Simulation Culling and Level-of-Detail

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Introduction

Current generation virtual environments have a wealth of applications, including military and civilian training, scientific experimentation, and entertainment. High-quality dynamics — motion, artificial intelligence, strategic simulation — are an essential requirement of many environments, particularly those intended to model the complexity of the real world. To meet this need, a wide range of models has been developed to realistically simulate natural phenomena, man-made vehicles, and human behavior, including many specifically intended for use in real-time environments.

However, combining many dynamic models into one environment rapidly overwhelms the computational resources of current and anticipated machines. This is of particular concern for disaster management training, for which environments must contain large numbers of virtual characters behaving with high fidelity. Applications for which expense and availability are a concern, such as future driver training simulators or current generation computer games, also must address the cost of dynamics computations.

Simulation culling and level-of-detail techniques offer tools to reduce the resource cost of dynamic simulation in large environments. Culling algorithms [4] avoid computations for simulations that a viewer cannot see, hence enabling truly scalable environments on a single machine. With effective culling, it is possible to experience an entire city simulated on one computer, as most of the motion is out of view and hence costs nothing. Level-of-detail methods [2, 5] aim to reduce the cost of dynamics when the system is far from the viewer, thus allowing for environments with large visible areas yet rich dynamic content. With effective simulation level-of-detail, a viewer could look out across a simulated crowd and see reasonable motion without the cost of accurate dynamics for everyone.

Simulation Proxies

Simulation proxies replace expensive dynamics, such as accurate vehicle models, with cheaper computations when the system is out of view. Along with Okan Arikan and David Forsyth at the University of California at Berkeley, I have demonstrated proxies for complex dynamic multi-agent path-planning and city traffic simulations [1, 3]. Our proxies replace the accurate simulation model with a discrete event simulation that models only events that are important to the long-term behavior of the system. This technique is particularly well suited to simulations with complex and important out-of-view dynamics. For example, in a traffic model we track only visibility change events and events related to cars passing through intersections. In this way we can simulate two orders of magnitude more vehicles than is possible running the complete simulation. We also demonstrate that a viewer would be unable to detect the use of the proxy, indicating that our proxies do not significantly alter the viewer's experience. In the case of multi-agent path-planning, we avoid computing the precise interactions between agents and replace them instead with random delays that mimic their effects. This allows us to simulate hundreds of thousands of agents with few restrictions on their behavior.

We are currently exploring the culling of rule-based artificial intelligence (AI) in ongoing work at the computer graphics group at the University of Wisconsin at Madison. Rule-based systems underlie much of the enemy strategic and individual behavior in computer gaming environments and those for training simulations. Enemy AI is also a significant drain on computing resources, which limits the number of virtual participants to the small number of thousands. In our current project we aim to reduce the cost for units that are not visible while still providing a high quality, realistic experience. We will achieve this through the use of multi-resolution behaviors that give the system the freedom to compute at fine temporal and behavioral resolution for nearby agents, while using course behaviors for distant enemy. Careful design of the behaviors will ensure that the long term behavior of the environment remains consistent with the designer's original goals.

Advances in simulation culling and level-of-detail will enable complex, realistic training environments that run on stand-alone commodity hardware. The environments will be scalable without the corresponding need to increase hardware or network resources. It will be possible to provide highly targeted training to small groups without the need to involve other personnel in supporting roles.

Future Directions

There are many future directions for research in this area. One long term goal is to provide practitioners with easy to use tools for producing efficient dynamic environments. A user could then take their preferred dynamic model, run it through a tool and obtain a new model suitable for use in very large virtual spaces. At the same time, quantitative metrics are required to evaluate the effectiveness of animations in virtual environments for quality assurance purposes. This topic is important for motion research in general, but it lies at the heart of culling and level-of-detail work, where our aim is to provide the best possible virtual experience at the cheapest cost.

Further Information

The web site for our work on simulation culling and level of detail can be found at http://www.cs.wisc.edu/∼schenney/research/culling. Links to the work of other researchers are included.

References

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