Other Issues

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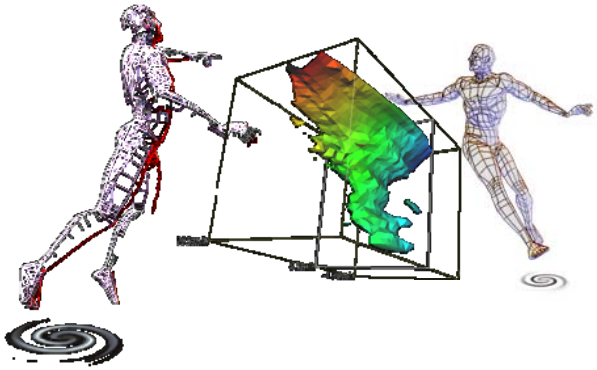
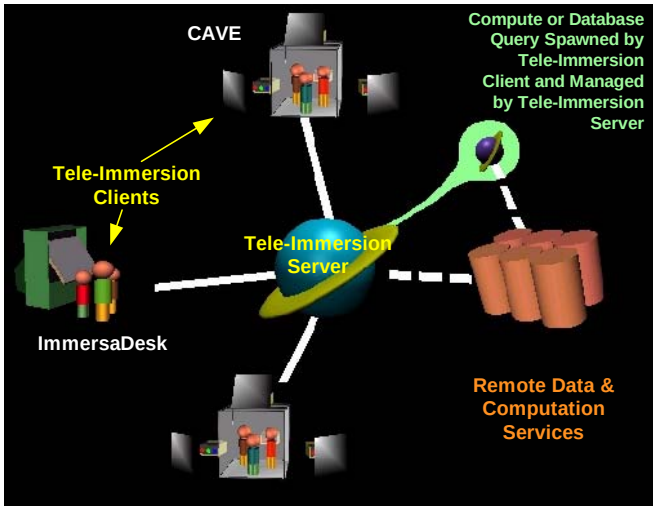
Tele-Immersion

- Networked virtual environments, especially in the context of significant computing and data mining
- Goal - not just making these collaborations possible, but making them **convenient**



Common Characteristics of Tele-Immersive Applications

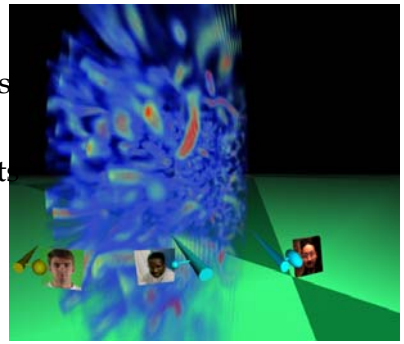


Tele-Immersive Applications

- **Tele-Immersive Data Explorer**
- In collaboration with National Center for Data Mining
- General framework for collaborative visualization of massive data-sets
- Current data-set is ozone data from NOAA

