Exploring Virtual Prototypes using Time-Critical Rendering Techniques

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At CRS4, in Cagliari, Italy, we developed a time-critical rendering algorithm that relies upon a scene description in which objects are represented as multiresolution meshes. In collaboration with other European partners we applied this technique to the visual and collaborative exploration of large digital mock-ups.

When undertaking a large and long-lasting engineering or architectural project, it is vital to verify quite often what could be the consequences of the decisions taken during the design phase. The aim of virtual prototyping research is to allow architects, engineers and designers to work on digital mock-ups which simulate visual appearance and behavior of objects on a computer. The expected benefits of virtual prototyping technology include: a substantial reduction of development time and of manufacturing costs, thanks to a reduced need for expensive physical mock-ups; the ability to continuously maintain digital mock-ups in sync with the design, and therefore the possibility to use them for documentation purposes and as a basis to help the dialogue between engineers from different fields who can talk, possibly with different words, about the same thing; the possibility of using mock-ups during collaborative design sessions among geographically distant partners, a very difficult option when using physical prototypes.

Time-critical rendering

As for all virtual reality applications, virtual prototyping systems have very stringent performance requirements: low visual feedback bandwidth can destroy the illusion of animation, while high latency can induce simulation sickness and loss of feeling of control. Since virtual prototyping tools have to deal with very large dynamic graphics scenes with a complex geometric description, rendering speed is often a major bottleneck. Typical virtual prototypes, once converted to an adequate accuracy often exceed the millions of polygons and hundreds of objects, which poses important challenges to application developers both in terms of memory and speed.

Since the complexity of a scene visible from a specific view-point is potentially unbound, meeting the performance requirements dictated by the human perceptual system requires the ability to trade rendering quality with speed. Ideally, this time/quality conflict should be handled with adaptive techniques, to cope with a wide range of viewing conditions while avoiding worst-case assumptions. The presence of moving parts, and the need for interaction of virtual prototyping tools, limits the amount of pre-computation possible, leading to run-time solution.

Time-critical rendering of scenes composed of many objects is an open research area. The traditional approach to render these scenes in a time-critical setting is to pre-compute a small number of independent level-of-detail (LOD) representations of each object composing the scene, and to switch at run-time between the LODs. This technique has multiple drawbacks, both in terms of memory requirements, because of the need to store multiple LODs, and quality of results, because of the NP-completeness of the problem. We recently demonstrated that these drawbacks are overcome when using appropriate multiresolution data structures (TOM, Totally Ordered Mesh) which enable to express predictive LOD selection in the framework of continuous convex constrained optimization.

Visual exploration

Our time-critical multiresolution scene rendering algorithm has been implemented and tested on both UNIX and Windows platforms. The TOM data structure is integrated in a collaborative virtual prototyping system developed in the framework of the ESPRIT project CAVALCADE (#26285, 1/1998-2/2000). All software modules are integrated in an in-house walkthrough application. We experimented with the system using multiple massive datasets, including the digital model of a very large machine (ATLAS) that is under construction at CERN in Geneva that, once built, will be the largest machine for High Energy Physics in the world.

The results obtained allow us to say that our approach can be useful when designing complex engineering or architectural models, to perform visual analysis at an early stage of the design phase. Our approach enables the handling of scenes totaling millions of polygons and hundreds of independent objects on a standard graphics PC. In a controlled environment, it guarantees a uniform, bounded frame rate even for widely changing viewing conditions. The technique does not rely on visibility preprocessing and can be readily employed on animated scenes and interactive VR applications.

We believe that ultimately a time-critical rendering system should combine algorithms such as ours with occlusion culling, image based rendering and other acceleration methods. The system should automatically partition the scene, choosing the most appropriate methods to use for different sets of objects based on cost/quality consideration and algorithm constraints. All these technologies have to be integrated in the same rendering context. This is an aspect often neglected in current research. Integration is made more complex by the fact that dynamic LOD and visibility culling often have different time constraints.

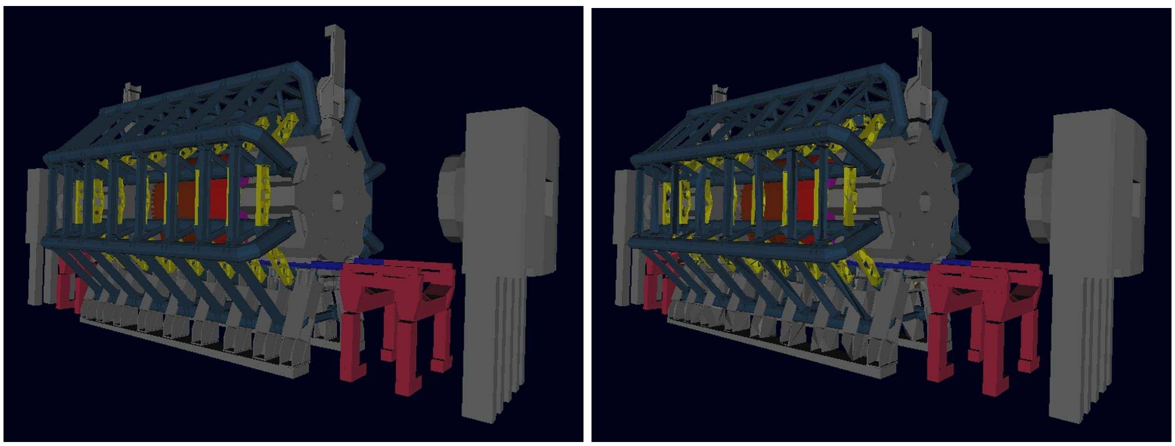

Figure 1: A view of the whole ATLAS Experiment Pit. Comparison between full (left, 1,072,858 triangles) and adaptive resolution (right, 41,487 triangles).

Links:

http://www.crs4.it/vvr

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