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Retrieving Extended High Dynamic Range From Digital Negative Image - An Experiment On Architectural Photo Imaging

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Abstract**—** The paper explores the development of an optimization of method and apparatus for retrieving extended high dynamic range from digital negative image. Architectural photo imaging can benefit from high dynamic range imaging (HDRI) technique for preserving and presenting sufficient luminance in the shadow and highlight clipping image areas. The HDRI technique that requires multiple exposure images as the source of HDRI rendering may not be effective in terms of time efficiency during the acquisition process and post-processing stage, considering it has numerous potential imaging variables and technical limitations during the multiple exposure process. This paper explores an experimental method and apparatus that aims to expand the dynamic range from digital negative image in HDRI environment. The method and apparatus explored is based on a single source of RAW image acquisition for the use of HDRI post-processing. It will cater the optimization in order to avoid and minimize the conventional HDRI photographic errors caused by different physical conditions during the photographing process and the misalignment of multiple exposed image sequences. The study observes the characteristics and capabilities of RAW image format as digital negative used for the retrieval of extended high dynamic range process in HDRI environment.

Keywords**—**High Dynamic Range Image, Photography Workflow Optimization, Digital Negative Image, Architectural Image.

I. Introduction

HIGH Dynamic Range Imaging (HDRI) has triggered high interest in the academia and commercial industries for scientific development and commercial value. The tone mapping process of HDRI is described as being similar to the burning and dodging process in the conventional film processing darkroom [1],[2]. HDR feature has been integrated in some of the recent commercially released smartphones or digital mobile tablets, boosting the capability and usability of the mobile-based camera. The HDR feature on mobile based camera however has various operational difficulties. Difficulties of HDRI generally begins with acquisition handling efficiency to post-process rendering issues such as ghosting error or multiple exposed images alignment error [5],[6],[7]. The HDRI concept has permitted amateur and professional cameras of having the capability to photographically capture subjects using HDRI method at the in-camera stage or the post-processing stage [11],[12] with the help of HDRI processing operators or tone mapping algorithm. Different HDRI processing operators however may produce differing rendered image outlook especially with various software rendering presets being enabled, this may give the HDRI users an impression that the HDRI technique is mainly meant for the usage of enhancing the aesthetic visualization of photography instead of archiving accurate imageries. The approach of using image documentation is one of the most useful research data collection process [8],[9],[10] and it can be used in the aspect of qualitative archiving architectural photographic context. Photographic imagery being used for any scientific study has to be non-bias in order to demonstrate a higher accuracy of photographic representation during the visual assessments for the assessor [13].

Architectural context from the build industry [14] may have direct relation with the urban morphology related studies [15]. Image is one of the core elements in multimedia [16]. For architectural and built environment, landscape analysis using digital imagery that demands highly accurate geometric registration of image [13] may promote higher accuracy of information assessment towards the targeted architectural context or location based subject.

Adobe introduced Digital Negative (DNG) specifications in 2004 allowing digital RAW image files to suggest further possibility to extract imagery information when improved image post-processing technology is available in the future [17]. The digital negative that carries the similar substances as the photochemical film may imply possibility of recovering extended dynamic range from single exposure that can be time-efficient when being used in the HDRI photographic environment.

II. Background of High Dynamic Range Imaging

This study explores the development of an optimization of method and apparatus for retrieving extended high dynamic range from digital negative image by experimentally working with architectural photo imaging. The study would provide researchers, photographic image users or operator developer an option for digital imaging workflow optimization in HDRI environment. It is being stated that the intention of wanting to have higher dynamic range of photographic luminance to be recorded might have started during the early stage of photography [18]. In the 19 century, Gustave Le Gray constructed photographs of seascapes constructed from two negatives, one exposed for the sky and another exposed for the

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seascape [30], with this approach he could preserve the luminance details from the high contrast photographic scenes. Several key benefits of HDRI have been stated [19] including the HDRI can preserve work for posterity, provide opportunities in post-processing, modest computation and storage costs.

Studies have shown that the effectively captured Low Dynamic Range Image (LDRI) source sequences in HDRI environment will be required in order to produce adequate HDRI result [5],[20],[21]. There are various potential photographic issues when using multiple exposure sequences in HDRI environment. It is reported in the studies that to obtain wider dynamic range in HDRI by utilizing multiple exposure based image fusion requires precise alignment for multiple captured images. It is an essential prerequisite to prevent ghost artifact after the blending process, where registration is difficult as each image is captured under different photographing conditions [7].

