Rapid Rendering of Massive Models

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The Challenge

Modern computer graphics applications often demand interactive displays of very complex environments. Such environments mainly come from computer-aided design (CAD) and scientific visualization applications. The growing reliance on CAD in mechanical design process has created a growth in model complexities to the extent that designers today regularly create components belonging to complex assemblies that exceed the interactive visualization capabilities of existing graphics systems. Furthermore, the ever-increasing speed and availability of 3D graphics hardware appears to be stimulating rather than solving the problem of rendering large models.

One of our major research goals is to develop algorithms and to enable software technologies to meet the challenge of rendering massive models at interactive rates on current graphics systems.

The Approach

Object Models and Representations. We are evaluating different formulations for representing large environments. Input models include polygons, spline surfaces, primitive solids, and their Boolean combinations. We have been developing robust and accurate algorithms to compute their boundaries and are using different spatial data structures to represent them hierarchically.

Automatic Simplification of Polygonal Models. The fundamental components of the display database are the different levels of detail for each model. We are working to develop algorithms that will give guaranteed bounds on model fidelity, as well as generate coarse approximations to the geometry, in terms of polygon count.

Visibility Culling. Given a large environment with high depth complexity, we are working to design general visibility-culling algorithms that make no assumptions about the structure of input models and that are able to cull away significant portions of the model that are not visible from the current viewpoint.

Interactive Display of Very Large Spline Models. We have been developing algorithms to display interactively models that are composed of hundreds of thousands of spline patches. Our goal is to display models composed of hundreds of thousands of patches at interactive rates.

Highlights

- **Rendering massive models**
- **Visibility culling**
- **Model simplification**
- **Texture-based simplification**
- **Dynamic tessellation of spline models**
- **Database management**
- **System integration and applications to massive CAD models**

Texture-Based Simplification. We are working to integrate geometry and texture into a single hybrid representation in order to have a texture-based representation that can be viewed as storing the geometry in an intermediate form after rasterization but before final display. Our planned rendering system would automatically balance the trade-off between a geometry-based representation and a texture-based representation.

Image-Based Rendering. Our initial application of image-based rendering techniques was to render from a set of images of the real world. We are using them for interactive display of large geometric models, using warping techniques.

Database Paging and Parallel Implementations. Many large models composed of millions of primitives may not fit in main memory. In such applications, the model is pre-fetched from the disk during interactive walkthrough. Our goal is to develop dynamic paging schemes that load parts of the model and appropriate simplifications that will soon be visible into main memory at runtime.

System Integration. Given a large model composed of tens of millions of primitives, none of the techniques described above is capable of displaying the model at interactive rates by itself. These techniques must be combined using appropriate data structures to represent geometry, levels of details, texture maps, images, etc. We have been developing an integrated system and have been applying it to interactive walkthroughs of submarines, outdoor models, and power plants.

Dynamic Environments. Many of the techniques described above involve significant pre-processing. In some environments, objects undergo motion or new objects are added or deleted. As opposed to re-processing the entire database, our goal is to develop incremental algorithms for updating the hierarchy, occluder database, levels-of-detail, and texture-based simplification.

Application to Massive Models. The resulting algorithm and systems have been used to accelerate the rendering of a large number of massive models. These include terrain models, medical datasets, and CAD models of a submarine, coal-fired powerplant and architectural models composed of millions of polygons.

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Selected Publications

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Key Words
Walkthroughs; model simplification; visibility culling; texture-based simplification; database management; interactive computer graphics.

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