TECHNIQUES ON HERITAGE PRESERVATION USING LIGHTING COMPUTATION IN VIRTUAL ENVIRONMENT

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ABSTRACT: This research presents the results of experiments of techniques on heritage preservation using lighting computation in virtual environment. In this research, three traditional houses built in the early 1900s were re-constructed based on the captured data that included texturing and lighting. A thorough study on the lighting solution and its impact to the design aspects of photorealism and issues discovered in processing the digital data will be emphasized. This includes complexity of the modeling, rendering and reality, and real-time lighting techniques. This research will suggest effective lighting techniques for re-construction of heritage preservation in virtual environment for architectural purposes.

KEYWORDS: Global illumination, HDRI, simulation, virtual heritage

RÉSUMÉ: Cette recherche présente les résultats d’expériences sur des techniques de préservation patrimoniale utilisant de l’éclairage numérique en environnement virtuel. Dans cette recherche, trois maisons traditionnelles datant des années 1900 ont été reconstruites sur la base d’information captée, incluant la texture et l’éclairage. Une étude fouillée de la solution d’éclairage, de son impact sur les aspects de design du photoréalisme et des problèmes découverts pendant le traitement des données numériques sera soulignée. Cette étude inclut la complexité de la modélisation, le rendu et la réalité, et les techniques d’éclairage en temps réel. Cette recherche suggère des techniques d’éclairage efficaces pour la reconstruction de préservation patrimoniale en environnement virtuel à des fins architecturales.

MOTS-CLÉS: Illumination globale, HDRI, simulation, patrimoine virtuel
1. INTRODUCTION

Global-based (GI) illumination techniques have widespread applications in digital cinema, digital photography, animation, virtual reality and computer games that have opened up many new possibilities, including dramatically improving the visual realism of digital photographs and videos, enabling the development of more accurate computational vision techniques (Qui 2006). While there are many sophisticated lighting simulation and illumination computation (Chevrier and Perrin 2003) tools available in the market for designers to explore and represent architectural spaces, virtual construction and heritage preservation, many of them are still time consuming (Czerner and Gatermann 2002), difficult to use, give insufficient digital output (Adel 2002), and are complex and expensive (Besuievsky & Pueyo 2001).

The early findings of this research were presented in the 23rd International Conference of Education and Research in Computer Aided Architectural Design in Europe 2005 (eCAADe), Lisbon, Portugal 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 algorithm namely ray tracing and radiosity. The results were based on static and using the same exposure factors, when capturing HDRI.

This research continues to present the results of experiments carried out under Science Fund on techniques on heritage preservation using lighting computation in virtual environment. Although GI-based lighting methods produced impressive image results as digital stills and animations compared to the conventional lighting simulation, the challenges for such techniques in a virtual environment (VE) require further attention on the illumination capturing tasks due to three key issues. VE often accepts low-polygon images to ensure smooth real-time simulation resulting in compromising the realism factor (the 'look and feel') of the models. Apart from this, architectural spaces, either internal or external, usually involved moving objects such as tree, cloud, sun and people, and often contribute to the inconsistency of illumination capturing tasks in the real sites. According to Serrato-Combe (2001), virtual re-construction of historical spaces has to incorporate with a smart illumination computation to achieve higher digital modeling and rendering qualities.

2. HERITAGE PRESERVATION

Virtual reality technology has opened up possibilities of techniques and effective ways especially for research in the field of design, architecture, interpretation and preservation of cultural and natural heritage (Ch'ng and Stone 2001) and education at least for the last 15 years. According to Ch'ng and Stone (2001) virtual heritage sets out to designate the use of computer-based interactive
technologies to record, preserve, or recreate artifacts, sites and actors of historic, artistic, religious and cultural significance and to deliver the results openly to a global audience in such a way as to provide formative educational experiences through electronic manipulations of time and space.

In the context of architecture, historical buildings can be preserved through physical restoration or renovation; however, these procedures are costly and may not be feasible due to deterioration of materials over time (Chan et al. 2003). They explained that in order to preserve important examples of cultural heritage, cost-effective methods that can generate a good representation for the public use and appreciation were the best solution. While there are many approaches by research scholars to put forward ideas on preservation of historical buildings, it is clear that the current digital technology has the vast potential to suggest preferences of representing the building ‘as built’ state or a specific time period of that time.

3. THE PROJECT

In this research, three traditional houses built in the early 1900s were selected in collaboration with Centre for the Study of Built Environment in the Malay World (KALAM), Universiti Teknologi Malaysia (UTM) to recommend the ‘conservation buildings’ for the experiments involving the searching of original documents and site visits. This involved a re-construction based on the captured data that included the texturing, lighting (from the original sources) and real-time rendering. A thorough study on the design aspects of photorealism factors and issues discovered in processing the digital data will be also emphasized. This includes accuracy, detail and complexity of the modeling, rendering and reality, and complexity and visualization speed.

