



**At least ten unsolved problems in
networking large-scale virtual
environments (LSVEs)**

Michael Zyda & Don Brutzman

Naval Postgraduate School

zyda@siggraph.org

Brutzman@cs.nps.navy.mil



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Talk Outline

What is a large-scale virtual environment (LSVE)?

What do we mean by network software architecture (NSA)?

Web-based VE interoperability

virtual reality transfer protocol (vrtp)

Area of Interest Management (AOIM)

Multicasting ...

Other issues we are not yet into ...

This is what we are working on ...



My presentation is a look at the way we think about the issues of networking VEs at NPS.

We make no attempt to cover the entire set of issues but rather focus on those for which there is time and desire ...

NPSNET Research Group

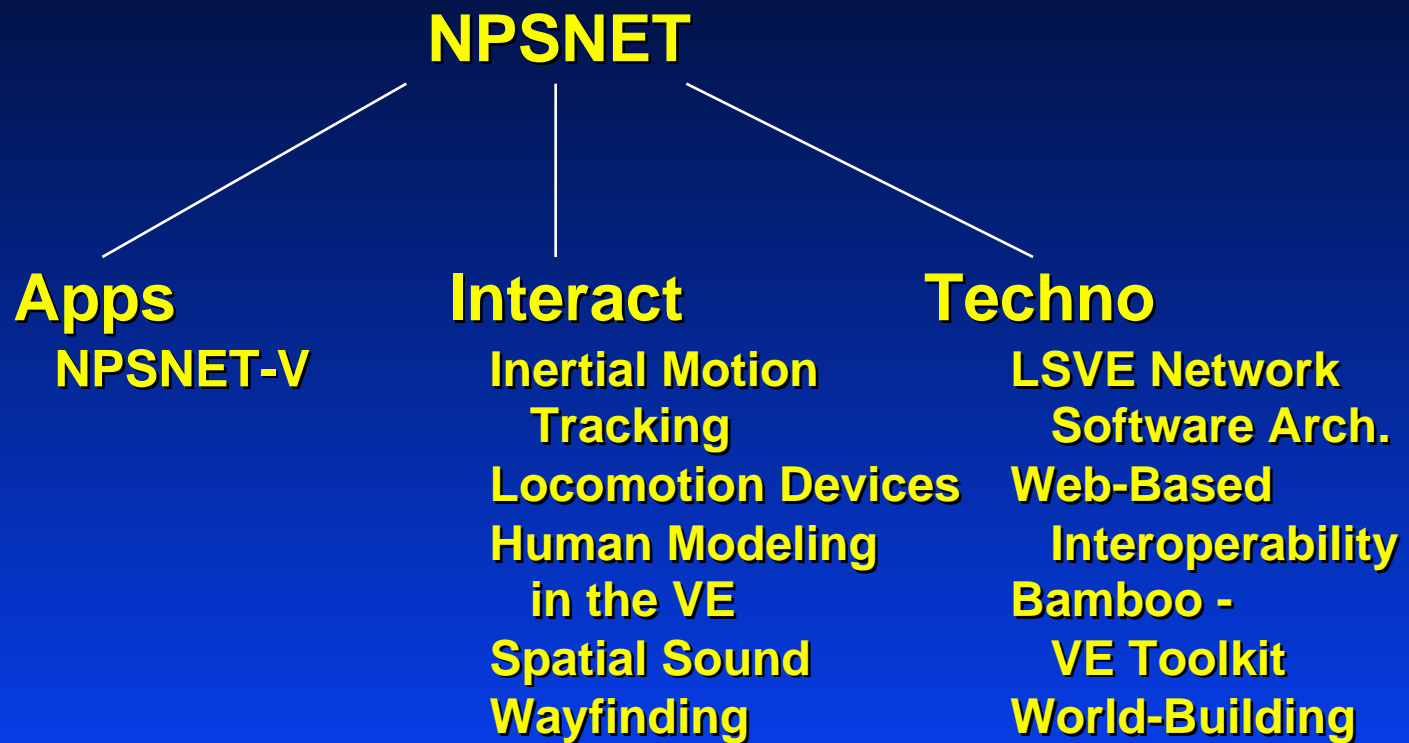


The focus of the NPSNET Research Group is on the complete breadth of human-computer interaction and software technology for implementing large scale virtual environments (LSVEs).

