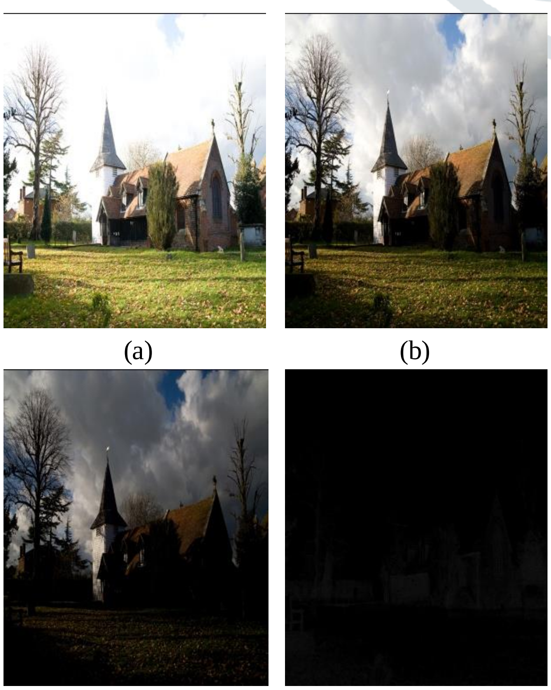


(a) (b) (c)

(d) (e)

Fig. 3: The detail layers extraction from the input images Z_k using algorithm in [12]. (a)-(c) are the input images, (d) is the D_{dark} detailed layer extracted from the thickest image Z_1 to get fine details at dark regions of a scene, (e) is the D_{bright} detailed layer extracted from the darkest image Z_3 to get fine details at bright regions of a scene.

Assume the set of LDR images Z_k $(1 \leq k \leq 3)$ with different exposure times. Assume the intermediate fused image as R. Z_1 be the thickest image and Z_3 be the darkest image in a set of LDR images. Let the luminance of the fused image is denoted as R_y and the luminance of the thickest and darkest images is denoted as Z_1^y and Z_3^y. The luminance of the intermediate fused image R, thickest image Z_1^y and darkest image Z_3^y are calculated by converting to Ycbcr image and extracting Y channel from the Ycbcr image. The edge preserved and smoothed images $\hat{Z}_1^y$ and $\hat{Z}_3^y$ can be obtained by applying WGIF on Z_1^y and Z_3^y respectively. The detailed layer of the



(a) (b)

(c) (d)

(e) (f)

Fig. 2: The proposed Detail-enhanced exposure fusion in [12]. (a)-(c) are input images, (d) is the extracted detail layer D_{dark}, (e) is the extracted detail layer D_{bright}, (f) is the detail enhanced image.

darkest regions D_{dark} from Z_k is obtained as

$$D_{dark} = \left(Z_1^y - \hat{Z}_1^y\right) \quad (6)$$

In D_{dark} only the darkest regions from the bright image are extracted into a detailed layer. When the image Z_1^y is the image to be edge preserved and smoothed then the image $(1 - R_y)$ behaves as a gradient targeting image. The detailed layer of the thickest regions D_{bright} is obtained as

$$D_{bright} = \left(Z_3^y - \hat{Z}_3^y\right) \quad (7)$$

In D_{bright} only the thickest regions from the dark image are extracted into a detailed layer.

Finally the extracted detailed layers are added to the luminance channel of the intermediate fused image as follows

$$R'_y = R_y + \theta\left(D_{dark} + D_{bright}\right) \quad (8)$$

Where θ is constant and the θ value can be in the range from 0.1 to 2. The obtained image R'_y is a single channel image. While the cb channel and cr channel remain the same as the intermediate fused image. So to get high quality LDR image which has to be in RGB format can be obtained by converting Ycbcr color space into RGB color space.

6. CONCLUSION

In this paper WGIF based multi-scale exposure fusion and detail enhanced exposure fusion algorithms were proposed. WGIF based pyramids which are multi-scale representation of images are formed and further the fused image of exposure fusion is extracted. In the detail-enhanced exposure fusion the detailed layers were extracted from the dark and bright images. Further to improve the quality of fused image the detailed layers are added to the fused image. By the proposed algorithm it is possible to view HDR images on LDR displays.

8. REFERENCES

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