The concept is to reconstruct 3D digital models of the traditional houses to give the ‘reasonable’ impression within the context of architectural elements, features and detailing. The key intention is to record traditional buildings accurately and be able to display the models efficiently by means of giving a sense of reality via real-time environment. The urgency of this research was triggered due to the following reasons:

(i) It has significant cultural meaning and historical values identified by KALAM and Arkib Negara (National Archives of Malaysia).
(ii) The selected houses are close to 100 years old, and in their current state, the physical building are beginning to deteriorate, in terms of the material (especially timber), in the hot and humid climate, and are not well maintained.
(iii) Lack of building conservation strategies due to individual ownership that is resulting in major changes in architectural forms, functions and features. These create difficult and unreliable references from the original design.
A few of the key features of the traditional timber houses are as below:

(a) **Rumah Melaka** (Melaka House): It was built around 1910. Amongst the key characteristics are the concrete staircases finished with decorative ceramic tiles and the timber structures built based on traditional wood carving detailing.

(b) **Rumah Negeri Sembilan** (Negeri Sembilan House): The house that was built around 1920 adopted the *Minangkabau* roof design originated from Sumatera (Indonesia) as one of the unique features. Apart from this, the *serambi* (balcony) is being utilized in three different space functions.

(c) **Rumah Perak** (Perak House): This double storey timber house that was originally built in 1909 is currently utilised as a private school.

The study and explanation in this paper is focused on the Traditional Melaka House due to its complexity of the architectural representations and lighting computations in virtual environment compare to the other houses.

4. **MODELING COMPLEXITY**

The digital modeling process was based on the original measured drawings carried out by a team of 4 to 7 researchers in KALAM. The basic architectural drawings were made available in manual and digital 2D and 3D drawings and models documented as AutoCAD files. Other supported documents include still photographs, personal interviews and video clips submitted in the form of research reports. The AutoCAD files were exported and reconstructed using solid modeling techniques with the right scale using Google SketchUp. These models were then exported to 3D Studio Max for the final touch up as .3ds files. The exporting of 3D Studio Max had several problems particularly the loss of polygons. In order to overcome this, the experiments adopted XML-based format (‘Collada’) that is transferable between many software’s (Figure 1).

**FIGURE 1: THE ORIGINAL AUTOCAD MODELING OF THE TRADITIONAL MELAKA HOUSE.**
In the first phase of modeling, the coordination was established to understand and construct with the exact scale using dimension tools and ‘align’ functions, saved as .dwg format. Using the raw data from AutoCAD files the basic structure of the houses were constructed. Models were grouped in different clusters to ensure smooth cross file referencing and transferring when exported in 3D Studio Max. All basic forms of the ornaments (i.e. timber carving) were modeled to establish the right shape and proportion. The total file size (polygon) at this stage was huge primarily due to the complexity of the timber carving. The key challenge at this stage was to reduce from 20000 to 1500 polygons without scarifying the overall ‘look and feel’ of the detailing (Figure 2).

**FIGURE 2:** A SOLID MODELING TECHNIQUE OF THE TRADITIONAL MELAKA HOUSE RECONSTRUCTION PROCESS USING GOOGLE SKETCHUP SOFTWARE.

The 3D files were exported to the 3D Max using solid modeling techniques for better rendering results without any issue on dimension and scale of the models. 3D Max was also used to control the polygon counts to achieve the optimum output in simulation environment. In this process, surfaces that were not viewed by users were deleted with the assistance of Poly Crunch software to reduce the overall number of polygons (Figure 3 and Figure 4).

**FIGURE 3:** A FULL SHOT OF THE TRADITIONAL MELAKA HOUSE WITH LOW (LEFT) AND HIGH (RIGHT) POLYGONS.
5. RENDERING AND REALITY

3D Studio Max was also used to assigning the material, texture and to render the object. For most of the projects the three components in ‘blinn shader’ (ambience, diffusion and specular) were used to establish different textures of the house spaces. As for the walls of the house, the ‘diffuse’ parameters of the blinn shader were then mapped to an edited bitmap image taken from the scene as texture map. It was mapped in the explicit map channel in U and V direction and ‘pyramidal’ filtering. Similar methods were taken to map the other surfaces except the inside doors and roofs. It was also identified that the inner part of the house had an extra layer of shininess that reflected the lights. Therefore, while mapping inside of the house as well as the roofs, a specular level was added to ensure the surface contains the glaze needed as it appears in the real house.