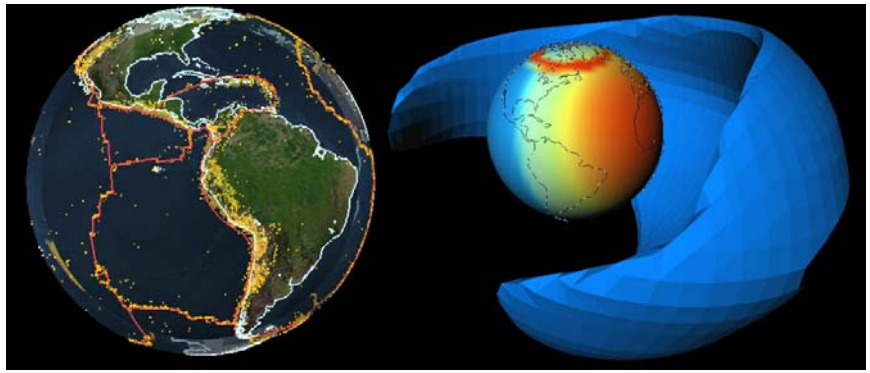
Tele-Immersive Applications

- **Collaborative Image Based Rendering Viewer (CIBRView)**
- Cosmology Hydrodynamic code by Julian Borrill, LBNL/NERSC shows theoretical condensation of diffuse matter into string-like formations during early stages of universe evolution
- Accesses volume data 512x256x 256x 256 frames ~ 40Gig data-sets
- Generates image slices that are distributed to collaborating clients
- Sent about 500, 1M slices/files from Chicago to Japan using parallel TCP.

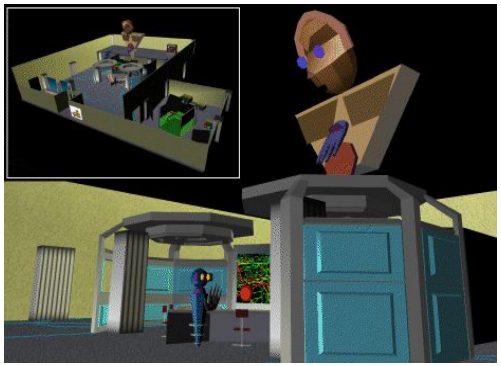


Tele-Immersive Applications

- **Network for Earthquake Engineering Simulation (NEES)** Visualization (U of Minnesota)
- Space Physics & Aeronomy Research Collaboratory (SPARC) (U of Michigan)



Tele-Immersive Applications



- **CALVIN (Collaborative Architectural Layout Via Immersive Navigation)**
- Persistent networked virtual environment
- Multi-perspective (Mortals and Deities) collaborative design

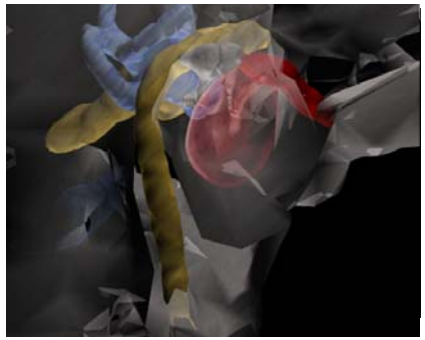
Tele-Immersive Applications

- **Architectural Linked Immersive Environment (ALIVE)** by SARA, The Netherlands & EVL
- Dutch architect Rem Koolhaas' design of the new Campus Center at the Illinois Institute of Technology in Chicago
- Architects in Amsterdam and clients in Chicago use StarTap and teleimmersion for navigating 3D CAD models

Tele-Immersive Applications

- **Visual Eyes** developed by General Motors Research, Hughes Research Lab & EVL
- Rapid prototypes for reviewing 3D CAD models
- Quick visual inspection then do life-sized design review
- Changes in lighting and materials propagated automatically
- GM extension for trans-global design and manufacturing
- Synchronous and asynchronous access to design that persist, evolve

Tele-Immersive Applications

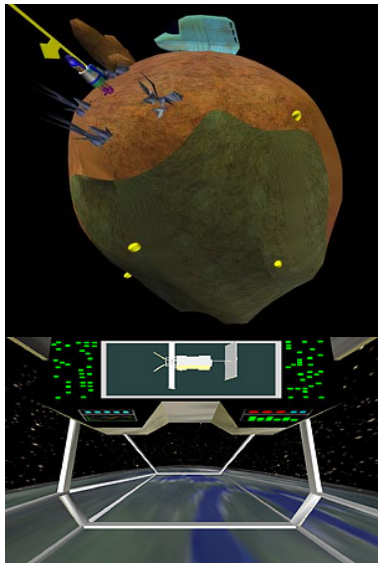


- **Virtual Temporal Bone**, developed by UIC's VR Medicine Lab lets physician teach medical students about 3D structure and function of the inner ear
- Remote physician teaches medical students about 3D structure and function of human inner ear
- Human temporal bone to reveal the delicate anatomic structures imbedded within bone
- Close-up view of the structure within the bone