During the construction process of an HDR image from using differently exposed source image photographs, two of the identified problems are the misaligned photographs and blurred long-exposed photographs [6]. These problems or issues have caused difficulty to reproduce reliable imagery features using the HDRI approach for architectural photo imaging.

For tone mapping process, the global operators mapping is based on the pixels' intensity and global image characteristics but not on the pixels' spatial location and the local operators mapping considers the pixels' surroundings as each pixel of a given intensity will be mapped to a different value depending on whether it is located in a dark or bright area [5],[22]. Fig. 1 illustrates an example process of compressing luminance exposed from different photographic exposure into a high dynamic range image.

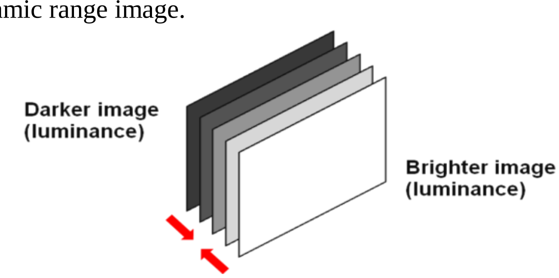


Fig. 1 luminance with different exposure for HDRI.

The process of fusing multiple luminances exposed from different photographic exposures into a high dynamic range image however would suggest imaging variables that may cause potential visual errors during the tone mapping process. This may arise during the situation of misalignment working with multiple source image sequences or the source images were acquired from inconsistent photographic conditions. The misalignment of multiple source image sequences can occur if the acquisition process was conducted on an unstable equipment configuration that provokes camera shake [5],[6]. The inconsistent photographic condition [5],[7] would happen during change of weather which causes unstable natural lighting distribution or when moving objects are present in the photographic scenes during the multiple image acquisition process, this sets an issue during the acquisition of architectural photo image where the weather condition is not a controllable element in photographic workflow that involves multiple exposure images.

The criticism of buildings having important architectural value cannot overlook the analysis of facades [36]. Architectural photography with HDRI techniques [23],[24] can be used for improving the recorded luminance in architectural context. Fig. 2 shows the examples of digital photographs on architectural subjects with insufficient dynamic range present in some identified shadow and highlight clipping image areas in the situation of low dynamic range image (LDRI). The architectural images being observed in such examples were not adequately recorded with luminance visibility for visual assessment.

Fig. 2 digital photographs on architectural subjects with insufficient dynamic range presented.

Fig. 3 is a comparison of LDR photograph image and the HDRI combined from the source of nine-image sequences exposed with different luminance. The HDRI however demonstrates certain difficulties such as the rendering errors of ghosting damaged effect caused by moving objects or difficult to maintain a consistent photographic condition across the entire multiple images sequence due to the nature of fast changing weather when photographing outdoor architectural exterior image with HDRI process.

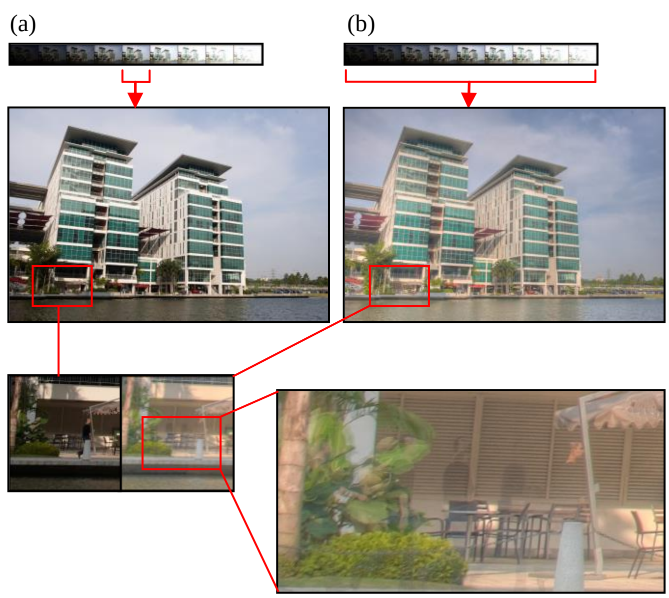


Fig. 3 (a) LDR photo image, (b) HDRI constructed from nine images sequence exposed with different luminance, local operator.

III. Considerations During The Optimization Process

Method of recovering high dynamic range radiance maps from photographs taken with conventional imaging equipment that involves multiple exposures has been presented [25], during the study it was also being stated that the photochemical negative or slide film however records a significantly greater dynamic range than can be displayed on a screen or printed on paper media. One of the key element being described about Zone System [2],[3] is that the photographer has to be able to visualize the final print during the time the image is being recorded and being considered on the technical aspects. In the work of "Examples: the make of 40 Photographs", light meter was used by Ansel Adams to measure the light of the subject, considering the highlight and shadow of the scene that falls into his gray scale pre-visualization.

