SCENE-AWARE HIGH DYNAMIC RANGE IMAGING

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ABSTRACT

High dynamic range (HDR) images offer better visual quality by allowing a wider range of luminance and the visual experience is much closer to reality. In this paper, a scene-aware HDR image system is proposed. According to the characteristics of the scene to be captured, the proposed system will first decide whether it is necessary to activate the HDR imaging mode. If the dynamic range of the scene is limited, no HDR imaging is performed. On the other hand, two or three LDR (low dynamic range) images with different exposures are captured to render high-quality HDR images in an efficient way. Experimental results show that the proposed HDR image system is capable of generating HDR images using either two or three LDR images and comparable to some existing techniques where three LDR images are always used.

***Index Terms*—** High dynamic range image, scene recognition

1. INTRODUCTION

HDR images attract growing attention in many practical applications by offering of an extended dynamic range, and improved visual experience. HDR image/video generation [1-2] had been studied for years. Due to the expense and rarity of HDR cameras, many studies generate HDR images using several LDR images with different exposures. When a picture is taken, different content is captured by changing the exposure settings, such as exposure time, ISO value and aperture. For example, there is more detail in the dark region for images taken with a longer exposure time and more detail in the bright region for images with a shorter exposure time. It explains why it is feasible to realize HDR imaging by combining several LDR images with varying exposure settings.

In general, there are two ways to generate HDR images: one is based on the construction of the camera response function (CRF) [3]; other one is fusion-based HDR, called exposure fusion [4]. Usually, the complexity of CRF-based HDR imaging is higher than that of fusion-based one. Furthermore, tone mapping [5] is needed to convert the HDR images into LDR images to display the HDR images on the conventional display. Usually, the quality of tone mapped LDR images is not only determined by the HDR image, but is also affected by the tone mapping technique used. In [6], a subjective evaluation of tone mapping methods is reported and it indicates that distinct visual differences exist between LDR images with various tone mapping methods for the same HDR image source. As a result, fusion-based method is more robust to reveal the quality of the synthesized HDR and several works address the improvement of exposure fusion by changing the method in determining the weight of each pixel [7-8] during the fusion process. Digital cameras supporting automatic HDR imaging are already available in the market. The quality of the rendered HDR image depends on the method of combining, as well as on the selection of the LDR images. One simple HDR imaging can be accomplished by fusing LDR images with various exposures, for example, well-exposed, under-exposed and over-exposed LDR images. Usually, the well-exposed image, denoted as 0 EV (exposure value) image, is the first captured image by metering on the center of the scene, and under-exposed and over-exposed images are captured by setting the exposure value by fixed values (i.e., -1EV and +1 EV). Although it is able to obtain the HDR image using these LDR images, the HDR image quality is not always guaranteed due to varying luminance condition and characteristics of the scene to be captured. To overcome this problem, our previous work [9] introduces a technique to intelligently determine the exposure parameters and the experimental results show that better HDR images can be generated, compared to those images created by the method with fixed exposures.

In additional to our previous work, several works also deal with the selection of LDR images [10-12]. According to different scenario, three algorithms to determine the minimum bracketing set for HDR imaging are proposed in [10]. In [11-12], HDR image systems are realized on a mobile camera. Both concern how to determine the shot number and the corresponding exposures. Two preview images with short and long exposures satisfying the given condition are selected and analyzed in [11]. The same problem is solved with an optimization criterion considering the dynamic range and the signal-to-noise ratio in [12]. This paper presents a system to capture the scene and produce high-quality image. The proposed system has two features. First, the image is captured after metering is performed on the region selected by the user, instead of on a fixed region (e.g., the center of the scene). Usually, enhanced contrast appears in the image region which

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corresponds to the metering region. If the metering region is the region of interest (ROI) for the user, the captured image will present high quality in the ROI. By allowing users to select the metering region, HDR/LDR image with good quality can be always yielded. Second, in the proposed framework, the number of multi-exposure LDR image is intelligently determined. We will analyze the first LDR image and decide whether HDR imaging mode should be activated. For the scene with limited dynamic range, the first LDR image is able to represent the scene and no further LDR image is shot to avoid the energy consumption due to picture capturing and HDR image fusion. On the other hand, if the HDR mode is used, the number of LDR image and the corresponding exposure will be efficiently determined by the proposed system.