Tele-Immersive Applications

- **NICE (Narrative Immersive Constructionist Environments) Persistent garden**
- Encourage learners to actively construct and interrelate knowledge and ideas
- Persistent garden
- Collaborative learning and narrative space
- 6-8 year old users

Tele-Immersive Applications



- **Round Earth**
- Conceptual change: flat to spherical Earth
- Learning paradox: prior knowledge
- Displacement theory
- First-person experience + bridging
- Tele-immersive application

Tele-Immersive Applications

- **Virtual Ambients - The Field**
- Populated with plants and moving objects such as turtles
- Similarity and difference lesson for the 2nd grade
- Interpolation and extrapolation for the 4th grade
- Co-occurrence rules; Beehive, salinity, moisture, and plants; Herbicides and plants for the 6th grade

Tele-Immersive Applications

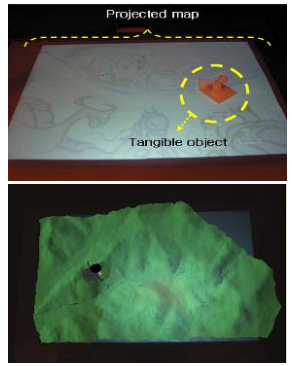
- **Virtual Harlem**
- Allows people at remotely located CAVEs to tour 1920-40 Harlem, and listen to African American artists, writers and intellectuals of that time - notably Langston Hughes, Marcus Garvey and others.
- Collaborative effort between Central Missouri State University, Advanced Technology Center at University of Missouri, and EVL at UIC.

Tele-Immersive Applications

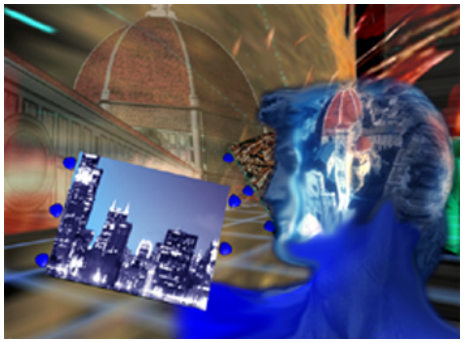
- **Tangible Moyangsung**
- Use of tangible blocks to interact with the virtual environment

Tele-Immersive Applications

- **Dream of Mee-luck @GIST**
- VR-based immersive cultural heritage system which supports context-aware, personalized human-computer interaction



Tele-Immersive Applications



- **CITYCLUSTER "From the Renaissance to the Gigabits Networking Age", EVL & Fabricat**
- Florence representing " Renaissance Age" & Chicago representing the "Gigabits Age" are interconnected by high speed network, enabling remote participants to interact and collaborate in shared environments

Collaborative 3D AR Interfaces

AR Hockey interface @ MR System Laboratory [Kiyokawa 2000] allows two users to play a game of air hockey using a virtual puck.

Collaborative 3D AR Interfaces

The Invisible Train @ Vienna University of Technology,
Real-time multi-user augmented reality application for handheld devices

AR Interfaces as 3D data browsers

Digilog Book – Temple Bell @ GIST

Digilog Book - Unjusa @ GIST

Requirements for Tele-Immersion

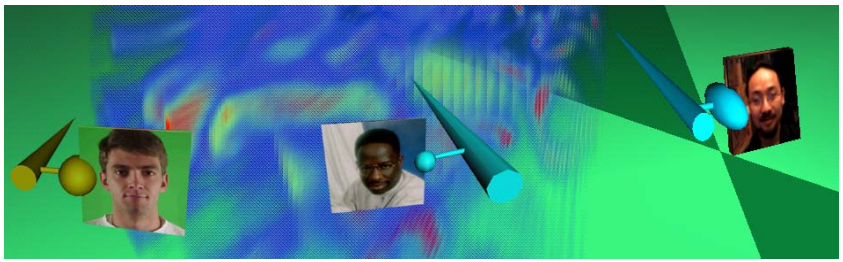
- Communication (audio & avatar)
- Collaborative interaction and manipulation
- Support synchronous and asynchronous work
- Network QoS (Quality of Service)
- Multiple heterogeneous data streams
- Flexible connectivity
- Connectivity to external application servers
- Fault tolerance
- High level modules for developers
- Performance monitoring

