Simulation of architectural lighting in a virtual environment

A case study on real and fake High Dynamic Range Images (HDRI)

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The early findings of this research were presented in eCAADe 2005 International Conference, Lisbon primarily to highlight the concept of High Dynamic Range Images (HDRI) when representing architectural spaces in the form of still images. An experiment had been carried out to compare the results between HDRI rendering and 'conventional' lighting simulation algorithms namely ray tracing and radiosity. The results were based on static and using the same exposure factors, when capturing HDRI.
This project, funded by Intensification Research Priority Area (IRPA) grant continues to present and report HDRI results in a simulation environment. In this paper, we first briefly explain the concept of real and fake HDRI. Then a comparison experiment is conducted to compare these two methods and discuss the impact and effectiveness of the illumination computation in architectural simulation environment. In order to carry out the experiment, a few models of the architectural scenes were developed. These models were then textured with real photos and manipulated with 'shaders', and further rendered using fake and real HDRI techniques. As for the fake HDRI, two methods were developed. The first was using an image as the ambient map and different exposures were created by increasing the value of Hue, V of HSV and saturation. The second involved a series of digital photos with the selection of the brightest and darkest area using Adobe Photoshop to establish the scale of luminosity. A few camera movements were triggered and position for 'real-time' rendering simulation. The result of the experiment has shown a significant improvement on the rendering time and quality of the rendering. Finally this paper suggests the selection criteria for choosing real and fake HDRI, and how each technique can be best utilized for architectural representations in a simulation environment.

Keywords: *HDRI; simulation; Real HDRI;Fake HDRI; illumination computation*

Introduction

While there are many sophisticated lighting simulations and illumination computation (Chevrier et al., 2003) tools available in the market for architects and designers to explore and represent architectural spaces, many of these are still time-consuming (Czerner & Gatermann, 2002), difficult to use, complex, expensive (Besuievsky & Pueyo, 2001) and giving insufficient digital output to predict especially at early design stage (Adel, 2002) of visualisations. According to Havran (2003), producing high quality animations featuring rich object appearance and compelling lighting effects is very time-consuming using traditional frame-by-frame rendering systems. Similarly, Chevrier (2003) explained that with the growing number of light sources used in a project, designers have difficulty presenting their projects with classical methods. He further explained that designers and clients encounter trouble imagining how the illumination will be, and the understanding of the project is not very reliable. As a result, many designers have been reluctant to use these tools and have decided just to concentrate on what is available in CAD software and only consider the simulation tools at the end of the design process (Serrato-Combe, 2004).

Experience shows that the success of a photorealistic simulation depends essentially on the choice of the light source characteristics and their correct positioning in the scene. However, this dependency can be reduced when using HDRI rendering. This is because high dynamic range photographic technique allows accurate measurements of scene radiance to be derived from a set of differently exposed photographs. This technique allows both low levels of indirect radiance from surfaces and high levels of direct radiance from light sources to be accurately recorded. The rationale behind using HDRI as lighting solution is because of its accuracy in illuminating the 3D scene, seamless integration of 3D into photograph/movie and photorealism factors (Debevec, 1997). Figure 1 shows the comparison between traditional 3D rendering and advanced photorealistic rendering using HDRI as its light source. From the figure it can be seen that the result of HDRI rendering is more photorealistic compared to normal lighting because the lighting used in HDRI rendering allows light to be bounced in the 3D scene, which is known as indirect lighting, while normal lighting only allows direct lighting.

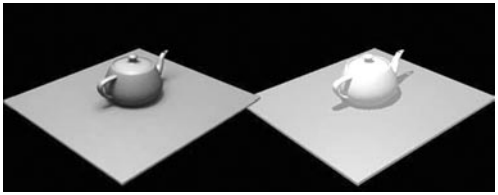

Figure 1
Comparison between traditional 3D rendering (right) compared to advanced photorealistic rendering (left) using HDRI as its light source

It is undeniable that the HDRI method for photorealistic rendering/lighting has increased interest in computer graphics (Debevec, 1998). However, to create an HDRI file is a very complex process and requires high technical skills. Technically an HDRI file involves a lot of file parameters to be adjusted to suit the final rendering. Good cameras with high speed frames and fish eye lens are expensive equipment required to capture these images. It is fortunate that nowadays we can find more and more commercial HDRI file libraries available in the market, but yet the price of these libraries is still high and there are chances that they may not be suitable for a comprehensive project. Most architectural visualization projects are time constrained, so to shoot and convert the HDRI file is not a practical solution. To overcome this problem, fake HDRI has been introduced.

