High Dynamic Range Image (HDRI) Rendering
A Technique for Architectural Pre-Visualisation

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Abstract. *This paper suggests a method known as High Dynamic Range Image (HDRI) to pre-visualise architectural elements in three-dimensional (3D) environment used by Computer Graphic Imaging (CGI) film-makers to integrate 3D models and characters into live action background (special effect). This Intensification Research Priority Area (IRPA) grant project was developed to suggest ways to achieve effective rendering solution and composition of the final output. It will focus on experimental modelling of local cultural elements that provides solutions for radiosity-type effects and dirt shadings. A set of data from an established site (i.e. environment) was captured and represented in High Dynamic Range (HDR) file. This data is integrated with architectural elements (e.g. 3D objects) and then pre-rendered to get the 3D visualisation of the actual environment. Several different exposures were also captured and tested to establish the correct rendering and lighting condition. This earlier result shows that HDRI method provides accurate visualisation and drastically reduces the rendering time without compromising the data (images) with accurate lighting. This paper will demonstrate the process of HDRI, compare the visual impact with 'radiosity' technique and other related rendering solutions and present the results, which are useful for architectural animation, simulation and other modelling developments.*

Keywords. *HDRI, pre-visualisation, modelling, rendering*

Introduction

Pre-visualisation for architectural and urban modelling is a tedious task to complete. This is due to management of large file sizes, the complexity and detailing of objects, and the demand for realistic experience (Gottig, et. al., 2004) especially in animation and virtual environments design. As Ucelli et. al, (1999) explained that the problem with the communication between designer and client rises when you notice that traditional graphic techniques (plans, sections, facades) are inadequate to make a layman feel the real architectural space. As a result, on-shelf conventional computer-based lighting methods were employed to demonstrate the space, environment and visual impact even though these methods have limitations such as rendering quality (figure 1), illumination and are time consuming.

Apart from this, it has been known that realistic rendering animation is an expensive processing task as it incorporates 'physically-based' global

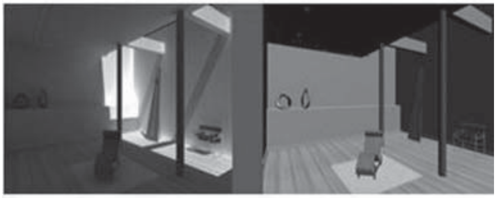

Figure 1.

illumination (GI) method to improve illumination details (Besuievsky and Pueyo, 2001). One of the greatest challenges in radiosity field (Bekaert, 1999) is to render the objects economically without compromising the quality primarily to achieve photo-realistic images. According to Ucelli (1999), now it is scientifically proven that the way man understands space is connected both to the physical act of seeing and to his own experiences and cultural background, but it is very difficult to find out the way these experiences interfere with perception of architecture. In Ucellis's case study of comparing real building and computer images, the results show that all of the computer visualisation techniques (i.e. real environment, photo re-touched, rendered images, shaded images and hidden line images) were very close (even though photo re-touched scored the most effective technique) to how the real building was perceived.

With the advancement of computer graphics, many researchers, designers and computer scientists are continuously developing algorithms to emulate the way real light behaves (http://www.rendermania.com/HDRI/index.shtml). Not only does it focus on the realistic look and feel (Gottig et. al, 2004) to represent the environment but it also trys to incorporate an economical 'radiosity-based' rendering (Besuievsky and Pueyo, 2001). One of the dominating techniques is the use of high dynamic range images (HDRI) for illumination. Inspired by the need for rendering solutions (i.e. rendering synthetic objects into real-world scenes) particularly in architectural and visual effects domains (Debevec, 1998), this research attempts to explore HDRI technique in our research project. The test results should be used as a benchmark for the actual 3D architectural project. This paper briefly introduces the history of HDRI and its process (http://hdri.mmu.edu.my). It then follows with a discussion of the potentials of using HDRI as one of the effective lighting source (Kollig and Keller, 2003) when a LDRI picture is altered in terms of its physical contents. This paper also highlights discussions on HDRI as a technique for architectural pre-visualisation and before concludes towards the end.

HDRI: A history

HDRI has gained lots of attention over the last 5 years. HDRI comes into picture as a result of the inability of digital cameras to capture a wide dynamic range present in a scene (Battiato et. al, 2003). The dynamic range is the ratio between the maximum and minimum signal levels present in an image, i.e. the bright and the dark regions. A digital camera can effectively capture only one of the two regions. Different techniques to overcome this draw back of digital cameras has been presented in past (Ward, 2001; Robertson et. al, 1999; Grossberg and Nayar, 2003; Nayar and Mitsunaga, 2000), however, the problem that still remains is the presentation is too complicated for non-technical artist. As such this paper is presented in such a way to help non-technical designers or artists to follow.