In addition, we apply that research in constructing VEs useful for the DoD.



NPSNET Research Group



LSVE Network Software Architecture



LSVE - large scale virtual environment -

- a networked virtual environment with greater than 1,000 players in it.
 - When we say this large a number of players, we mean both live/interactive and autonomous/computer-generated characters.

LSVE Network Software Architecture



Network Software Architecture (NSA) -

- the combination of the network protocol used for the LSVE and the software architecture that supports that protocol within the confines of available bandwidth and processor cycles.
 - There are many protocol-only and software architecture-only solutions. There are few full NSA solutions.

NSA for the VE Research Directions



Web-Based (Internet-based) VE Interoperability

- What are the issues?
 - What types of information need to be transferred between web-based networked VEs?
 - How do we transfer that information on the Internet (protocol)?
 - What is the NSA for this?

Web-Based VE Interoperability



What types of information need to be transferred between networked VEs?

- State changes/entity interactions (peer-to-peer).
- Heavy-Weight Objects (client/server requests).
- Network pointers (URLs).
- Real-time streams (Mbone audio/video).

Web-Based VE Interoperability



***How do we transfer that information
(protocol)?***

- Projects
 - Dial-a-protocol project (peer-to-peer).
 - virtual reality transfer protocol - vrtp (the application-layer protocol used to wrap together dissimilar application layer protocols).

Web-Based VE Interoperability



Dial-a-protocol project

- Development of tools/methods for the rapid generation of peer-to-peer VE application layer network protocols.
 - How do we formally specify the state change and entity interaction information?
 - How do we embed semantics in syntax in general? How do we do this on-the-fly?

Web-Based VE Interoperability



Dial-a-protocol project

- How do we formally specify the state change and entity interaction information?
 - Formal BNF specification of DIS.
 - PDU specification editor and code generator for DIS readers/writers.
 - HTML combo-form PDU specification editor.

Web-Based VE Interoperability



Dial-a-protocol project

- How do we formally specify the state change and entity interaction information?
 - DIS-Java-VRML

There is a working group working on how we provide DIS-like interoperability for the web. This is a fast-track effort with early success (120 PDUs per second).

Web-Based VE Interoperability



Dial-a-protocol project

- How do we embed semantics in syntax in general?
How do we do this on-the-fly?
 - What we are looking at very much has the flavor of Internet agents.

Behavior is encoded in a packet.

Syntax is (identifier type, number of bits).

Semantics is Java object & methods (or something else).

Web-Based VE Interoperability



General Entity Model

Objects are
anything you
want.



Rendering



Computation &
Network Access

Shared Data/Interaction

Internet



Web-Based VE Interoperability



How do we transfer that information (protocol)?

- The dial-a-protocol project looks at a very small piece of the peer-to-peer, light-weight entity interaction problem in networking VEs.
- If we go back and look at our list of types of information to be transferred between VEs, we see there are other types of data in our VE ...

Web-Based VE Interoperability



virtual reality transfer protocol - vrtp

- the applications-layer protocol used to wrap together dissimilar application layer protocols.
- vrtp will support:
 - Light-weight entity interactions (peer-to-peer).
 - Network pointers (URLs).
 - Heavy-weight objects (http client/server request).
 - Real-time streams (Mbone audio/video).

vrtp - a full spectrum applications layer protocol



client
server

peer
peer



http
web browser
multi-user worlds

audio
video
DIS behaviors

group-cached http
servers (NCSA)

“reliable”
multicast



vrtp & http



HTML

http



VRML 2.0



Web-Based VE Interoperability



What is the network software architecture for this?

- Remember we defined NSA to be the combination of the network protocol used for the LSVE and the software architecture that supports that protocol within the confines of available bandwidth and processor cycles.

Web-Based VE Interoperability



*We've kind of talked about protocols.
Let's talk about the software architecture
end of things ...*

Web-Based VE Interoperability



The primary problem we are trying to solve is how to optimize available bandwidth and available processor cycles for our LSVE.

- We don't want to bury the CPU in processing packets at the applications layer of the operating system.
- We don't want to flood the network with unnecessary packets.