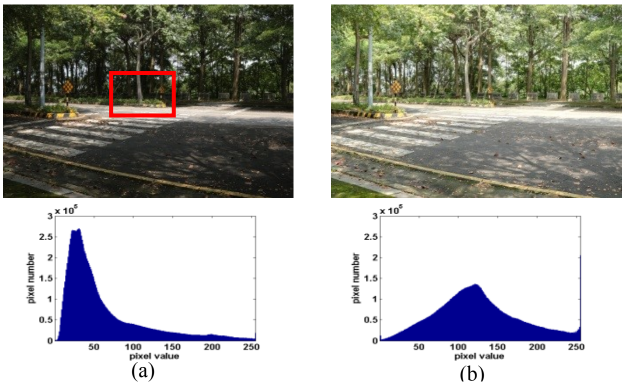


Fig. 1. LDR images and histograms for the scene “Campus”.

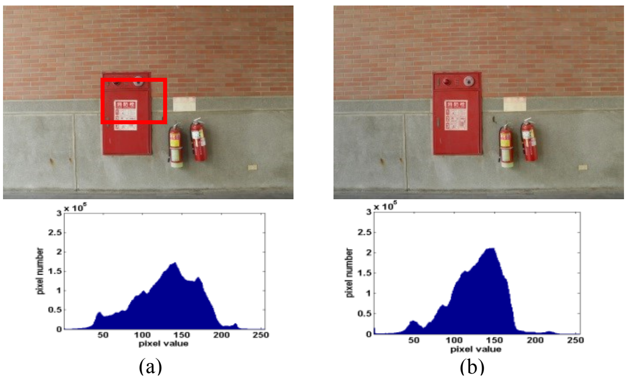


Fig. 2. LDR images and histograms for the scene “Wall”.

2. OBSERVATIONS ON THE SYNTHESIZED HDR IMAGES

HDR images provide a better visual experience by presenting a wider dynamic range. To illustrate the visual difference, as well as some statistics between the LDR image and HDR image, Fig. 1 and Fig. 2 show the pictures captured in two scenes and their luminance histograms, where (a) is a LDR image and (b) is a fusion-based [4] HDR image by fusing three-exposure LDR images (i.e., 0 and ±2 EV). The red frame in the image represents the metering region and the picture is shot using the exposure after metering is performed on it. In the scene “Campus”, Fig. 1(a) shows that the brightness on the road is not consistent due to the shadow and it is almost impossible to have a good shot revealing all the detail in this scene. The histogram in Fig. 1 shows that the distribution in (a) is mostly concentrated in the low intensity area and thus the entropy is smaller than that in (b). From Fig. 1, we realize that the HDR image provides richer brightness information, in addition to a wider dynamic range.

Fig. 2 presents the results for the scene “Wall”, where the brightness within the scene is more homogeneous. We find that both the picture quality and histograms in (a) and (b) are similar. Based on the observation in Fig. 1 and Fig. 2, we arrive at the conclusion: if the histogram of the LDR image is concentrated in low intensity range, the scene is probably not well reproduced in this image and HDR imaging is suggested to be activated. Similarly, it should be also applicable to LDR image with concentrated density in high intensity range. On the other hand, if the intensity distribution is more flat and over a wide range, there might be no need to take additional pictures for accomplishing HDR imaging.