In general, fake HDRI is created from a single LDR image (for example jpg, bitmap and tiff) and using scale map, multiple exposures of this image is created. In other words, in fake HDRI, we need not to capture image with multiple exposures but instead we generate the multiple exposures from a single image.

These two methods have their own advantages and disadvantages. In our research, we would like to explore and compare these two HDRI rendering methods through a series of experiments and finally identify some suggested application for using real

and fake HDRI, in order to best utilize the technique for architectural representations in a simulation environment.

The experiment

In order to compare and study the differences between real and fake HDRI rendering, we have conducted a series of experiments to measure both performance based on memory used and rendering duration. These two criteria are very important since it will give us some basic idea on a practical solution for a particular situation. The entire rendering was based on 5 sec camera based animation for each scene. However the comparison data was based on 1 frame rendering time. The models used in this experiment were taken from model library developed by Evermotion[1]. The lighting set up has been manipulated to suit our experiment's needs. In completing this experiment, we have applied global illumination renderer namely Vray and it uses 3D Studio Max software as its 3D platform.

Architectural scenes

For the purpose of our experiments, we have chosen 3 indoor scenes and 3 outdoor scenes with various props in the scene. All of these models were developed using polygonal modelling and fully/partially textured. Each model has different level of complexity. This is to ensure that we will get various data collections for comparison.

- Indoor scene 1: Kitchen
  We used a kitchen interior that contains kitchen furniture and some electrical appliances. In this scene there was one window opening has been created to allow HDRI light source enters through it. From here we can see the HDRI illuminated the scene and fairly distributed the light energy in the scene.
- Indoor scene 2: Bedroom
  Bedroom has been arranged with some furniture and the opening for this 3D scene is bigger than kitchen scene to allow more lights penetrate through it.
- Indoor scene 3: Living Room
  Living room that we used for this experiment also has a big opening which allowed the external light entered through it and illuminated the scene.
- Outdoor scene 1: Water Tank
  Water tank has been placed in one environment and only 1 light source which is HDRI has been used to illuminate the scene.
- Outdoor scene 2: Mosque
  Mosque and water tank shared the same HDRI light source. In order to emphasize the reflection we used a shiny reflective dome to reflect the HDRI.
- Outdoor scene 3: Factory
  For the factory we changed the HDRI light source to blue sky and rendered with blue sky HDRI light source to match the lighting condition.

Lighting

Two kinds of environmental map have been used as a light source for all the scenes which is the real and fake HDRI. In addition we added some additional built-in lights in 3D Studio Max to enhance the scene and for aesthetical value. Lights such as spotlight and Vray light play an important role to increase the illumination particularly in interior scene. As for outdoor scenes we have added one daylight for exterior lighting. All the scenes were rendered using global illumination rendering system.

Results and discussion

Table 1a and 1b illustrates the final rendering output for different scene type and rendering methods. From the observation, we can see that in general the quality of each image using real and fake rendering is almost the same with only a slight different. However, looking a particular items as summarized in Table 2, we can see that both methods varies in terms of scene setup duration, rendering duration, and memory usage.

[1] www.evermotion.org

Table 1a
Rendering output for different scene types and rendering methods

Lighting / Scene	Real HDRI	Fake HDRI
Indoor Scene 1: Kitchen		
Indoor Scene 1Bedroom		
Indoor Scene 1: Living Room		

Lighting / Scene	Real HDRI	Fake HDRI
Outdoor Scene 1: Water Tank		
Outdoor Scene 1 Mosque		
Outdoor Scene 1: Factory		

Table 1b
Rendering output for different scene types and rendering methods

Based on our observation during the experiment and also analysis on the results presented in Table 2, we have come out with some interesting points which compare the real and fake HDRI. The points are discussed below:

1. File size: A real HDRI image is huge. A 3K pixel real HDRI image goes normally to 29 to 32 MB while a fake HDRI which can be in jpg takes only

1.5 MB. This matters when we load the real HDRI in Maya because a very big or heavy file can easily cause the 3D application to crash.

