Real-Time Global Illumination

Using Graphics Hardware and Algorithms to Enhance Visual Realism in Virtual Environments

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The Challenge

The quest for a convincing sense of presence in Virtual Environments (VE) demands increasing visual realism from real-time computer graphics. This requires fast and accurate simulation of the interaction of light and matter, beyond the effects of simple direct illumination. Real environments contain a variety of materials, each of which interacts with light in different ways. The illumination of a scene is only partially due to direct illumination; much of the light falling on a surface has been reflected or transmitted at least once before reaching it.

The human visual system knows how a real environment looks; subtle differences in illumination can cause *Breaks in Presence* (BiPs). To provide a truly immersive Virtual Environment, we must simulate global illumination.

The Approach

One area of research the Effective Virtual Environments (EVE) group is pursuing is the improvement of visual realism through real-time global illumination.

Interactive Glossy Reflections

Many real environments include reflective or semi-reflective surfaces. While simulating perfect mirror reflections is straightforward with geometric multi-pass rendering, glossy surfaces are harder to simulate.

We have developed a hybrid geometry- and image-based approach that uses images to produce interactive reflections. We use standard graphics hardware to rapidly compute a set of radiance maps (images with depth) that represents what each reflective surface "sees." Each pixel in a radiance map stores the radiance and location of a point in 3D space. At run-time, a subset of radiance maps is selected and reprojected onto the reflective surface. Pixels of the radiance maps are transformed into world space and then projected into the new view using graphics hardware.

Real-Time Glossy Reflections

This image-based approach outperforms geometry-based reflections and provides reasonable results for glossy surfaces.

Layered Effects. *Upper left:* base + light map. *Upper right:* highlight. *Lower left:* pseudo-Fresnel reflection. *Lower right:* composite of all four.

Environment Mapping

Environment mapping is a texture mapping technique that simulates reflection of a surrounding environment by an object. Standard environment mapping uses a view-independent implementation, causing the object to reflect the same image regardless of the position of the viewer. We use a view-dependent calculation of the mapping that allows more realistic reflectance simulations.

Our view-dependent environment mapping formulation allows us to simulate complex light-surface interaction and the view-dependent reflectance properties of many real materials. We have used environment mapping to simulate effects such as Fresnel wavelength shifts (exemplified by copper) and Cook-Torrance illumination. We have simulated real materials—such as iridescent automotive lacquer—by using general BRDF data with view-dependent environment mapping.

While effects such as image-based reflections and environment mapping are useful alone, we are exploring methods of combining several effects simultaneously on objects in virtual environments. We experiment with new techniques by using programmable shading hardware to build layered effects on objects in our scene graph.

Real-Time Cloud Rendering

Clouds are such an integral feature of our skies that their absence from any synthetic outdoor scene detracts from its realism. In the past, clouds in flight simulators and games have been hinted at with images—both static and animated—and with semi-transparent textured objects and fogging effects.

There are many effects associated with clouds that are not achievable with existing techniques. In a flight simulator, we would like to fly in and around realistic, volumetric clouds, and to see other flying objects pass within and behind them.

We are developing realistic hardware-accelerated shading and rendering algorithms for interactive clouds. Our cloud rendering method is a two-pass algorithm that computes cloud shading in the first pass using graphics hardware, and uses this shading to render the clouds in the second pass. Cloud shading accounts for multiple anisotropic forward scattering in clouds modeled as particle systems. We use impostors—dynamically generated billboards—to accelerate cloud rendering.

Real-Time Cloud Rendering

Project Leaders

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Selected Publications

Harris, M., and A. Lastra. “Real-Time Cloud Rendering,” *Computer Graphics Forum (Proc. Eurographics 2001)*, 20(3), September 2001, 76–84. Also *Department of Computer Science technical report TR01–005*, University of North Carolina, 2001.

Bastos, R., K. Hoff, W. Wynn, and A. Lastra. “Increased Photorealism for Interactive Architectural Walkthroughs,” *Proc. 1999 Symposium on Interactive 3D Graphics*, Atlanta, Ga., 26–28 April 1999.

Key Words

Global illumination; realistic rendering; real-time cloud rendering; glossy reflections; multi-texture effects

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