5.1. Real-time lighting techniques

Lighting is one of the most crucial parts of the whole processes. For realistic lighting computation, this project suggested high dynamic range images (HDRI) to suggest sufficient data and simulation tasks. Two key advantages for such lighting computation are:

1) Correct environment lighting: As HDRI uses multiple exposures to combine single HDRI, it can re-create lighting situation realism close to the real environment.

2) Visibility of the low-key light: Either for lot of indoor environment putting 2D lights (such as Omni or Directional lights) created too much light or too little which makes the indoor environment overexposed or underexposed. Using photons with HDRI has solved the problem as the lighting computation correctly enabled the indoor details captured with the texturing but was not visible due to normal 3D lighting placements (Figure 5).

FIGURE 4: A CLOSE UP SHOT OF THE TRADITIONAL MELAKA HOUSE WITH LOW (LEFT) AND HIGH (RIGHT) POLYGONS.
5.2. Real-time rendering computation

Generally, the output of a 3D program is in jpeg- or video-based was established to enable viewers to explore the visualization task in any existing image viewing or video viewing programs. However, when the intended use is for virtual environment, it is required to prepare the files to be exported in the form of virtual reality modelling language (VRML), .x3d or other format so that viewers can navigate in real-time.

Current lighting computations in virtual worlds still limit direct export of modeling even though experiments carried out by researchers within this field. According to Pomi and Slusallek (2005) research findings, interactive ray tracing can provide interesting result yet still very expensive and time consuming to compute. Similarly as shown by Flog Canvas 3D ray tracing system with Javascript and HTML 5 (http://labs.flog.co.nz/raytracer/), computing real-time lighting computation is very slow and impractical. Furthermore, a demonstration carried out by Wald et al. (2006) shows that for freeform geometry and complex shading a frame per second above ten took a very long time to compute especially in a simulation environment.

In this experiment, the solution was to bake the textures for the environment (including shadows) and use normal 3D lighting for specularity and lighting effects. Bake texture (also referred as render to texture) is a process to render the lights and shadows of a scene onto the relevant textures. When this scene is being rendered in Texture Baking mode, the renderer uses the surface of the target objects to cast the rays into the scene. Thus the complex lighting features can be built into the texture without needing to render it real-time. Objects that required such effects were textured and rendered in 3D Studio Max (via dialogue box) using a complete map. Most target map slots were diffused and rendered in the output section with the color size of 256 x 256 pixels to ensure fast loading and reduce lagging during the virtual experience (Figure 6).
The rendered UV map files were unwrapped using the edit modifier stack. This technique was applied for all the objects in the scenes and saved in different version together with the removal of all lighting effects and HDRI. Objects were then assigned with a new ‘blinn’ material before loaded the pre-saved map (pre-rendered image) as a texture map. One key advantage on this is that complex textures (baked) allow objects to be lit up and emphasized accordingly (in reference to the real environment). Apart from this, such technique also permits ‘ray traced HDRI-based’ visual output with a fast loading virtual experience and higher realism effects (Figure 7).

5.3. Advanced shadow technique

In order to create realism, one of the most commonly used terms is ambient occlusion. Ambient occlusion is a type of shading method used in 3D computer graphics that helps add realism to local reflection models by taking into account attenuation of light due to occlusion. Unlike local shading options such as lambert, blinn or phong shading, ambient occlusion is a global method that allows illumination at each point in the scene. However, it is a very crude approximation compare to full global illumination. The soft appearance
achieved by ambient occlusion solely is similar to the way an object appears on overcast day. Besides creating the soft shadows around the object it also helps to eliminate the floatness of an object. As for this technique, since baking the texture is by establishing the lights directly on top, light movements and positions will remain static (Figure 8).

**FIGURE 8.** THE FINAL TEST MODEL OF THE TRADITIONAL MELAKA HOUSE WITH HDRI RENDERING AND ADVANCED LIGHTING COMPUTATION FOR VIRTUAL ENVIRONMENT.

6. CONCLUSION

This research experiment suggested that a hybrid solution of lighting in virtual environment to better represent architectural realism. Ray tracing was used to light the scene and later was baked as textures to sustain the realism. In contrast with normal lighting (i.e. typical three-point lightings) solution, ambient occlusion technique managed to create subtle ‘look and feel’ of the overall scene and was preserved using the texture baking in virtual environment. HDRI offered time-based lighting solutions to be visualized using the same ray tracing setting with different exposures to create options for a real-time architectural lighting visualization. Further expansion may focus on utilizing the suggested techniques with bigger heritage samples to outline the common denominators of such lighting solutions for virtual environment.

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