The study by Larson et al [26] has considered the following two criteria most important for reliable tone mapping in HDRI, visibility is reproduced and viewing the image produces a subjective experience that corresponds with viewing the real scene. The visibility is reproduced would expect objects in imagery are visible in underexposed or overexposed regions, and imagery features are not lost in the middle. The overall impression of brightness, contrast, and color should be reproduced ideally correlate with the viewer's memory towards the real-world scene. The two criteria stated for having reliable tone mapping process matches the ideas inspired by Adams [2] during a photographic initiation of the real-world scene, overall visibility in terms of luminance to be photographically recorded has to be put in mind during the pre-visualization of planning [3],[4]. In Adams' situation, multiple exposures of images computed with radiance map in digital post-processing for having an automatic compressed HDRI rendering was not available. A single shot in photographic film and darkroom was the limitation during the time Zone System was innovated by Adams.

The digital RAW [17] format on digital camera equipments offers greater possibilities for recollection of imagery information, having the option of using different types of post-processing method on a same source of image RAW file. During RAW processing, RAW processors in digital may have the control function that is similar to the camera exposure compensation that the exposure can be adjusted the same way a photographer might have initially when shooting an image photographically [34]. With exposure compensation, the adjusted exposure value causes the change of luminosity for the processed digital image, this provides opportunity of preserving imagery features in the shadow and highlight areas. There are various RAW processors having different capabilities of control in terms of being able to maintain a consistence white balance, chromatic aberration correction, noise reduction, sharpness control, curve setting and exposure parameter [35] that eventually can permit non-destructive exposure compensation or improvements that lead to possible luminance recovery from the source of digital negative image in RAW format.

IV. Configuration of Apparatus

The Nikon manufactured D3X camera is used for this experimental preparation of high dynamic range imaging (HDRI) digital workflow, for the acquisition of the RAW images for study. The Nikon D3 series has been used by NASA ISS Crew Earth Observations experiment [27] and Image Science & Analysis Laboratory [28]. NASA obtained the prototype series of Nikon manufactured D3 camera units for their space exploration operation as the capabilities of the digital cameras being able to preserve content that has been helpful during the image data collection for the period of the operation assessments. Inspired by the configurations of The HDR Photographic Survey [21], the instrument of D3X is equipped with the Nikkor 18-35mm f/3.5-4.5D IF-ED Zoom lens and the auto-bracketing function of the camera allows continuous nine exposures to be made with one stop exposure increment at pre-user-defined aperture. This permits a HDR image archiving that covers a nine-stop exposure range to be acquired continuously, if required. The D3X is a photo recording instrument can deliver 24.5 megapixels of imagery features, this permits high magnification of inspection during the study. To reduce the possible bias of appearance resulted by the processed RAW image files, Gretagmacbeth color checker chart is used to have higher color consistency across the HDR imaging digital workflow during the experimental. Sekonic J510 light meter is used to obtain the exposure reading and for pre-visualization. During the observation process, the digital displays such as the viewing monitors are being calibrated to D65. TABLE I is the list of three different RAW Processors being used in this study for the test of dynamic range quantification with equipment D3X at ISO100. Image acquisition was recorded in Nikon's RAW electronic format, and all acquired RAW image files were being processed to 8-bit Jpeg format with linear curve setting. Linearity of images during the processing [29] is part of the workflow in this study.

TABLE I
RAW Processors For The Test Of Dynamic Range Quantification

RAW Processor	Name /Version	Manufacturer /Developer
A	Capture One Pro 5	Phase One
B	Camera Raw 6.5	Adobe (Photoshop CS5 extended)
C	ViewNX 2	Nikon Corporation

V. Methodology of Quantifying the Optimization

One of the main considerations of the optimization process is to be able to examine the quantifiable latitude and the extension of dynamic range from the RAW produced by the photographic equipment used. The quantification of potential dynamic range extension can lead to the possibility of using the digital negative RAW format as the single source for constructing an adequate high dynamic range image (HDRI) with sufficient extended luminance covering the shadow and highlight clipping image areas. Observing exposure range has been brought up by various discussions [5],[32],[33]. Fig. 4 is the inspection process of the acquired 18 image sequences sampling from darker to brighter exposures for identifying the values of Neutral5 patch from the Gretagmacbeth color checker chart in a lab environment, with fixed source of constant lighting. Fig. 5 illustrates exposures originated and extended from RAW with RAW Processor A, the approximation of exposure range where Neutral5 patch of the color checker has been used to measure the darkest 0 to brightness 255 pixel value from the 18 photographed exposure sequences, having the exposure parameters of -2EV, 0 and +2EV with RAW Processor A.

