Electronic Letters on Computer Vision and Image Analysis 16(2): 13-16; 2017

Detail Enhanced Multi-Exposure Image Fusion Based on Edge Preserving Filters

Harbinder Singh

Department of Electronics and Communication Engineering, Jaypee University of Information Technlogy (JUIT), P.O. Waknaghat, Teh Kandaghat, Distt. Solan, PIN- 173234, India

Advisor: Dr. Sunil Vidya Bhooshan

Date and location of PhD thesis defense: 01 September 2016, JUIT, Waknaghat, Solan, India.

Received 15th Jul 2017; accepted 8th Oct 2017

Abstract

Recent computational photography techniques play a significant role to overcome the limitation of standard digital cameras for handling wide dynamic range of real-world scenes contain brightly and poorly illuminated areas. In many of such techniques [1, 2, 3], it is often desirable to fuse details from images captured at different exposure settings. One such technique is High Dynamic Range (HDR) imaging that provides a solution to recover radiance maps from photographs taken with conventional imaging equipment. One of the long-standing challenges in HDR imaging technology is the limited Dynamic Range (DR) of conventional display devices and printing technology. Due to which these devices are unable to reproduce full DR. Although DR can be reduced by using a tone-mapping, but this comes at an unavoidable trade-off with increased computational cost. Therefore, it is desirable to maximize information content of the synthesized scene from a set of multi-exposure images without computing HDR radiance map and tone-mapping. This thesis attempts to develop a novel detail enhanced multi-exposure image fusion approach, which exploits the edge preserving capability of adaptive filters.

Introduction

It is impossible to capture the entire DR of the real world scene with single exposure. This is due to the limited capabilities of Charge Coupled Device (CCD) or Complementary Metal Oxide Semiconductor (CMOS) sensor chip. Human eye is sensitive to relative rather than absolute luminance values and can observe both indoor and outdoor details simultaneously while digital camera cannot record indoor and outdoor luminance variations in single snapshot. This is because the eye adapts locally as we scan the different regions of the scene and can adapt 10 orders of magnitude of intensity variations in the scene [4], while standard digital cameras are unable to record luminance variation in the entire scene. To circumvent this problem, modern digital photography offers the concept of exposure time variation to capture details in very dark or extremely bright regions, which control the amount of light allowed to fall on the sensor. Currently, there are many applications that involve variable exposure photography to determine the details to be captured optimally in the photographed scene. The intention of exposure setting determination is to control charge capacity of the CCD or CMOS.

In exposure fusion, compositing is done on the pixel intensity values rather than irradiance values. Approaches proposed in this thesis do not care about the exposure times and CRF, which is required to

Correspondence to: harbinder.ece@gmail.com

Recommended for acceptance by Anjan Dutta and Carles Sánchez
http://dx.doi.org/10.5565/rev/elcvia.1126
ELCVIA ISSN: 1577-5097
Published by Computer Vision Center / Universitat Autonoma de Barcelona, Barcelona, Spain

linearize the image data before combining LDR exposures into HDR image [2]. Following the consideration of pixel intensity based fusion; the ultimate goal of this thesis is the utilization of computationally simple and robust texture features for the identification of well-exposed regions across input exposures and detail enhancement in the fused image.

Motivation

Nowadays much research is going on in the area of exposure fusion. The techniques proposed in the present thesis do not limit interest for developing yet another new algorithm. Rather, the aim is to select and apply the aspects of perception of weak textures which should be considered in the context of exposure fusion, to generate weight maps, and to seek further possibilities for detail enhancement by exploiting edge preserving capability of non-linear filters. Although the proposed frameworks do not require human intervention, in practice, the present work provide set of parameters that allow users to interactively control the detail enhancement in the fused image.

Contribution

The first proposed technique [4] takes N identically sized multi-exposure images taken from a fixed viewpoint, and produces output fused image of the same size, in which well exposed pixel value is computed by combining information from all input images at each scale of the decomposition. Unlike earlier image-based compositing techniques [3], our technique separates coarse scale details called Base Layer (BL) from fine details known as Detail Layer (DL). Therefore, it is effective to manipulate finer and coarser details separately during the compositing process, and needs no further post processing for detail enhancement. After the manipulation of each redundant layer, fused base layer, and fused detail layer are recombined to produce well exposed detail enhanced fused image. Thus, the magnitude of the BLs is modified based on the decision maps [4] to ensure that resulting fused image contains well-exposed regions, while the magnitude of the DLs is unchanged. This technique exploits the properties of nonlinear Anisotropic Diffusion (AD) [5] which permits to manipulate and combine details at multiple scales [4].

In second approach [6], with the multi-exposure images captured under different exposure settings, first the fine details are extracted based on Guided Filter (GF) [7]. Next, the BLs (i.e. images obtained from GF) across all input images are fused using multi-resolution pyramid [6]. Exposure, contrast and saturation measures are considered to generate weight map function that guides the fusion process of the BLs. Finally, the fused base layer is combined with the extracted fine details to obtain detail enhanced fused image. The GF [7] is preferred over AD [5], because it has better response near strong edges [6].