Tips

- Based on past experiences with these collaborative virtual worlds, several tips have been assembled about the following:
  - Avatars (Virtual Representation of Participants)
  - Audio
  - Networking
  - Shared Manipulation and User-Interfaces

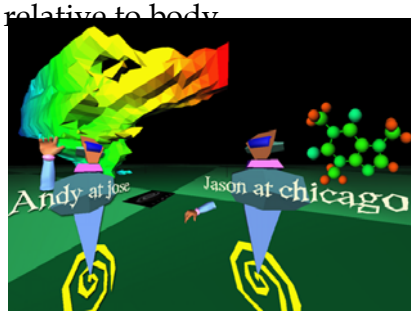
Avatars

- Tracking head and hand position and orientation give good cues
- Extendable pointing rays can be useful in large spaces
- Exaggerated head and hand motions give better cues than just hand



Avatars

- 1 tracked hand is nice but you need 2 hands to express certain concepts
- Good to be able to see the head move relative to the body
  - for our avatars, their bodies face the front of the CAVE / Idesk based on CAVENav
  - head position and orientation relative to body
- Distinct avatar shapes
- Obvious front and back
- Textual names as on jerseys or name tags
- Some way of knowing who is speaking is good when there are many participants



Avatars

- Collision detection is useful to preserve social comfort, except in tight spaces or if your audience has poor navigation skills
- When giving a tele-immersive demonstration let the remote user give the entire presentation – this helps draw the local user into the virtual world

Audio

- Audio is really important to maintaining presence of the remote participants
- Need a reliable back channel for when networked audio fails
- Use ambient microphones for easy group interaction but use personal microphones whenever possible
- Ambient mics should also use an echo canceller
- Regular old fashioned phone conference call works well too. Use a cordless phone with a head set
- Network-based audio has advantages in the ability to control levels

Networking Topologies

- **Shared centralized** – clients connected to central server
- **Replicated homogeneous** – clients with no centralized control (multicast)
- **Shared distributed with peer-to-peer updates** –clients with full connectivity to each other
- **Shared distributed using client-server subgrouping** – subgroups for areas of interest management

Networking

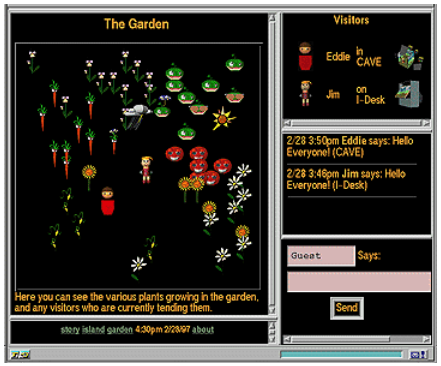
	Estimated bandwidth (bits/s)	DiffServ Types	Burstiness	Latency sensitive	Jitter sensitive	Error sensitive
UDP avatar	6K x n (15fps)	Interactive Real-time	**Constant**	**Y**	**Y**	**N**
UDP audio stream	64K x n		**Brief**	**Y**	**Y**	**N**
UDP video stream	10M (2-way only)		**Constant**	**Y**	**Y**	**YN**
UDP stream With Playback	depends	Non-interactive Real-time	**Constant**	**Y**	**N**	**YN**
TCP control data	7K x n	Reliable	**Brief**	**YN**	**YN**	**Y**
TCP bulk data	depends	Best Effort or Deadline Delivery	**Sustained burst**	**N**	**N**	**Y**