Fig. 4 Inspection on Neutral patch 5.

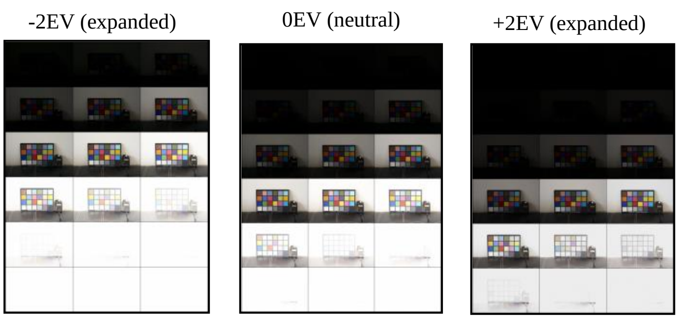


Fig. 5 Exposure originated and extended from RAW.

TABLE II is the pixel value reading of Neutral5 patch from processed images at -2EV, 0 and +2EV exposure parameters with RAW Processor A.

TABLE II
PIXEL VALUE READING OF RAW PROCESSED FROM RAW PROCESSOR A

Sequence	-2EV (expanded)	0EV (neutral)	+2EV (expanded)
S01	0	0	0
S02	0	0	1
S03	0	0	3
S04	0	1	12
S05	1	6	25
S06	2	14	44
S07	5	26	78
S08	14	42	121
S09	25	74	177
S10	42	117	223
S11	74	174	249
S12	118	223	253
S13	173	251	254
S14	223	254	254
S15	237	255	254
S16	237	255	255
S17	238	255	254
S18	237	255	255

Fig. 6 shows the pattern of exposure range in exposure value (EV) observed from the processed RAW image on -2EV, 0EV and +2EV exposure parameters with RAW Processor A, in the situation of dynamic range -2EV and +2EV has been extended using RAW Processor A, approximately.

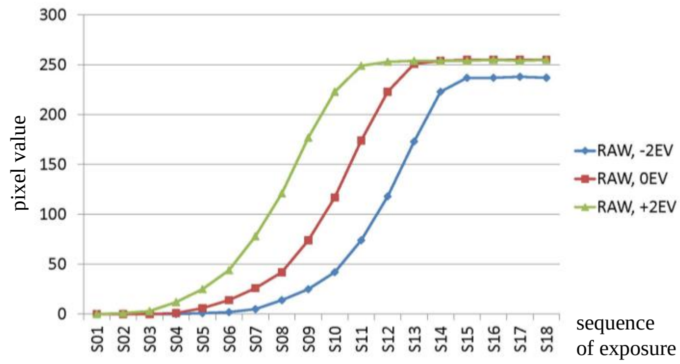


Fig.6 Processor A observation of dynamic range, exposure value (EV) from the processed RAW images -2EV, 0EV and +2EV.

The reading illustrates the approximation of usable exposure range of 8.5 exposure value (EV) using the instrument D3X with ISO100 at the curve of neutral 0EV parameter. This is averagely similar to the test by Rehm [31] with similar camera equipment tested using calibrated Stouffer Step Wedge. The compensated -2EV and +2EV has been expanded with RAW Processor A forming the curve pattern shows in Fig. 6, the expansion has been observed having the approximation of -2EV and +2EV increment but not qualitatively consistent across the entire pixel value reading of the expanded curves.

Similar process with Fig. 6 of using RAW Processor A, the Fig. 7 (a) shows the pattern of exposure range observed from the processed RAW image on -2EV, 0EV and +2EV exposure parameters with RAW Processor B. Fig. 7 (b) shows the similar processed content observation from RAW Processor C.

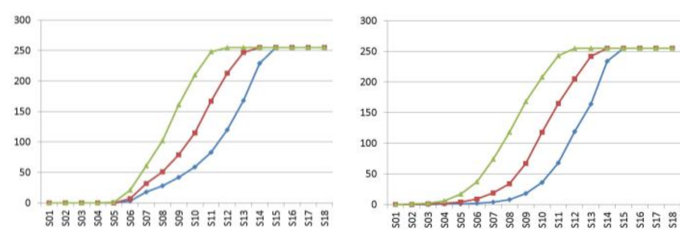


Fig.7 (a) Processor B observation. (b) Processor C observation.