In this thesis a novel technique for exposure fusion is proposed in which Weighted Least Squares (WLS) [8] optimization framework is utilized for weight map refinement [9]. Computationally simple texture features (i.e. DL extracted with the help of AD) and color saturation measure [9] are preferred for generating weight maps that control the contribution from an input set of multi-exposure images. Instead of employing intermediate HDR reconstruction and tone-mapping steps [1, 2], well-exposed fused image is generated for displaying on conventional display devices. The block diagrammatic representation of detail enhanced WLF framework is shown in Figure 1. This third method is proposed for automatic exposure fusion that exploits the capability of edge preserving filter [5] to generate weight function. Furthermore sigmoid function based weight map refinement is utilized for detail layer fusion.

Results

Another interesting interactive tool of proposed third approach [9] for manipulating the detail and contrast in multi-exposure and multi-focus image fusion has been experimented. Figure 2 illustrates the detail enhancement in multi-exposure image fusion by varying the free parameters used in [9]. The source images used in multi-exposure fusion are shown in Figure 1. Figure 3 shows the results of multi-focus image fusion by varying the free parameters used in weight map optimization technique [9]. The input images used in multi-focus image fusion are shown in Figure 3 (a) and 3 (b).

Conclusion

The present thesis proposes three methods to construct a detail enhanced image from a set of multi-exposure images by using multi-resolution and single-resolution fusion frameworks. When compared with the existing techniques which use multi-resolution and single resolution analysis for exposure fusion the proposed methods perform better in terms of enhancement of texture details in the fused image.