3D rendering technology has managed to find its way into the utilisation of many non-professional and professional purposes such as architectural visualisation, artistic manipulation, and electronic arts industry and motion-pictures, just to name a few. Generally there are two types of rendering, namely, photorealistic rendering and non-photorealistic rendering. One of the common methods in photorealistic rendering is used of HDRI, a method that uses HDRI file as a light source.

Conventionally, 3D artists use 3D lights available in 3D software or more advanced technique like photorealistic rendering using image-based lighting. The idea of HDRI technique is developed from an image-based lighting method to illuminate the 3D objects. Since HDRI technique uses image-based lighting, there are no standard lights required to do the final render. All of the HDRI renderings can be performed without any lighting; however it needs to be used with the global illumination rendering (Debevec, 1998) approach. The difference of these two methods is illustrated in the figure 2 and obviously that HDRI rendering allows a more realistic output.

HDRI development was inspired by the reflective mapping technique back in late 70's and early 80's. Most of the reflection maps were generated by capturing images on the mirror ball assuming it covers 180 degree of the environment. As a result more precise integration of 3D objects into live action background can be made (Figure 3). The development has continued until the development of HDRI file format.

HDRI Process

This research employs the technique similar to Debevec (1998) integration of the synthetic objects into real scenes research in which the process can

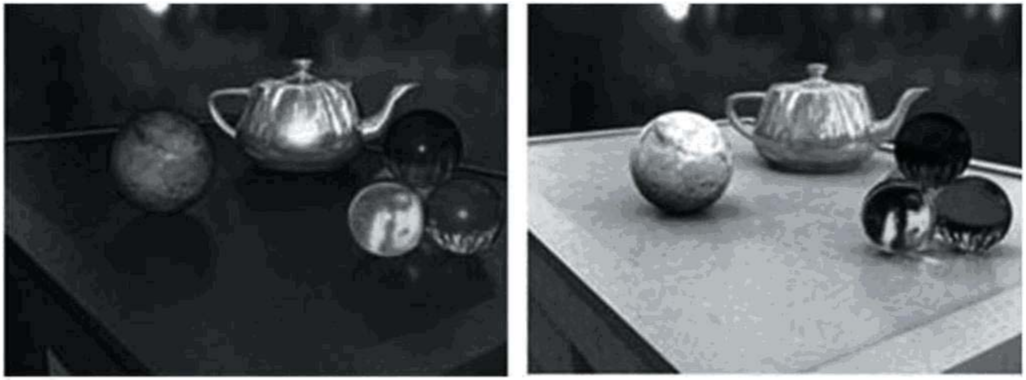

Figure 2. Rendering using standard 3D light (left) and HDRI rendering (right)

Figure3. Reflective map used for integrating 3D into live action background

be described in Figure 4.

In order to understand the process of creating HDRI file, one must understand the fundamentals relevant to HDRI. It includes renderer behind the process. It is very important to understand the concept of radiosity and what it can offer. The beauty of radiosity is the realism it creates. Besides revealing the main and soft shadow, the core process is that it is bouncing light that imitates the natural global lighting. HDRI process manages to capture effective low dynamic range images (LDRI) for the production of an acceptable HDRI. To explain the process, this research shows an example of work that has been carried out in a historical city of Melaka. A' Famosa, a fort built by the Portuguese in the 14th Century was selected due to the importance as one of the listed ruin conservation areas by the State Government. The following are required for HDRI generation.

•Access to a manual camera (this research used Nikon D100)
•A location having enough dark and bright regions
•Multiple pictures with different exposures
•Software that enables to combine all these different exposed pictures (e.g. HDRI Shop)

Capturing LDRI Sequence

Capturing HDRI sequence images can be developed through two methods which are listed as follows:

-Light probe reflection or
-'Fish eye' lens

Light probe is considered as a more economical way because it can be created easily by using a normal camera. The difficulties lie on how smart the images are being captured as this technique has the tendency to depict the photographer himself as part of the images. On the other hand, using fish eye lens would give a more accurate image solution since as the process is prepared automatically and the fact that its ability to capture 180 degree of the environment. The comparison between these two techniques is shown in Figure 5.