RAW Processors A, B, and C have shown different characteristics in the situation of dynamic range expansion capability. Different RAW processors may suggest imagery features being digitally rendered differently, in terms of digital noise, sharpness and rendering appearance of the photographic subjects when working with RAW image format. The RAW Processor B has shown a narrower capability in expanding the dynamic range at the shadow areas. Obstacle faced when using the RAW Processor C was it being difficult to maintain a consistent white balance across all the source image sequences in RAW format due to the difficult control of processor function. RAW Processor A has been used for the experimental of HDRI on architectural photo imaging in this study for observing its characteristics working in HDRI environment. The initial observation from this method for the testing however may require further inspection or verifying of validity.

VI. Experimental with HDRI

In this study of digital imaging workflow optimization, we explore the method and apparatus for producing high dynamic range image (HDRI) from a single source of RAW. This process can be operated by mapping or masking the individually expanded +2EV and -2EV layers using the monotonic RGB channel from 0EV as a base guide. This approach can be suitable for examining the capability of dynamic range expanded from a single source of RAW however may not be as a precision method for mapping the HDRI from multiple exposed source images. The benefit of this method can permit observation opportunity for the researchers to visualize the visual characteristics when the layers of -2EV, 0EV, +2EV are being combined into a single HDRI constructed from a single source of RAW. Fig. 8 is the process of preparing the HDRI expanded from single source of RAW that has been processed from RAW Processor A.

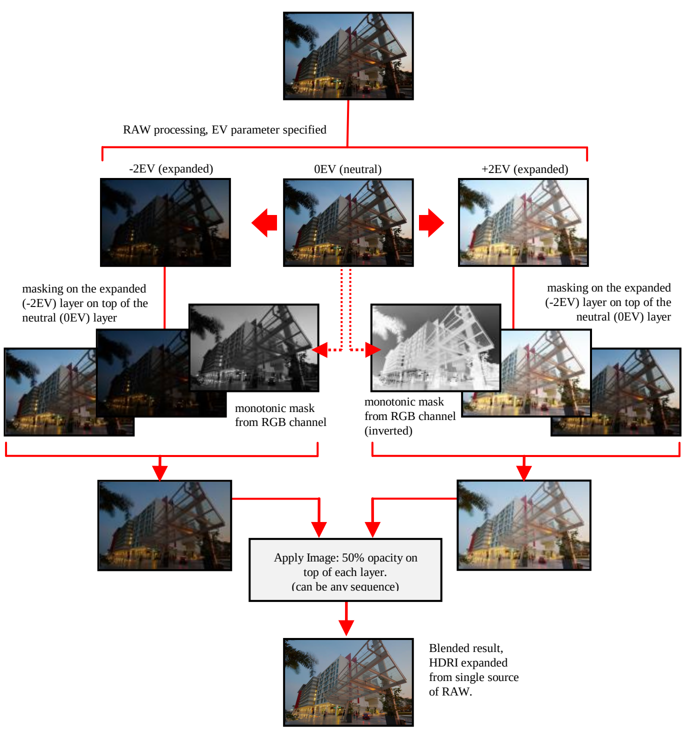


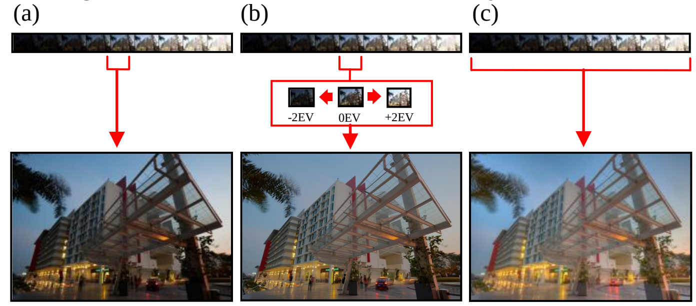
Fig. 8 process of preparing the HDRI expanded from single RAW.

Similar working process can be tested with other desired color space setting with similar concept given for observing the characteristics of RAW image being expanded with additional dynamic range retrieved from a single photographic source.

Fig. 9 HDRI produced from single source of RAW.

Fig. 9 is a HDRI produced from single source of RAW. Fig. 10 shows the comparisons of low dynamic range photograph image, the HDRI from single source of RAW and the HDRI from multiple image sequences using local operator by Photomatix v4. The method used as illustrated in Fig. 8 permits HDRI reproduction that can be free from ghosting error and misalignment issue while maintain a visibility at the middle.