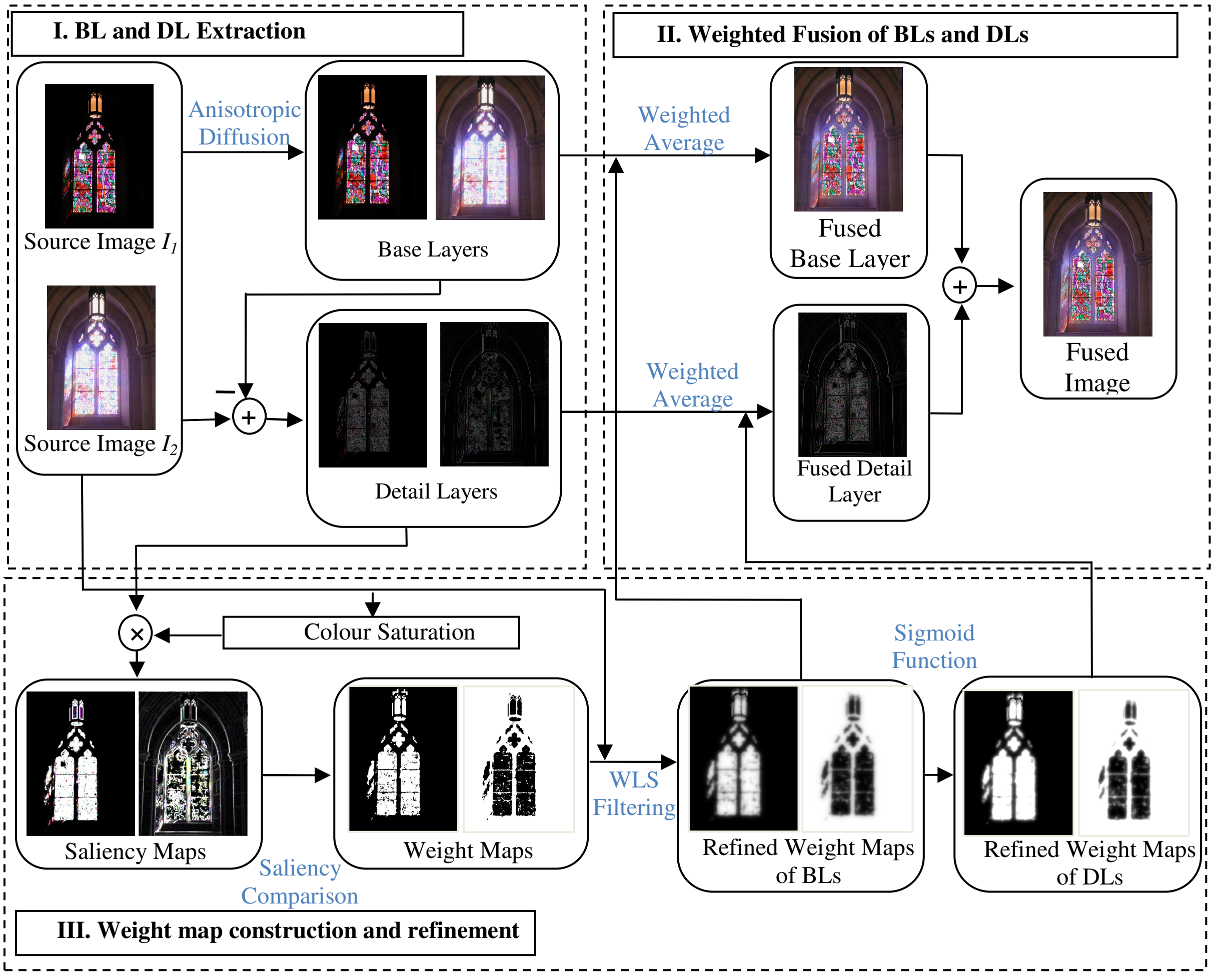

Figure 1: Illustration of WLS filter based proposed framework that consists of three principal blocks. (I) BL and DL extraction. The input images are transformed into two scale decomposition. (II) Weight map construction and refinement. (III) Weighted fusion of BLs and DLs. The BLs and DLs across input image series are fused using simple weighted average approach.

Figure 2: Visual inspection of fine detail enhancement using third approach [9] for multi-exposure image fusion in typical lighting situations. The free parameters in [9] control detail enhancement and sharpening. (a) a = 1, (b) a =6, (c) a = 12.

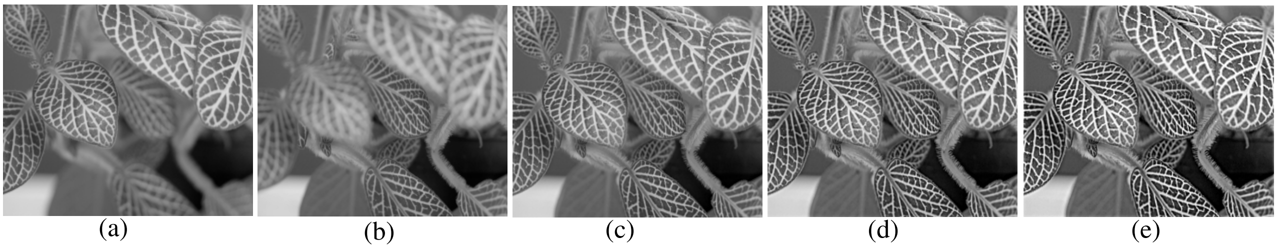

Figure 3: Visual inspection of contrast and detail enhancement in third approach for multi-focus image fusion. The free parameter used in [9] controls detail enhancement and sharpening. (a,b) input multi-focus images, (c) $\psi = 0.5$, a= 7, (d) ψ=0.5, a= 12, (e) $\psi = 0.5$, a= 17.

Permanent web link to the original thesis

https://drive.google.com/file/d/1cVBu_dyB3bt51mflWtSFiOJK5cT-CvbI/view?usp=sharing

References

[1] Fanping Zhou, and Jochen Lang, "Efficient spherical high dynamic range imaging for image-based virtual environments", in *Proc. of IEEE International Symposium on Haptic, Audio and Visual Environments and Games (HAVE),* pp. 124 – 129, October 2014.

[2] Li Zhengguo, and Jinghong Zheng, "Visual-salience-based tone mapping for high dynamic range images", *IEEE Transactions on Industrial Electronics,* vol. 61, no. 12, pp. 7076 - 7082, December 2014.

[3] T. Mertens, J. Kautz, and F. V. Reeth, "Exposure fusion: a simple and practical alternative to high dynamic range photography", *Computer Graphics Forum*, vol. 1, pp. 161-171, 2008.

[4] Harbinder Singh, Vinay Kumar, and Sunil Bhooshan, "Anisotropic Diffusion for Details Enhancement in Multi-exposure Image Fusion", *ISRN Signal Processing,* vol. 2013, Article ID 928971, 18 pages, 2013. doi:10.1155/2013/928971.

[5] P. Perona, and J. Malik, "Scale-space and edge detection using anisotropic diffusion", *IEEE Trans. on Pattern Analysis and Machine Intelligence,* vol. 12, no. 7, pp. 629–639, 1990.

[6] Harbinder Singh, Vinay Kumar, and Sunil Bhooshan, "A Novel Approach for Detail-Enhanced Exposure Fusion Using Guided Filter", *The Scientific World Journal,* vol. 2014, Article ID 659217, 8 pages, 2014. doi:10.1155/2014/659217.

[7] K. He, J. Sun, and X. Tang, "Guided image filtering", in *Proceedings of the ECCV, Lecture Notes in Computer Science, Springer,* vol. 6311, pp. 1-14, 2010.

[8] Z. Farbman, R. Fattal, D. Lischinski, and R. Szeliski, "Edge-preserving decompositions for multi-scale tone and detail manipulation", *ACM Trans. on Graphics,* vol. 27, no. 3, article 67, 2008.

[9] Harbinder Singh, Vinay Kumar, and Sunil Bhooshan, "Weighted Least Squares Based Detail Enhanced Exposure Fusion", *ISRN Signal Processing,* vol. 2014, Article ID 498762, 18 pages, 2014. doi:10.1155/2014/498762.