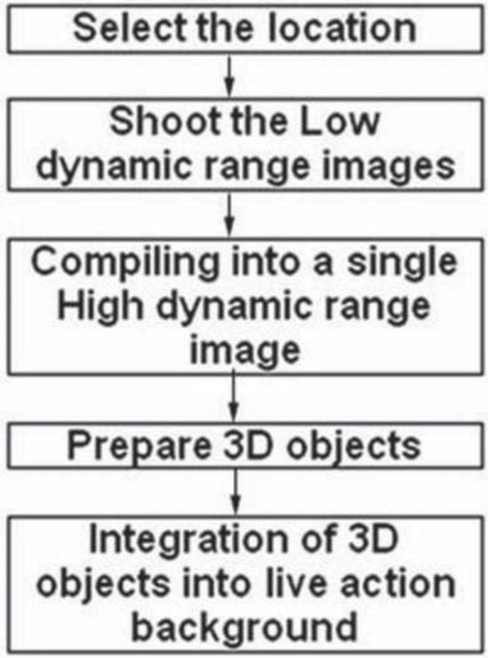

Figure 4

In this case the researchers choose to use fish eye lens to capture the images of the surrounding. There are two ways to capture multiple images of the same content; either by varying apertures or keeping the apertures same and varying shutter speed. Even though both aperture and shuttle speed can be varied, this research focuses on varying apertures while keeping the shutter speed constant. Figure 6 to Figure 10 show a few example images at 2 f-stop differences.

The process continues by combining all images using HDR Shop that is freely available on Internet.

Figure 5. Fisheye lens (left) and light probe (right)

Assembling and Generating HDRI using captured image sequence.

Step 1: Calibrating Camera Curve

Depending on the type of the software one uses, the camera response curve must be calibrated using the given features in the software that one selects to use. It is important to take a careful consideration because even the same camera sometimes gives different response curves to almost same situations.

Step 2: Assembling Images

While assembling the only precaution is to insure that one uses the correct camera response curve.

HDRI as a Lighting source

Neither human nor any existing tool can produce exact lighting conditions as they were at any particular moment of the day. It would require lots of experience and enormous "hit and try" method to do so. One way to produce such condition is by capturing the environment at a particular time in which the output would be closest to the actual lighting or illumination scene through HDRI solution. The HDRI has to be established using at least 180 degree lenses to ensure the atmosphere is well captured. Apart from this, all static images and sequences (e.g. animation and time-based media) can be manipulated using HDRI as surrounding lights in order to get exact light conditions. In fact, the use of HDRI for lighting manipulation can be a perfect integration of 2D and 3D object in the same scene.

The explanation is demonstrated and compared in Figure 11 and Figure 12. The researchers captured a ground shot image of daytime in front of the main courtyard of Multimedia University (MMU). In Figure 11 there is a chopper in front of the building, whereas in Figure 12 similar angle is established without the presence of the object (chopper). The chopper is a 3D object and it was placed in the image using 3D Studio Max 6.0 and the lighting was provided using a HDRI.

Figure 6. Famosa1

Figure 7. Famosa3

Figure 8. Famosa5

Figure 9. Famosa7

Figure 10. Famosa9

HDRI as a technique for architectural pre-visualisation

A critical look on images presented in Figure 11 and Figure 12 may cause any intelligent person to stop and think, and to ask himself or herself these questions, "Is the chopper really there?" or perhaps "Is it really within the university premises?" Only those who are involved in the creation of the image would know the real answer. The chopper has been placed in perfect lighting conditions.

Since the chopper was placed within the image, it is also possible to place any other form of architectural objects at any location or environment. A fountain can be placed within a building; a building can be placed in an urban area. This technique can be used to pre-visualise architectural space in a relevant stage of design especially when the stage

Figure 11. Chopper in MMU

Figure 12. MMU

requires a certain level of detail as to what has been proven through Ucelli's et. al (1999) experiments, Mullins's et. al (2002) accuracy research in the presentation of design ideas across networks, Rafi's (1999) reports on computer animation trends in architectural practice and digital modelling.

Conclusion and Recommendation

This early research results suggest that capturing HDRI using a sequence of LDRI provides both technical and non-technical designers to become aware of the potential of the technology and rendering solutions that provide a more realistic image effectively and economically (i.e. time and cost). By using this process described in this paper, many complicated and time consuming tasks can be drastically reduced and still yield results that are equivalent, if not better, than the traditional methods used. This process provides designers the opportunity to represent architectural problems especially during the pre-visualisation stage, thus, allowing the designers and lay person alike to experience the space that is being constructed (or proposed) and to suggest the appropriate modifications, if need be. There are still areas that require attention for further research especially when dealing with data compression as the current state is dealing with a huge data of HDR images. HDRI has a huge potential in real-time environment and virtual world application especially when 'realistic' architectural representation or visualisation is concerned.

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