(a) (b) (c)



(a)

(b)

(c)

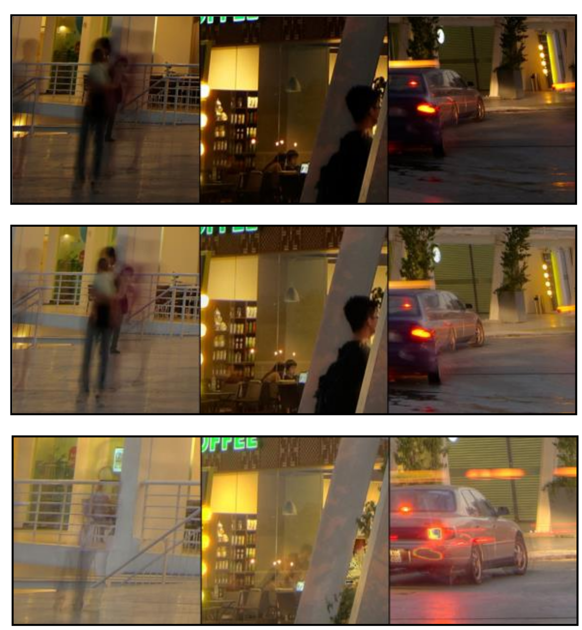


Fig. 10 (a) LDR photo image, (b) HDRI from single source of RAW, (c) HDRI from multiple image sequences with local operator.

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Fig. 11 HDRI produced from single source of RAW.

Fig. 11 is a HDRI produced from single source of RAW. Fig. 12 shows the comparisons of low dynamic range photograph image, the HDRI from single source of RAW and the HDRI from multiple image sequences using local operator by Photomatix v4. Fig 12 (b) shows that HDRI produced from single source of RAW demonstrates an improved preservation of luminance in the underexposed and overexposed areas.

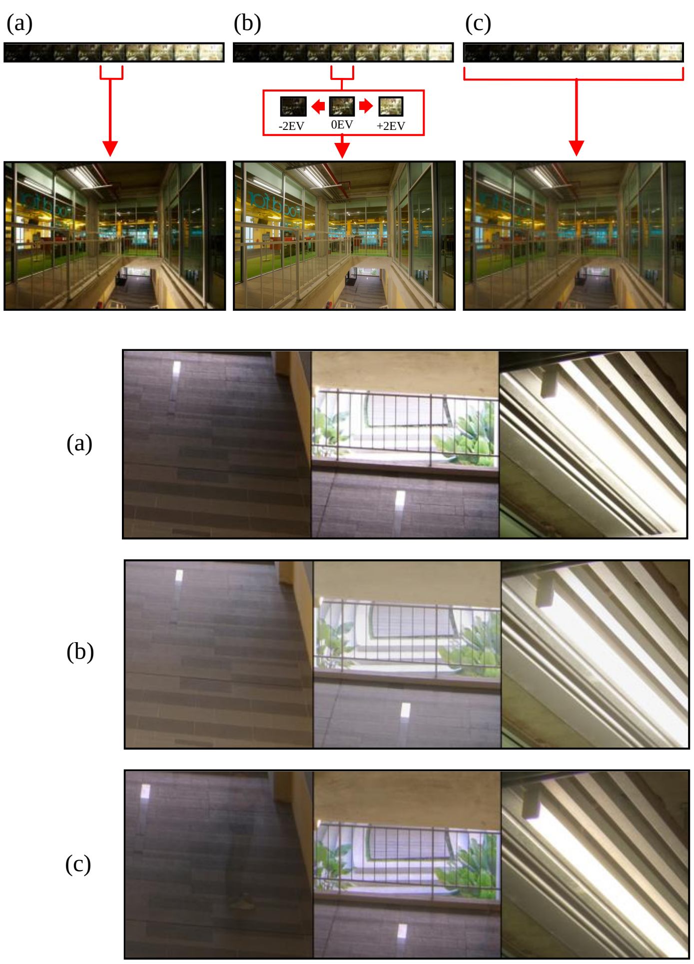

Fig. 12 (a) LDR photo image, (b) HDRI from single source of RAW, (c) HDRI from multiple image sequences with local operator.

Fig. 13 HDRI produced from single source of RAW.

Fig. 13 is a HDRI produced from single source of RAW. The chosen scene has photographic condition with extreme potential flare, as flare can be a limiting factor in dynamic range of image in HDRI environment [21]. Fig. 14 shows the comparisons of low dynamic range photograph image, the HDRI from single source of RAW and the HDRI from multiple image sequences using local operator by Photomatix v4.

