participant virtual environment.

Having observed that it is difficult to begin to explore networked virtual environments, this tutorial is intended for undergraduate students who are competent programmers and who now wish to implement a distributed, multi-participant application. It describes the fundamental concepts of distributed computing for multi-player simulations and includes a C source code template available via the Internet. The template was designed so that students can quickly create their own distributed applications. The template source code uses broadcast communication and a technique called dead-reckoning to improve performance.

JOHN MORRISON, MAK TECHNOLOGIES

Experiences with DIS-based Virtual Environments

MaK was founded in October 1990 by John Morrison and Warren Katz, two well-known developers of the SIMNET system. MaK has one of the highest concentrations of experienced SIMNET and DIS developers in the industry, measured against companies of any size. MaK personnel have participated in every large DIS simulation contract since the invention of the technology, including SIMNET, Advanced Distributed Simulations Testbed, War Breaker, and the emerging Synthetic Theater of War (STOW).

Three challenges to building large Networked Virtual Environments are ever-increasing complexity, scalability, and portability. We require a software infrastructure to overcome these challenges. We examine one such example software infrastructure which is currently the basis of dozens of virtual environment efforts. Its use of object-oriented inheritance and its use of an interpreted configuration programming language meets these requirements while achieving the efficiency to support large numbers of entities on current-generation hardware.

SANDEEP SINGHAL, DISTRIBUTED SYSTEMS GROUP, STANFORD

Strategies for Minimizing Network Traffic for Large-scale Virtual Environments

Sandeep K. Singhal's research is in communication protocols and algorithms for dead reckoning -- the problem of accurately displaying the real-time position, orientation, and structure of objects actually being modeled on remote machines. He is also researching how to enable dynamic multicast channel aggregation by applications. The PARADISE Project at Stanford is a testbed for his work.

Distributed virtual reality systems require accurate, efficient remote rendering of animated entities in the virtual environment. Position, velocity, and acceleration information about each player is maintained at the player's local machine, but remote hosts must display this information in real-time to support interaction between users across the network. Prior applications have transmitted position information at the local frame rate, or they have relied on dead reckoning protocols using higher derivative information to extrapolate entity position between less frequent updates. These approaches require considerable network bandwidth and at times exhibit poor behavior. We describe a position history-based protocol whose update packets contain only position information. Our evaluation suggests that the position history-based protocol provides a network-scalable solution for generating smooth, accurate rendering of remote entities.

MICHAEL MACEDONIA, NAVAL POSTGRADUATE SCHOOL

Mega-Scale Virtual Environments

Michael R. Macedonia is a US Army major and a Ph.D. student in computer science at the Naval Postgraduate School. His research is directed toward the development of software architectures supporting large-scale distributed virtual environments.

We present our ideas in the context of NPSNET-IV, the first 3D virtual environment that incorporates both the DIS application protocol and the IP Multicast network protocol for multi-player simulation over the Internet. The fundamental idea behind the NPSNET approach is to logically partition virtual environments by associating spatial, temporal, and functionally related entity classes with network multicast groups. This is accomplished by exploiting the actual characteristics of the real-world large scale environments that are simulated, and by focusing or restricting an entity's processing and network resources to its area of interest via a local Area of Interest Manager (AOIM).

RESOURCES

The special double issue of the journal PRESENCE on Networked Virtual Environments includes articles from all the members of the panel. See *ftp://taurus.cs.nps.navy.mil/pub/PRESENCE_MOSAIC/presence_mosaic.html* for more details. Additional information from each of the members of the panel is available via WWW or email:

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Sandeep Singhal, http://www-dsg.stanford.edu/SandeepSinghal.html.

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