High Dynamic Range Images: Evolution, Applications and Suggested Processes

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Abstract

Three dimensional (3D) and Computer Graphics (CG) industries nowadays require ‘instant’ realism and extreme special effects while imposing the balance in cost, time and solution acceptance standard. It has been known that realistic rendering is time consuming, difficult to use, complex, expensive and often produces insufficient digital output to predict particularly in the early visualization process. This paper focuses on one of the emerging technologies, High Dynamic Range Image (HDRI) and how it can be developed in achieving effective solution, while maintaining ‘realism’ or required result based on a specific application. We firstly introduce the overall HDRI processes before continue to present a framework of captured Low Density Range Image (LDRI) source sequence effectively in HDRI environment. This paper concludes with discussions and lists the application of HDRI.

Keywords: HDRI, Rendering, HDRI Applications

1. Introduction

Realism in computer graphics has gained enormous amount of attraction over the last two decades [1]. Realism is becoming more critical due to the new and demanding needs of virtual reality, human computer interface (HCI), multimedia applications, scientific visualizations, pre-architectural visualization, growing education needs [2]. The existing 3D development tools provide quite a few techniques for achieving realism to represent or replace reality [3]. 3D Studio Max and Maya are two common tools used by academicians and content industries especially for 3D digital development due to the fact that both has certain built in features and allow 3rd party plug-ins for achieving special effects and realism.

The open and the growing 3D industry raises a cost and balance issue, i.e. the realistic solution has to be cost effective, time effective and the final solution in an acceptable form to audience and researchers [4]. The cost effective solution includes parameters such as minimum required ram, processor, engine to render (renderer, e.g. final render), and number of developers to setup. The time effective solution refers to parameters such as time needed to render (including in real-time environment), time needed to setup lights, and special effects.

There are several solutions to achieve realism while ensuring time and cost effective results. These are:

• Special effects via detailed lighting
• Realistic detailed textures for each object
• Network rendering
• Global illumination
• Radiosity
• Mental ray
• Final gather renderer, Brazil plug-in and
• High dynamic range image (HDRI)

In comparing to other solutions, we select HDRI due to its capability and strength as an alternate to detailed textures, detailed lighting, cost of texture collection [5] while reducing the overall processing time and cost. In fact, image processing, manipulation, display, recognition and other operations will no longer be limited by the number of bits used to represent each pixel [6]. According to this research, it is anticipated that in the next decade, the imaging industry will inevitably move to HDRI which will affect all aspects of the imaging pipeline, from capture (sensor, camera), to storage (compression coding) to reproduction (rendering, tone mapping, printing and display). New image processing and computational vision algorithms will also be developed around this new emerging imaging paradigm.

The idea of HDRI originated from exposure bracketing [8-9,11-12] explained in section 3.2.2. In the paper we will present the A-Z of HDRI, starting from skills needed to generate an HDRI till its effective use. We define HDRI, relevant essential skills and terminologies significant for HDRI in section 3.0. In section 4.0 we present and discuss a framework for
ensuring an effective HDRI. Later in section 5.0 we discuss and present HDRI uses and its applications [7].

2. High Dynamic Range Images

High dynamic range image, referred as HDRI is a combination of multiple images with different exposures. HDRI comes to picture due to the inability of standard digital still cameras to capture the dark and the bright regions present in a scene under observation [8, 9, 10 and 11]. HDRI removes this basic inability of these cameras by combining a sequence of differently exposed images into a unit image. The sequence of low dynamic range images can be captured either by varying aperture, varying shutter speed or by varying both [5]. The term varying aperture means changing the depth of the scene, choosing which is debatable. The suggestion by a few is to keep the aperture constant and change the shutter speed, which seems logical, however the results of both seem to be pretty much the same.

Figure 1- Figure 3 explain two scenarios implicating the significance of HDR images. In scenario 1, we focus the design in the figures bounded by the white rectangles, and in scenario 2 we discuss the shields encircled.

In the case of scenario 1, we focus the design in the rectangular boundaries and the design is visible in Figure 1 and 2. This however is not detailed in Figure 3. In contrast with scenario 2, the encircled are visible in Figure 2 and 3, and very vague in the Figure 1. The two scenarios exist in the same scene under observation, which clearly highlights the importance of HDRI as if there was only one image with unit exposure, the details of both design and shields could never had been observed.