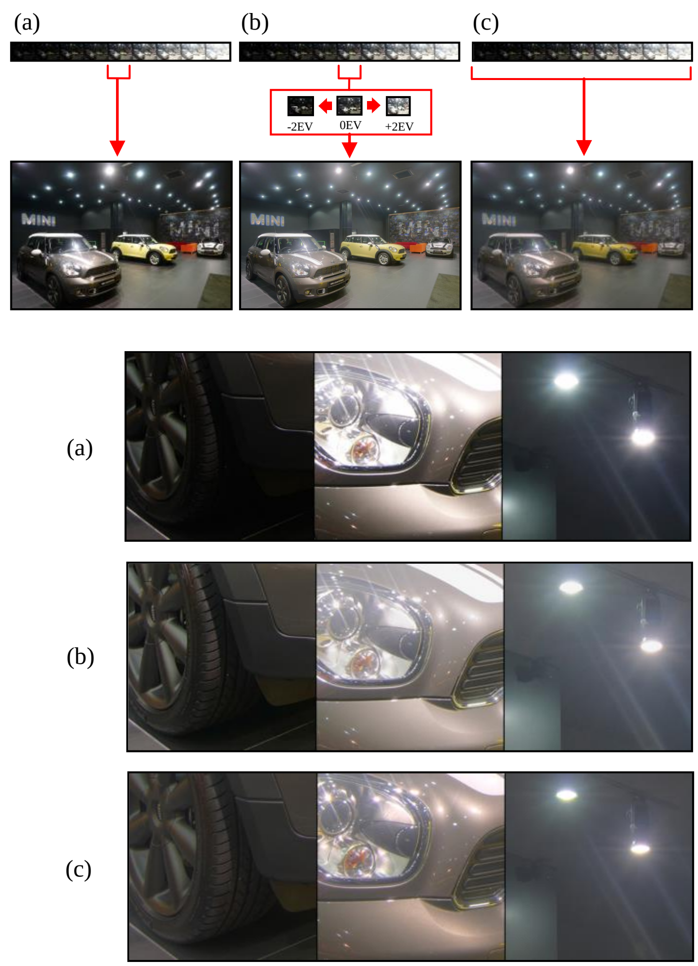

Fig. 14 (a) LDR photo image, (b) HDRI from single source of RAW, (c) HDRI from multiple image sequences with local operator.

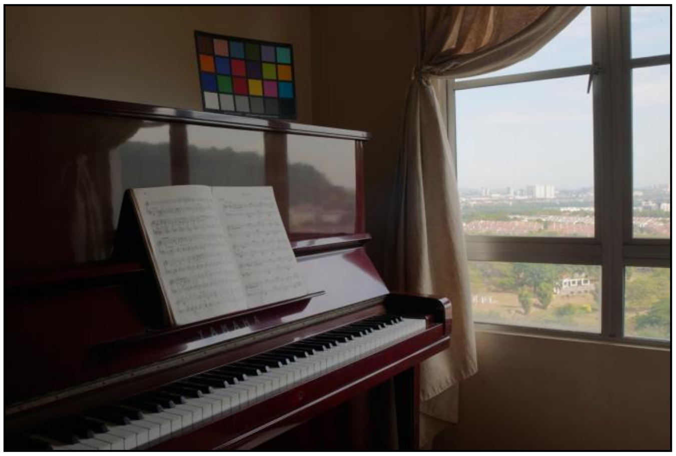

Fig. 15 HDRI produced from single source of RAW.

Fig. 15 is a HDRI produced from single source of RAW and is a case that is particularly difficult for operating the HDRI produced from a single source of RAW due to the extreme luminance beyond the range of -2EV and +2EV. Fig. 16 shows the comparisons of low dynamic range photograph image, the HDRI from single source of RAW and the HDRI from multiple image sequences using local operator by Photomatix v4.