Networking

- Use UDP to send avatar position and orientation data
- Use broadcast UDP rather than multicast - avoids having to set up tunnels
- Use TCP for reliable state information
- Transmit absolute rather than relative values
- Transmit high level states rather than button presses or commands to help support late joiners

Networking

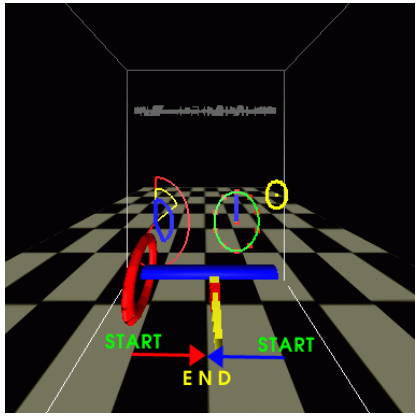
- Use persistence to reduce having to download lots of big data
- Persistent servers encourage casual collaboration
- WWW is an easy way to monitor your persistent world



Shared Manipulation & User Interfaces

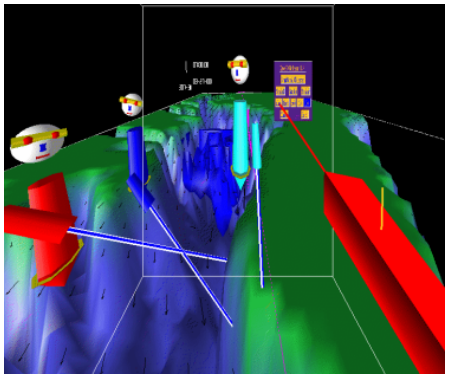
- Most importantly - it's easier to design an application with collaboration in mind, rather than trying to retrofit collaboration in later
- Take advantage of multiple collaborators for multiple perspectives
- Encourage awareness via action indicators
- Strict turn taking is usually too restrictive
- At 250 ms round trip time collaborative coordination breaks down to wait-and-see
- Social cues can 'replace' coding for mutual exclusion- tug of war is natural in the real world and imposes no network latency overhead

Effects of Network Latency and Jitter on Collaborative Manipulation



- Tightly collaborative interaction task between two remote users
- 200ms latency is the threshold where performance begins to suffer.
- 200ms latency with 0 jitter is same as 10ms latency with 7ms jitter.
- **Jitter is worse than latency.**

Employing Multiple Perspectives in Collaboration

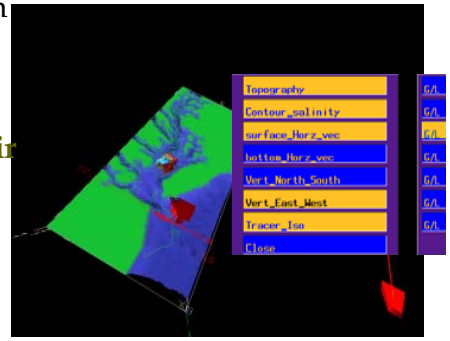


CAVE6D Tele-Immersive tool for visualizing Oceanographic Data, ODU and EVL

- Take advantage of having more than 1 expert to help with interpretation or manipulation.
- **Provide multiple cooperative representations – e.g. Partition multi-dimensions across viewers.**
- When would customized vs. shared views be most useful?
- How do we minimize confusion?
- What should the interface be for these tools? e.g., collaborative brushing.

Lessons Learned from Employing Multiple Perspectives in Collaboration

- Collaborative scientific problem solving between two remote users using CAVE6D
- **Even though people say they prefer a fully shared view, their interaction history tended to show they employed more localized control to test their own little hypotheses.**
- Making visualization tools collaborative also requires every aspect of the interface to be shareable. Use Action Indicators to convey intent.



CAVE6D: Chesapeake Bay Dataset