2.1 HDRI Process

In HDRI, the image files record the actual colour and dynamic range of the real world scene rather than the limited gamut and dynamic range of the monitor or other reproduction media [6]. The process of HDRI generation is explained in Figure 4.
2.1.1 Scene Selection. The selection of scene is crucial to ensure researchers have enough illumination data between dark and light scene. Standard variation can neither be a good lighting source later nor can it serve the purpose of a stand-alone HDRI image, i.e. to see all the objects present in the scene. An example scene is shown in Figure 5.

![Figure 5: Example Scene](image)

2.1.2 LDRI sequence shoot. In the HDRI generation process, the next step after scene selection is shooting the sequence of images with different exposures. To capture different exposures, there is a need for a camera that allows option to control the exposure before capturing an image, via changing the shutter speed or aperture. The variance in shutter speed has to be constant from the minimum F-Stop value to the maximum. To avoid the displacement in camera while shooting the sequence of images, the F-stop can be set to the minimum and then for each image, a transition of 1-2 F-stop(s) is established until it reaches the maximum F-stop value or vice versa.

2.1.3 Assembly and HDRI formation. The simplest task of all in HDR image generation is assembling of the sequence of images and forming a resultant HDRI curtesy to HDR shop and other plug-in tools to convert the sequence into a unit image, called HDRI.

2.1.4 Photography skills for HDRI. Photography fundamentals can be seen as one of the required skills before developing any HDRI formation. This includes the understanding of aperture, dynamic range, F-stop, and shutter speed.

2.2 Related terminologies

2.2.1 Aperture. Aperture is the diameter of a camera’s lens opening. The larger the diameter of aperture, the more light is allowed to pass through the lens into the cameras film or image sensor. The unit of measuring aperture is F-Stop.

2.2.2 Exposure bracketing. Exposure bracketing is a simple technique used by photographers when they are not sure of the exact exposure or if they want to ensure that the exact exposure is captured. Most of the advanced digital/non digital cameras have exposure bracketing as a built in feature. Before capturing the image, an exposure value is calculated by the light meter, this value is chosen as the exposure settings. Two or more images of the same scene of the chosen exposure setting are required, including under exposed and over exposed settings. The task of capturing exact exposure values is called exposure bracketing.

2.2.3 Dynamic range. Dynamic range is the amount of detail present in a scene, a camera can capture, i.e. the dark and bright regions present in a scene in the form of shadows and highlights. Neither camera nor the naked eye can capture the dynamic range present in a scene in reality; however the camera dynamic range is based on the sensitivity of human naked eye. Conventional films have a dynamic range of 5 F-stops, black and white have about 9 F-stops.

2.2.4 F-Stop. The unit of measuring aperture is called F-Stop. Smaller F-Stop value refers to larger lens opening (diameter of the lens). Most good apertures are ranging from F1.8 till F16.

2.2.5 Depth of field. Depth of Field (DOF) is the distance from the nearest object till end of sight, which you want to focus while capturing an image. Two extreme examples about the use of DOF are landscape shoots and portraits. When the subject is a portrait the DOF has to be deeper, i.e. the F-Stop value has to be smallest and whereas incidence of landscape the DOF should be narrowed, that employs to a bigger F-stop value.

2.2.6 Shutter speed. Shutter speed controls the amount of light to be allowed to pass through the lens. Shutter speed does not affect the aperture directly, though it shuts the cover slowly or rapidly controlling the amount of light to pass through the lens independently of the aperture. A fast shutter speed can capture a fast moving object whereas to blur an image, a slower shutter speed is applicable.

3. A framework to identify captured LDRI source sequence

Compiling of HDR images include capturing of many images of the same scene with different exposure values. In general while taking photographs there is a high tendency that a photographer will introduce certain camera movements while changing the exposure settings, unless the camera is handled by a remote control. In our experiments such movements often reveal a duplication of images (circled) as shown in Figure 6. With a closer observation, a light shadow is revealed just besides the real buildings. This issue is carefully considered as part of the overall HDRI framework design development as shown in Figure 8.
The framework introduces the first image as the reference image before passing through the edge detection process that is useful at a later stage. Each image is required to undergo four major processes and sequences of basic mathematical manipulations. A more comprehensive explanation is discussed in section 3.1.

