Intel Technologies for Scalable Virtual Environments:

Beyond "Simulator in a Box"

Three years ago, researchers in Intel Labs set out to investigate new technologies that would enable massive multiplayer virtual environments (MMVEs) to deliver experiences that are more immersive, interactive and complex. Since then, the researchers have identified and removed a number of performance bottlenecks in OpenSimulator, an open source, multi-user platform that can be used to create virtual environments.[1] Removing the bottlenecks improved OpenSim's performance. But the "simulator in a box" architecture that is common to many MMVE applications continued to limit simulation to the compute capacity of a single server. Applications based on this widely used architecture can scale *out* (i.e., add new virtual land) but cannot scale *up* (i.e., add complexity or enable more users to interact within the existing land). The architecture limits the number of avatars that can participate in a scene to a few hundred, eliminating the potential for a broad range of applications involving hundreds or thousands of participants, and preventing the rich interactions that are crucial to creating a virtual experience that is truly immersive.

The limits of "simulator in a box"

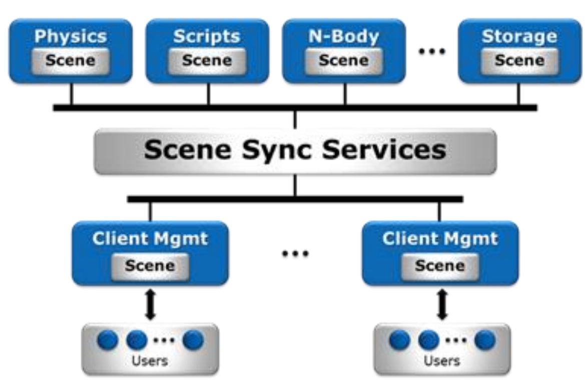
A variety of components must work together to create MMVE applications, from physical simulation to object behavior. Each component requires a different piece of software code to run. In the "simulator in a box" architecture, one master program runs all the pieces of code simultaneously, limiting the amount of computation that can be devoted to each component.

As the number of concurrent users increases and more objects are added to scenes, the number of potential interactions among avatars and objects grows quadratically, putting tremendous demands on the server. If any component runs out of resources, the entire application loses its integrity. Object behavior becomes distorted. The motion of avatars and objects is no longer fluid but discontinuous, as the server cannot execute the scripts and physical simulation rapidly enough. The quality of the simulation declines precipitously.

The solution: Distributed Scene Graph (DSG)

To address the limitations of the "simulator in a box" architecture, Intel researchers have invented a new software architecture called the Distributed Scene Graph (DSG). This architecture enables massive scaling of the number of participants and the complexity of scenes by making it possible to add as much hardware as needed to create a truly immersive experience.

Distributed Scene Graph (DSG) Architecture



To enable this, the DSG architecture separates the technologies bundled in the traditional "simulator in a box" architecture into discrete components, such as client management, physical simulation, script processing, and scene persistence. Each

[1] See C. M. Bowman, D. Lake, and J. Hurliman. Designing Extensible and Scalable Virtual World Platforms. Extensible Virtual Worlds Workshop (X10), 2010. Available at http://techresearch.intel.com/ProjectDetails.aspx?Id=154.

component is run on a separate server process, as an independent service, and the components are connected through the shared “scene graph”—the state of the virtual space they collectively simulate. This architectural structure enables scaling operations with available hardware (computation and communication) as necessary to meet the simulation requirements of a given application.

Think of the components as ingredients that can be combined in varying amounts depending on the “recipe” for an application. For example, the recipe for hosting a large meeting in a virtual space might only require single instances of persistence and object behavior (since the scenes are less complex and object behaviors less sophisticated); a few instances of the physical simulation service (which are computationally complex); and a large number of instances of client management components (since hosting a large meeting requires many, high bandwidth connections to the simulation). On the other hand, the recipe used by a scientist to visualize a protein folding sequence may require fewer instances of client management and many more of object behavior and physical simulation, since the behavior of the objects in the scene is far more complex. The key is to choose the appropriate type and amount of hardware resources needed to execute the code for each component, to achieve the high overall level of performance required to create an immersive virtual experience.

The ability to use the appropriate type of hardware is a major benefit of the DSG architecture. Unlike the “simulator in a box” architecture, which performs most simulation functions but is not optimized for any particular application, the DSG architecture enables each component to be run on the type of server optimized for that function. Physical simulation can be executed on one architecture, client communication on another, scripts on a third. In this way, the performance of the overall application can be optimized.

Potential applications

The modular, flexible DSG architecture opens up the possibility for developing a wide range of large-scale MMVE applications. Training and education are two application areas with significant potential. The ability to scale up, to allow hundreds or thousands of people to interact in a virtual world, could enable applications as diverse as military training simulations and immersive virtual college courses. Corporations also could leverage the technology to host large virtual meetings.

Virtual travel, sporting events and concerts are other compelling application areas. The DSG technology could support applications that enable people to experience the world in a deeply immersive way, without the need to leave home. Imagine taking a virtual trip to the Louvre, the pyramids of Giza, or Machu Picchu, interacting with other virtual travelers along the way. Envision a virtual World Cup soccer stadium with 10,000 screaming fans immersed in a virtual game that accurately portrays a real game in progress. Visualize a virtual concert that recreates the feeling of audience participation that’s missing when watching a favorite band on a flat screen TV. These are just a few of the possibilities for creating immersive virtual experiences that will push far beyond the limits of today’s MMVE applications.

Looking ahead

Intel has demonstrated its DSG technology on ScienceSim with more than 1,000 interacting clients, 13 client managers across multiple geographies, and 1,000 bots and 20 humans connected to client managers. Network processing on the scene was reduced by 99% compared to the theoretical processing required to host 1,000 clients on a “simulator in a box” architecture. The software to implement the DSG architecture will be released later in 2011 under an open source license.

While the Intel Lab researchers have succeeded in scaling simulations using the DSG architecture, there is much to learn about doing so dynamically. In addition, the researchers still must explore how to include the client in the scaling of the virtual world, which involves the challenges of last mile bandwidth, rendering of user-generated scenes, and delivering immersive experiences on mobile devices. To tackle these challenges, future research will focus on the "reduction pipeline"—finding ways to deliver the minimum data needed to create a realistic simulation for a given device (e.g., less data for smart phones, more for large HD screens).
In the meantime, researchers at Intel Labs continue to test and refine the DSG technology. Their novel approach to server architecture for virtual environments illustrates the power of thinking outside the box.

For more information, go to Scalable Virtual Environments.