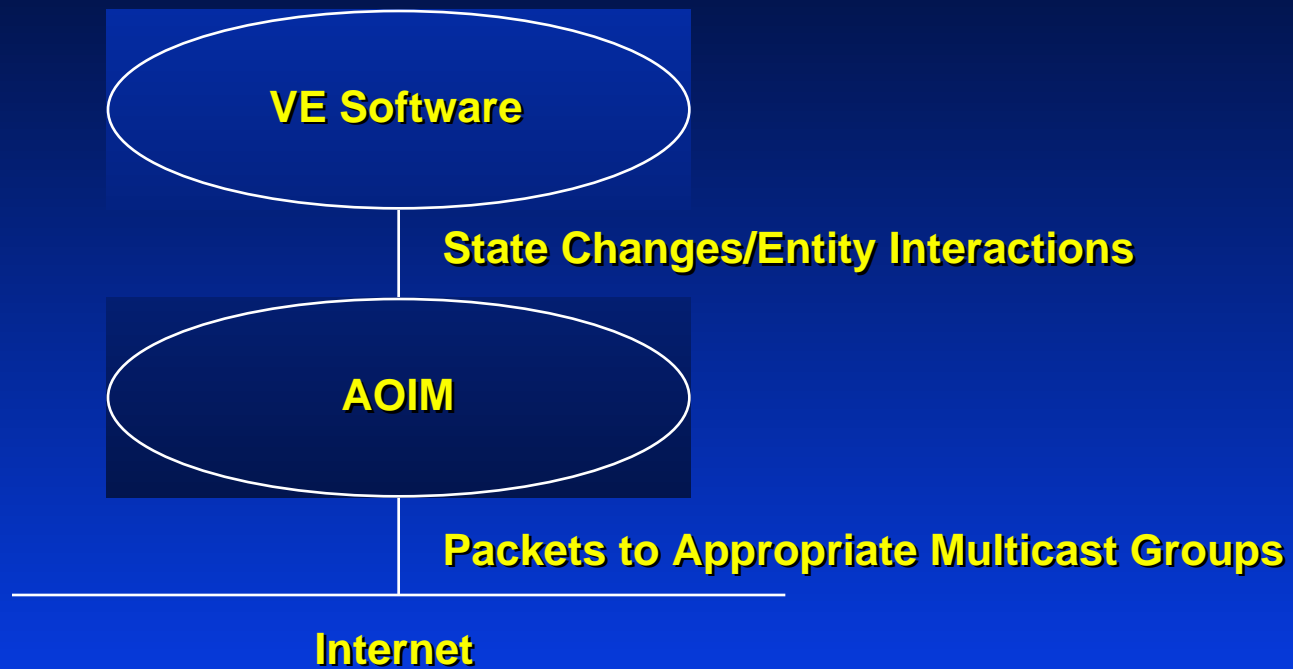


Area of Interest Management

We have done a lot of software experimentation and systems testing to get a good understanding of the software architecture issues.

- We are now focusing on a layer of software we call the Area of Interest Manager (AOIM).

Area of Interest Management





Area of Interest Management

State Changes/Entity Interactions

- instead of being broadcast to everyone, are assigned to particular multicast groups (groups are interested parties, spatial partitioning, functional partitioning, temporal partitioning, ...).



Area of Interest Management

Packets to Appropriate Multicast Groups

- Multicast groups are subscribed to by appropriate parties.
- Packets not part of subscribed multicast groups are killed off at the network interface unit rather than at the applications layer in the CPU!
- So your VE only gets packets from groups formally subscribed to.



Area of Interest Management

Research Issues in AOIMs

- How do we program an AOIM in a general way?
- AOIMs are application dependent. How do we design such systems for dynamic AOIM replacement?
- In a distributed fashion, how do we dynamically assign information to a particular set of multicast groups?

Things we are not yet working on ...



But are nonetheless important ...

- Latency & predictive modeling.
- Dedicated VE research network (to learn what we don't know).
- Heterogeneous interoperability.
- Authoring tools that are network based/aware.
- Miscellaneous unfunded VE issues (see NRC VR report, NRC M&S: Linking Entertainment & Defense report).



Web Sites

NPSNET Research Group Page

- <http://www.npsnet.nps.navy.mil/npsnet>

Information Infrastructure Research Group

- <http://www.stl.nps.navy.mil/~iirg/>

virtual reality transfer protocol (vrtp)

- <http://www.stl.nps.navy.mil/~brutzman/vrtp>