



MMR: Massive Model Rendering System

Using Multiple Rendering Acceleration Techniques and Database Management to Interactively Display Large Geometric Models

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The Challenge

Overview. Computer-aided design (CAD) applications and scientific visualizations often need user-steered interactive displays (walkthroughs) of very complex environments. Structural and mechanical designers often create models of large structures such as ships, oil platforms, spacecraft, and process plants. While both the design process and the design review process would benefit from interactive walkthroughs, the size and complexity of these models exceed the current interactive visualization capabilities of even high-end systems such as the SGI Infinite Reality Engine.

The Approach

The Walkthrough Project Team has been attacking the problem of rendering such massive models (models which consist of one million primitives or more and which often do not fit within online memory) in real-time. We chose a

15-million-triangle model of a coal-fired electric power plant (Figure 1) as our challenge model and driving problem, and have been pursuing the following goals:

- **Interactivity.** We aim at 20 frames per second.
- **Modularity.** We want to be able to incorporate and substitute a variety of acceleration techniques into the system.
- **Automaticity.** Each of the model re-representation and rendering acceleration techniques (e.g. visibility culling, model simplification, substituting distant



Figure 1. A view of our 15-million polygon model of a coal-fired power plant. The MMR system partitions the model into viewpoint cells. Surrounding each cell is a cull box (white outline) that separates the model primitives into near geometry (highlighted) and far geometry (tinted).

geometry with images, etc.) should be performed automatically without the intervention of human judgement or action.

- **Scalability.** The system should require a human set-up that is at most sublinear in the number of elements. Run-time overhead should grow sublinearly with the number of elements. The system should operate effectively on models that cannot be contained in graphics engine memories.
- **Applicability.** The system should be applicable to real-world massive models.

MMR System. We have developed a system for rendering very large 3D models at interactive rates. The fundamental idea behind our system is to render objects “far” from a viewpoint using fast image-based techniques and to render all objects “near” the viewpoint as geometry (Figure 1). The system performs extensive preprocessing (Figure 2) to reduce the execution time of the run-time rendering system.

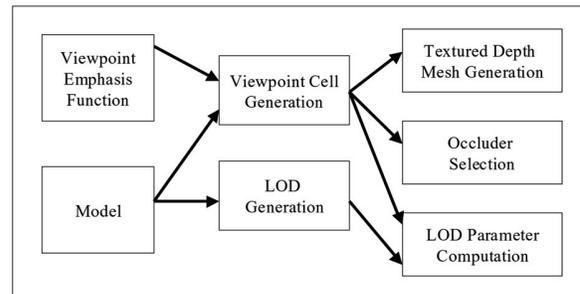


Figure 2. Preprocessing Pipeline. A model and a viewpoint emphasis function are the inputs to the preprocesses of virtual cell generation and LOD generation. These preprocesses produce textures, meshes, occluders, and LOD parameters for the run-time system.

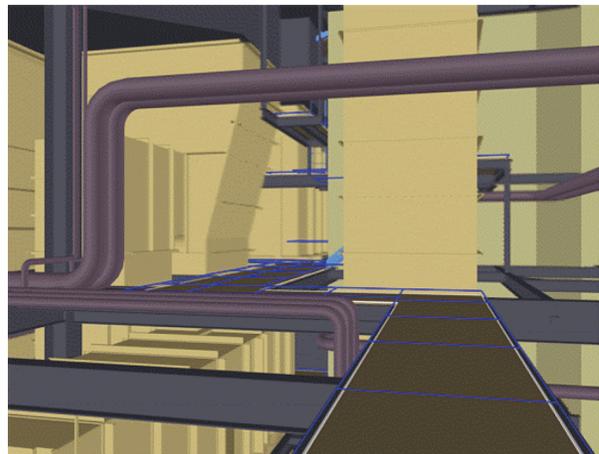


Figure 3. A view of the inside of the power plant, including the distribution of viewpoint cells.

The MMR system also employs prefetching and data management schemes, which are necessary when dealing with models larger than online memory.

We have successfully applied our system to accelerate the walkthrough of a large coal-fired power plant model with more than 15 million triangles, and to a 2 million triangle architectural model.

System Characteristics. The massive model rendering system resulting from our work has the following characteristics:

- A rendering scheme that reduces polygon count using both images and geometric levels of detail, where appropriate, and that automatically balances the quality and speed-up of the two approaches.
- An approach to rendering massive models that partitions the model into cells with manageable polygon complexity, each of which can be optimized separately for speed, quality, and memory usage.
- An effective system pipeline to manage the resources, (i.e., the CPUs, the main memory, the texture memory, the graphics engines) and to allocate them among the various acceleration techniques.
- An integrated database, with a coherent representation technique, and memory management, and prefetching of geometry and textures larger than hardware memory capacities, which is crucial for scalability.

Lessons Learned. In the process of creating and implementing the massive model rendering system, we made the following observations:

- With a massive model it is crucial to construct carefully a single database representation that supports all the expected rendering acceleration techniques, because we cannot afford to replicate large amounts of data.
- Traversing the model database is a very expensive operation; hence, algorithms that must frequently access the entire database do not scale well.
- A single rendering acceleration algorithm might provide a performance increase over naive rendering, but their combination does not necessarily achieve their combined speed up. Thus, the order in which the techniques are applied becomes very important.

Further Information. Further information on the MMR system is available via the Web (www.cs.unc.edu/~walk/research/).

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Selected Publications

Aliaga, D., J. Cohen, A. Wilson, E. Baker, H. Zhang, C. Erikson, K. Hoff, T. Hudson, W. Stuerzlinger, R. Bastos, M. Whitton, F. Brooks, and D. Manocha. "MMR: An Interactive Massive Model Rendering System Using Geometric and Image-Based Acceleration," *Proc. 1999 Symposium on Interactive 3D Graphics*, 199–206.

Key Words

Interactive walkthrough; massive models; occlusion culling; levels of detail; textured depth mesh; image-based rendering; prefetching.

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