### 3.1 Framework processes

#### 3.1.1 Histogram equalization
Histogram equalization is performed on each image; the purpose to do so is to normalize the image.

#### 3.1.2 Edge detection
The edge detection is the most crucial part of the system, therefore three kinds of edge detection techniques are utilized, i.e. Sobel, Roberto and Candy within the process. The edge detection process obtains three edges vector and sums it all together. Finally the resultant edge vector is digitized.

#### 3.1.3 Zigzag
Zigzag is the standard operation in image processing. The initial idea behind zigzag is to obtain a vector for analyzing at a later stage. The zigzag pattern is employed so that the matrix takes a new row of the vector shape. This process helps in reducing the matrix size representation when the zeros are extracted from the resultant vector in the ‘Extract Zeros’ process.

#### 3.1.4 Extract zeros
Extract zero is a simple process that is used to extract all zeros out of any vector under observation or analysis. We utilize it to remove all the zeros in the obtained resultant vector.

### 3.2 Framework Explanation

The framework is developed on simple digital image processing concepts. All reference images are required to go through ‘Edge Detection’ process. Each image in the sequence will pass through ‘Histogram Equalization’ stage. The edges of the sequence are subtracted from the reference image to obtain the difference in the image and edge detection. The results of the difference images are summed up and passed through the ‘Zig Zag’ process to obtain 1 row vector. The zeros in the one row vector are extracted the ‘Extract Zeros’ process. The final
calculated vector is the result of the process, analysis of which reveals the camera movement while the images are being taken. The resultant vector consists of positive and negative decimal values.

The positive values refer to those edges that were presented earlier and not in others, while the negative values refer to those points that were not existed in the first but were revealed in the second.

In general the size of the vector is enough to continuously observed image sequences for producing HDRI. Though however the values of the vectors can also be utilized, as for example if there was no handshake at all, the vectors would consist of almost same positive and negative values and the size of the vector will be small and in the opposite case the values would be entirely different and the size of the vector would be exceptionally large.

4. HDRI Applications and examples

4.1 HDRI-based lighting and environment

Neither human nor any existing tool can produce exact lighting conditions as they were at any particular moment of the day and environment. It requires vast through a ‘trial and error’ method. We can easily capture different light intensities at a designated surrounding using HDRI with at least a 180 Degree Lens for a better (‘realistic’) atmosphere especially when the images are developed in the form of animation, games or real-time simulation (virtual reality).

4.2 Pre Architectural Visualization

Pre-visualization for architectural purpose is crucial to better understand the architectural design, look, and its feasibility before actually building it in reality [12, 13 and 14]. Its complexity increased due to existence of complex and design demands. It becomes even more complicated particularly realistic rendering of architectural and building detailing when visualizing and comparing to realistic experience [1]. Pre-architectural visualization plays an important role for the client and the designers. The problems of traditional design techniques including (plans, sections, facades) have been reported by Ucelli et. al, [2]. He claimed that these basic designs are insufficient for non-professional to feel or understand what the designs actually represent.

Ideas of visualizations are made possible through computer graphic technologies and presented in the form of 3D animations and virtual environments. One of the key problems is how to establish ‘fast’ or ‘instant’ 3D visualization able to portray ‘effective’ visual for design decisions while at the same time reduce the rendering time and cost. We experimented with HDRI to visualize architecture in a particular place. One example of this
work is the feasibility study of a helipad in Multimedia University, Malaysia.

We imposed a 3D model of a helicopter in the existing (real) environment to compare and discuss on certain design factors. This includes scale, shadows, visibility and noise issues. This 3D object placement is just an example of possibility of visualization understanding (Figure 12).

![Figure 12: A 3D object (helicopter) is imposed in a ‘real’ environment using HDRI technique](image)

Similar ideas for use of computer-animated objects have been well proven by researchers on computer animation trends in architectural practice and digital modeling [12 and 13].

5. Conclusion

The paper explains the basic understanding of the HDRI. We enlisted a few applications of HDRI namely HDRI-based lighting and environment, and Architectural visualization. We analyzed how it provides a cost and time effective solution. We also presented a framework to enhance the speed of creating HDRI. Future consideration based on the suggested framework may consider brightness variables suitable for specific application of HDRI image generation such virtual environment and games.

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