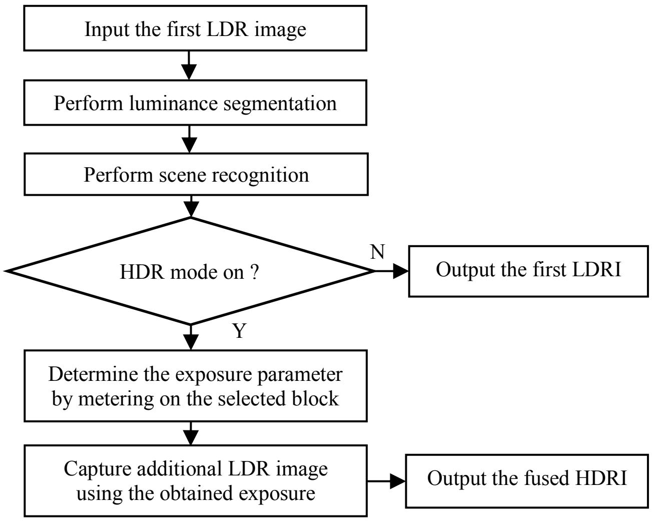
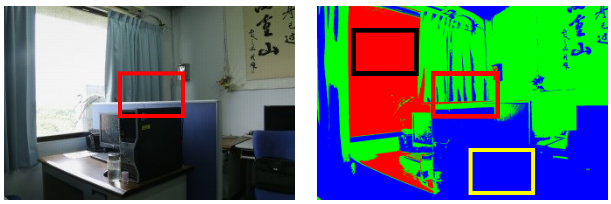


Fig. 3. The flowchart of the proposed system.



(a) the first LDR image (b) luminance segmentation

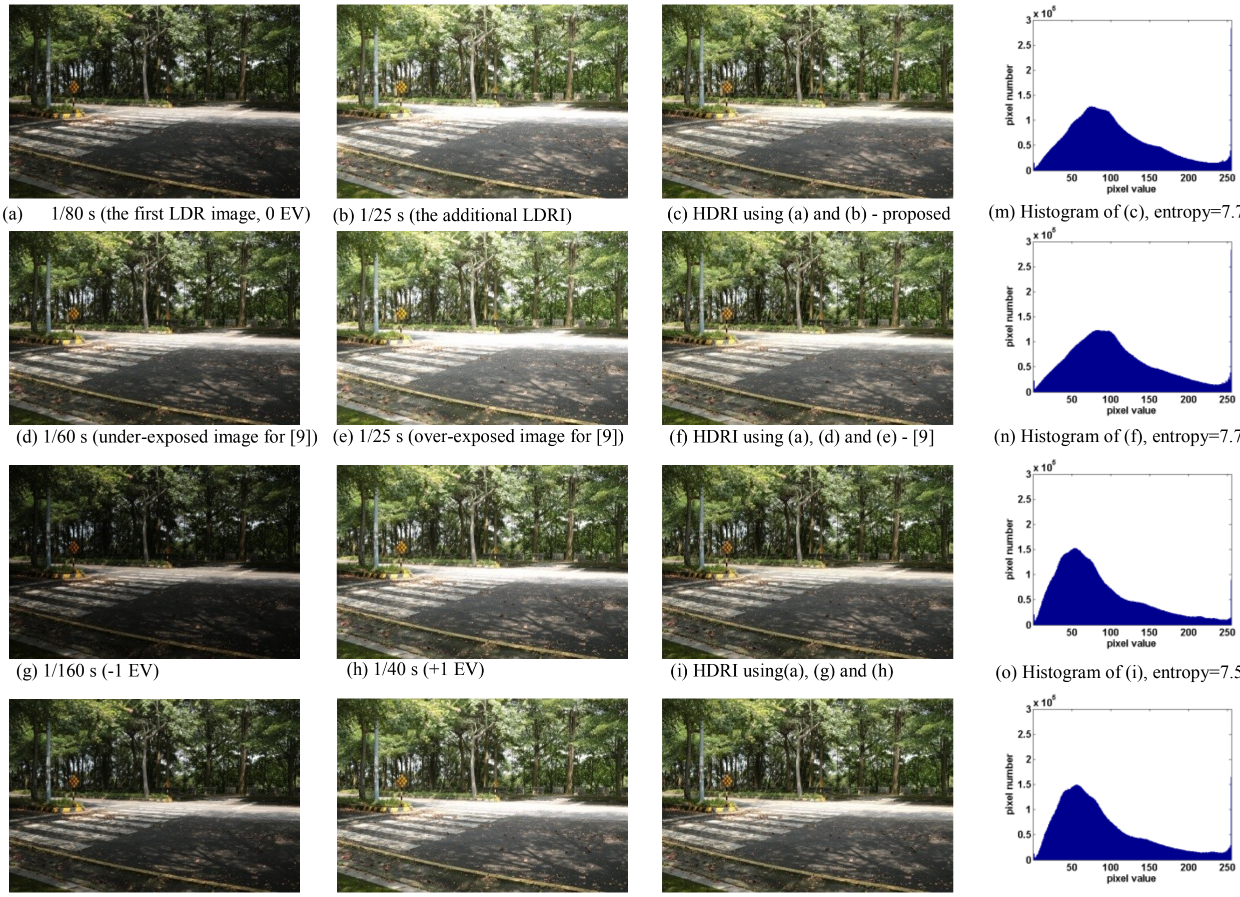
Fig. 4. The luminance segmentation and representative blocks.

