AN IMMERSIVE VIRTUAL REALITY SYSTEM FOR INTERIOR AND LIGHTING DESIGN

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Abstract. We are developing an immersive virtual reality system for interior and lighting design where, inside a CAVE®, one can change at will the color, texture and finishing of all elements in the simulated environment (walls, floor, furniture and decoration) as well as position, type, color and intensity of all light sources. Although the rendering algorithm used in the system is the ray tracing, preliminary results show we are able to achieve almost real time performance. The system is intended to both help architects to better communicate their design ideas to clients through an advanced visualization tool and also speed up the interior and lighting design processes.

1. Introduction

The CAVE (Cave Automatic Virtual Environment), firstly developed by the Electronic Visualization Laboratory at the University of Illinois at Chicago (Cruz-Neira et al., 1993), is a cubic, "room-sized advanced visualization tool that combines high-resolution, stereoscopic projection and 3-D computer graphics to create the illusion of complete sense of presence in a virtual environment" (Fakespace, 2002). The installation available in our laboratory is a 5-face (4 walls + floor) stereoscopic system, driven by a 6-Pentium4 PC cluster, equipped with Ascension's Flock-of-Birds trackers and 3D-mouse.

Parameterized Ray Tracing (Séquin and Smyrl, 1989) is a computer graphics algorithm derived from ray tracing (Whitted, 1980) aimed at re-rendering synthesized photo realistic images. Like ray tracing, images generated by parameterized ray tracing can display realistic multiple reflections and refraction, transparency and shadows as well as approximate diffuse illumination effects. Although interactive ray tracers have been implemented in very expensive high-end parallel machines (Parker et al., 1999), the rendering time required by this algorithm is usually too high for interactive applications in standard hardware. This fact is even more critical in a virtual reality setting like ours where 10 images (5 walls x 2 eyes for stereo) are needed each time. However, by using parameterized ray tracing, it is possible to achieve interactive rendering times on standard PC clusters, although coping with this algorithm restrictions.

2. Interior Design and Parameterized Ray Tracing

Parameterized ray tracing allows a ray traced image to be re-rendered with changed optical parameters (object surface colors, textures and finishes, light source colors and intensities) in a small fraction of the time needed to compute the original image. No geometrical parameter (object geometry and position, viewer position) can be changed.

Before using the parameterized ray tracing algorithm to re-render an image with new optical parameters, a base image has to be generated by the standard algorithm so that the image ray-trees can be computed and stored. The ray-trees are data structures which registers the path of all the rays fired to render each image pixel, encoding the scene geometry and viewer position.

Such algorithm is adequate to an interior design application where the designer is mainly interested in experimenting with different color paints or wall tiles and papers as well as different floor finishes.

A total of 25 parameters can be configured for each material in our system in the simulated environment through a virtual interface.

3. Lighting Design and Extended Parameterized Ray Tracing

Designing the illumination of real environments has always been a difficult and often tedious task, requiring much time and effort with the manipulation of physical light sources, shades, reflectors, etc. (Loscos et al., 1999). Today, many software packages provide a practical way to simulate the light effects in internal and external ambients. However, the visualization of the results are not ideal as the computer screen not always convey the true sensation a lighting design will create in the real environment. An immersive virtual reality simulation is the best choice for this visualization task, only second to the “real thing”.

The standard parameterized ray tracing algorithm is not able to fully support lighting design needs because light source positions and geometries cannot be changed, although their colors and intensities could be. An improvement on the original algorithm, known as the Extended Parameterized Ray Tracing (Santos, 1994, 1998), can be used to that end. This algorithm allows all light sources in the environment be moved, correctly computing the new shadows and illumination effects, without degrading too much the re-rendering time. Spotlight direction and aperture angles as well as fall-off rates can be adjusted. Color gobo light patterns can be freely chosen too. Being so, the Extend Parameterized Ray Tracing is the rendering algorithm used in our system, with more than 15 customizable parameters for each light source.

4. Conclusions

The system requires previous modeling of the geometry of the environment as well as assignment of materials to each element on it. Pre-renderings of the scene from the center of the CAVE facing each of its 4 walls and floor are also necessary. After these steps, interactive experimentation with all the parameters is possible. Preliminary results show we are able to achieve almost real time performance and that the system can be an effective tool for interior and lighting design.

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