2. Complexity of the process. Overall, real HDRI process is more complex compared to fake HDRI. One of the biggest problems of real HDRI is that it is very hard to setup. It is difficult to make sure that all the elements involved such as objects, camera etc. remain static while capturing the HDRI. In addition, the process also involves a lot of parameters to handle. For an artist this can be quite tiring as tweaking more parameters takes lot of time and many control results in many combinations that can easily bring problems than solutions. Consequently, the process requires longer rendering and setup time. Thus, if time constraint is a big issue in completing a certain project, real HDRI might not be a good choice.
3. Reflection clarity: Real HDRI shows a clearer reflection compared to fake HDRI. Thus, if we need to blow up the image to a bigger size such as a billboard, fake HDRI will cause the reflection to become a lot more blurry than what it is in real life.
4. Frame extension reflection: With real HDRI although we can get clearer reflection however in an animation sequence, the reflection becomes static. But by using fake HDRI, since we can take shots from the movie clip we can use that as a frame extension and we will get a realistic moving reflection.
5. Lighting condition: Real HDRI gives more control on the exposures compared to fake HDRI. This is an advantage when we would like to get a clear object during dark or extreme bright scene. By simply increasing or decreasing the value channel parameter, HDRI can still produce a realistic effect as compared to fake HDRI
6. Effects: Effects like motion blur, color bleeding,

Scene type	Rendering method	Scene setup duration	Rendering duration	Memory usage
Indoor 1: Kitchen	Real HDRI	3.7 sec	00:34:00	P861.9
Indoor 1: Kitchen	Fake HDRI	3.5 sec	00:33:38	P805.2
Indoor 2: Bedroom	Real HDRI	2.2 sec	00:15:32	P424.3
Indoor 2: Bedroom	Fake HDRI	1.5 sec	00:15:29	P381.9
Indoor 3: Living Room	Real HDRI	3.2 sec	00:22:32	P554.1
Indoor 3: Living Room	Fake HDRI	2.9 sec	00:21:29	P541.2
Outdoor 1: Water Tank	Real HDRI	1.5 sec	00:16:49	P448.9
Outdoor 1: Water Tank	Fake HDRI	1.2 sec	00:15:32	P424.3
Outdoor 2: Mosque	Real HDRI	1.8 sec	00:36:49	P433.1
Outdoor 2: Mosque	Fake HDRI	1.2 sec	00:33:32	P414.3
Outdoor 3: Factory	Real HDRI	1.5 sec	00:26:40	P498.9
Outdoor 3: Factory	Fake HDRI	1.1 sec	00:22:31	P444.3

Table 2
Summary of scene setup duration, rendering duration, and memory usage for different scene type and rendering method

Real HDRI	Fake HDRI
• Time is not a crucial issue • Need to have a realistic effects • Lots of experts involved in the project and have high budget • Requires a big size image • Surrounding lighting is too bright or dark • Does not involve animation and 3D application	• Have a limited time • Need to speed up the process • Limited experts and budget • Only requires small size image • Surrounding lighting is sufficient • Involve animation and 3D application

Table 3
Suggested application of real and fake HDRI rendering.

texturing and shadows generally is more realistic in real HDRI compares to fake HDRI.

According the points discussed above, we have summarized some factors that need to be considered in choosing real or fake HDRI rendering. This is summarized in Table 3.

Conclusion and future works

It is widely accepted that by using real HDRI, more realistic lighting effects can be achieved. However, this does not conceal the fact that it involves a difficult process, is time consuming and also a high budget. Under those limitations, fake HDRI might be a better solution. Nevertheless, we can never say that one method is better than another because each has their own advantage and disadvantage that benefit a particular condition.

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