3. PROPOSED SYSTEM

Inspired by the observation in Section II, we have an idea to design our system: it is not necessary to always capture three LDR images for HDR imaging. If the scene to be captured has very limited dynamic range, there is no need to activate HDR imaging. To know whether HDR mode should be used, we need to estimate the dynamic range of the scene. We call it “scene recognition” in our system. The flowchart of the proposed framework is illustrated in Fig. 3. One LDR image is captured after the metering

(a) The captured LDR image - proposed (b) HDR image [9] (c) HDR image by 0, ±1EV (d) HDR image by 0, ±2 EV

Fig. 5. HDRI (HDR image) for the scene "Chair". (ISO: 100, lens: f/10)



(a) 1/80 s (the first LDR image, 0 EV) (b) 1/25 s (the additional LDRI) (c) HDRI using (a) and (b) - proposed (m) Histogram of (c), entropy=7.70 bits

(d) 1/60 s (under-exposed image for [9]) (e) 1/25 s (over-exposed image for [9]) (f) HDRI using (a), (d) and (e) - [9] (n) Histogram of (f), entropy=7.70 bits

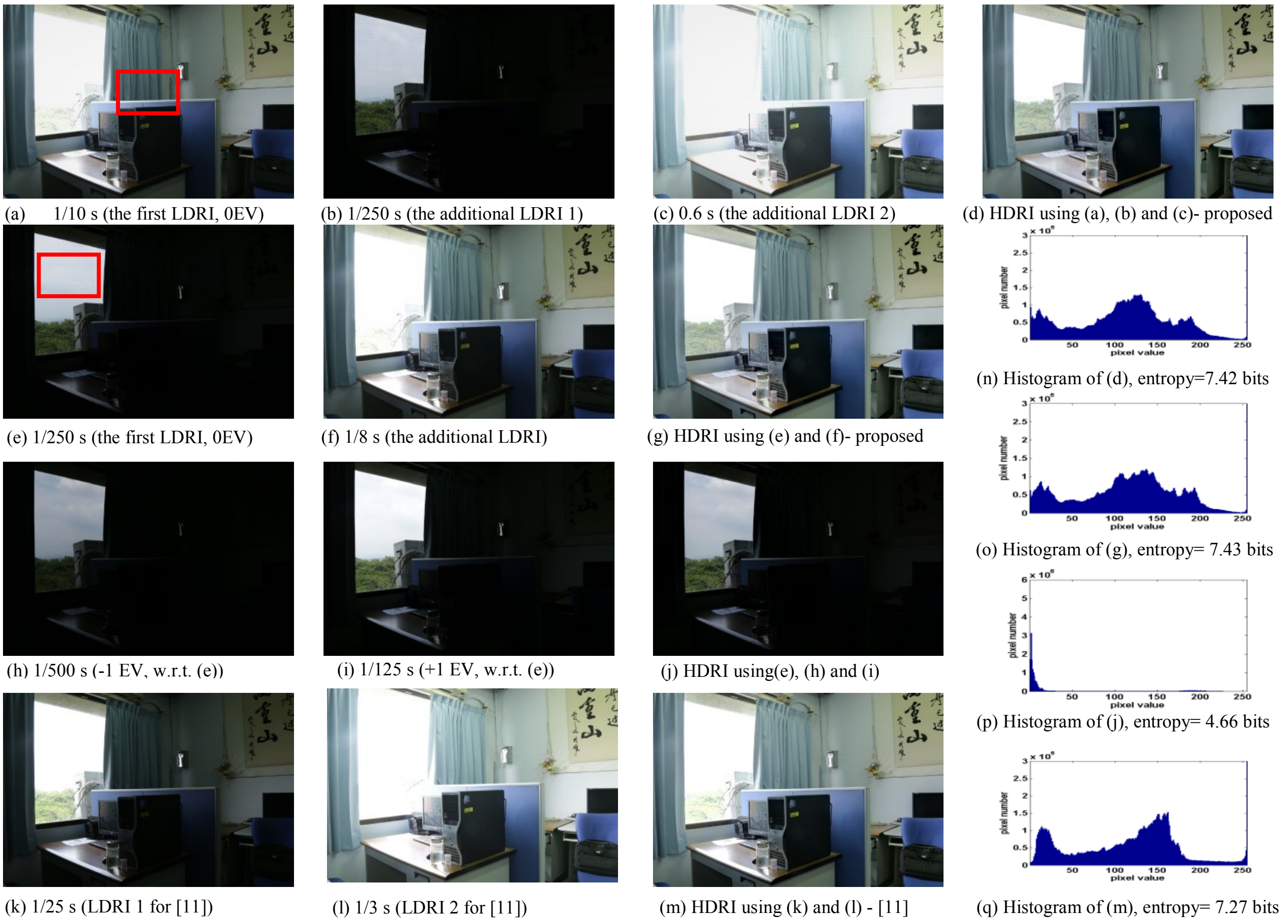
(g) 1/160 s (-1 EV) (h) 1/40 s (+1 EV) (i) HDRI using(a), (g) and (h) (o) Histogram of (i), entropy=7.56 bits

(j) 1/80 s (LDR image 1 for [11]) (k) 1/40 s (LDR image 2 for [11]) (l) HDRI using (j) and (k) - [11] (p) Histogram of (l), entropy=7.59 bits

Fig. 6. HDRI (HDR image) and histograms for the scene "Campus". (ISO: 100, lens: f/10)

region is selected by the user. From Section II, it shows that histogram is able to reveal some information about dynamic range of the scene. We perform luminance segmentation on the downscaled first-LDR image and three groups representing low, middle and high intensities, marked as blue, green and red, respectively, are classified by Lloyd's algorithm. Fig.4 shows an example. The group G_c, to which the metering block belongs, is first identified. In this case, it belongs to group green due to a higher number of green pixels. G_1 and G_2 stand for the remaining two groups. The standard deviation in each group is then computed, denoted as σ_c, σ_1 and σ_2. Usually, more contrast presents in the image part where the metering is performed and it leads to a larger variance for G_c. The scene recognition is accomplished after σ_c, σ_1 and σ_2 are compared and the result is used to decide whether HDR mode should be activated, as well as the number of LDR image to be captured. The rules can be summarized as: If both σ_1 and σ_2 are not smaller than σ_c, it implies G_1 and G_2 also present rich details in the first LDR image and there is no need of HDR mode.