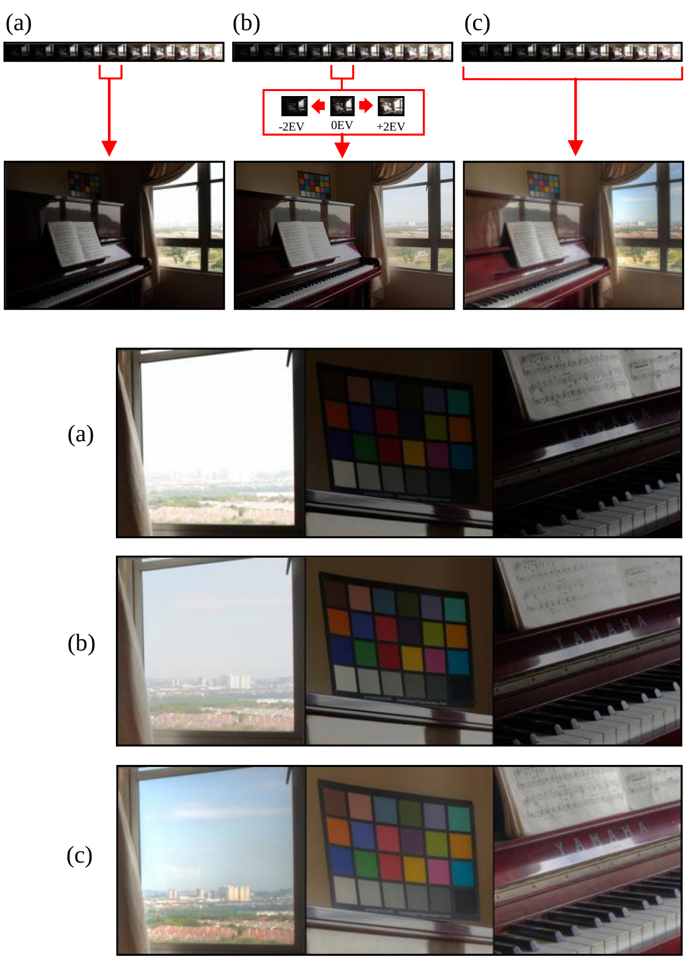

Fig. 16 (a) LDR photo image, (b) HDRI from single source of RAW, (c) HDRI from multiple image sequences with local operator.

VII. Discussion and Implications

The approach of producing HDR photography image from a single source of RAW may have a few advantages, this method and apparatus configuration requires only a single source of photographed RAW image instead of multiple source image sequences from different exposure. This configuration will not present ghosting errors that caused by multiple images with different photographic condition such as object movements. The issue that misalignment of multiple sources of differently exposed photograph images will not be presented in this method as it only requires single source of RAW image acquired from the photographic source. The main limitation of this approach is the dynamic range preserved and presented will not expand beyond the recorded latitude from a single source of RAW image. In the situation a greater dynamic range is preferred or required beyond the latitude contained from the recorded single source of RAW, the approach of producing HDRI from multiple source of differently exposed photograph image will be more likely suitable.

The process of pre-visualization of the intended imagery outcome, cautiously exposing the photographic negative and post processing that matches the actual or correlated appearance of the original scene [2],[5],[21],[26] has been carefully considered in this study. The study implies that the dynamic range presented in this method and apparatus configuration potentially can be greater than the tested range of indication if the following conditions can be met:

1) If the recorded range that permits expansion to a certain great extend had been recorded during the apparatus configuration during the acquisition process.
2) If the method of retrieval from suitable processor or operator is capable of translating the recorded dynamic range data of analog-digital conversion into the visible luminance during the post processing phase.

VIII. Conclusion

For retrieving extended high dynamic range from the source of digital negative image in RAW format, to certain extend the method and apparatus proposed may be used for HDRI photographic applications that have the following expectations:

1) Limited time allowance or restriction during acquisition.
2) Physical condition does not permit stability of apparatus configuration for multiple exposures acquisition needed for HDRI, such as a photographic tripod could not be used.
3) Higher luminance level to be preserved or presented in shadow and highlight image areas comparing to the conventional low dynamic range photograph image.
4) Visually, imagery features to be preserved moderately in the situation of high contrast photographic scene.

The variables in the method and apparatus explored can be replaced with other suitable components such as camera equipments that technically can be capable of recording a greater dynamic range in RAW or different tone mapping operators to be used for constructing adequately rendered HDRI with different parameters. Different tone mapping operators or algorithms can be used to assist fusing the extended dynamic range retrieved from the single source of RAW for producing HDRI with the benefits and settings carried by each different tone mapping operator.

The study also implies that the approach of producing HDRI from a single source of acquisition may be viewed as a considerable possibility for developing the photographic image processing workflow for professional photographic camera that comes with built-in HDRI processing function or mobile devices with photographic capability as an auxiliary function that comes with HDRI option.

Comparing to the limited luminance preserved in a typical low dynamic range photograph image with the example of 8.5EV in this study which has approximately contrast ratio of 362:1, the high dynamic range image produced from the single source of RAW that has been extended to 12.5EV with approximately contrast ratio of 5793:1 may have excluded some of the imaging variables such as the ghosting errors and misalignment issue. With the reduced imaging variables that usually leads to potential technical issues or rendering errors, the approach of producing HDRI from a single source of RAW image with least imaging variables may be consider less bias towards a non-bias approach of imagery assessment when it is required for the relative photographic utilizations such as the intention of having improved accurate representation of architectural photo imaging.

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