If σ_1 or σ_2 is smaller than σ_c and the difference is larger than a given threshold, the characteristics of the group G_1 or G_2 are not well presented in the first LDR image, and other LDR image revealing the detail for group G_1/G_2 should be captured. Depending on the difference between σ_c and σ_1/σ_2, the number of shot will be determined. To obtain the exposure parameter, we need to find the representative block of G_1/G_2, and performing metering on these blocks. Take the image in Fig. 4(b) for example, to find the representative blocks for group blue and group red in an efficient way, 400 overlapping blocks uniformly partitioned on the luminance image are evaluated. Then the block has minimum sum of distance with respect to



(a) 1/10 s (the first LDRI, 0EV) (b) 1/250 s (the additional LDRI 1) (c) 0.6 s (the additional LDRI 2) (d) HDRI using (a), (b) and (c)- proposed

(e) 1/250 s (the first LDRI, 0EV) (f) 1/8 s (the additional LDRI) (g) HDRI using (e) and (f)- proposed

(h) 1/500 s (-1 EV, w.r.t. (e)) (i) 1/125 s (+1 EV, w.r.t. (e)) (j) HDRI using(e), (h) and (i)

(k) 1/25 s (LDRI 1 for [11]) (l) 1/3 s (LDRI 2 for [11]) (m) HDRI using (k) and (l) - [11]

(n) Histogram of (d), entropy=7.42 bits (o) Histogram of (g), entropy= 7.43 bits (p) Histogram of (j), entropy= 4.66 bits (q) Histogram of (m), entropy= 7.27 bits

Fig. 7. HDRI (HDR image) and histograms for the scene “Lab”. (ISO: 100, lens: f/10)

the mean value of G_1/G_2 will be treated as the representative block, shown as yellow and black frames, respectively, as illustrated in Fig. 4(b).

4. EXPERIMENTAL RESULTS

Several scenes with varied characteristics are captured to evaluate the performance of the proposed system. Due to limited space, only results of three scenes are presented here. For more experimental results, please refer to [13]. In our experiment, the aperture and ISO value are fixed and only the exposure time is changed to capture LDR images for the same scene. The fusion based method [4] is used for HDR imaging. We present the fused HDR image and entropy of the HDR image for subjective and objective quality assessment.

Fig. 5 to Fig. 7 show the results where the HDR images from three LDR images captured with fixed EV, our previous work [9] and the method in [11] are also presented for comparison. The metering is on the center for Fig. 5 and Fig. 6. Fig. 5 presents the results for a scene with limited dynamic range. After analyzing the captured LDR image, the proposed system decides that there is no need for HDR imaging. Compared to fused results using three-exposure LDR images, the captured LDR image presents comparable image quality. Fig. 6 and Fig. 7 present the results for scenes with wider dynamic range, where the captured LDR images, the fused HDR image and luminance histogram for different schemes are illustrated. We find that the proposed system and [11] use two LDR images to accomplish the HDR imaging while [9] and the fixed EV method use three LDR images. Although the proposed system uses two LDR images, it produces visually pleasing HDR image with highest entropy. In [11], it takes time to select two-exposure LDR images and the proposed system is much simpler in deciding the number of shot and the exposure while producing good HDR image.

Fig. 7 demonstrates the influence of the metering region on the first shot. Fig. 7(a) shows the first LDR image when metering is performed on the center. Then two additional LDR images are captured after scene recognition, as shown in Fig. 7(b) and (c). Fig. 7(e) presents the LDR image when metering region is changed to the outdoor. The proposed system determines that only one additional LDR image is needed. In this case, the fixed EV method produces bad HDR image, as shown in Fig. 7(j). The method in [11] is independent from the metering region. It decides that two shots are required. These results show that the shot number in the proposed system depends on the metering region, in addition to dynamic range of the scene. Under the assumption that the ROI will be well rendered in the HDR image, the proposed system determine the shot number efficiently. Regardless of the metering region, the proposed system produces a HDR image with high quality, as demonstrated by the fused HDR images and the histograms.

5. CONCLUSION

This work proposes a simple and intelligent HDR imaging system. Depending on the metering region and the characteristic of the scene to be captured, the proposed system efficiently decides the number of LDR image to record the scene with good quality. When the HDR imaging mode is activated, the experimental results show that the proposed framework is capable of yielding good HDR image using two or three LDR images for a variety of scene.

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