INTRODUCTION

It is 2010 and you have a very important meeting with your business associates in Chennai. However you have visitors from Japan coming for a mega business deal the same day. Is there any technology by which you can deal with both of them? The answer is yes and the name of that technology is Tele-Immersion. Tele-Immersion is a technology by which you'll interact instantly with your friend on the other side of the globe through a simulated holographic environment. This technology, which will come along with Internet2, will change the way we work, study and get medical help. It will change the way we live. Tele-Immersion (TI) is defined as the integration of audio and video conferencing, via image-based modeling, with collaborative virtual reality (CVR) in the context of data-mining & significant computation. The 3D effect behind the tele-immersion makes it feel like the real thing. The ultimate goal of TI is not merely to reproduce a real face-to-face meeting in every detail, but to provide the "next generation" interface for collaborators, world-wide, to work together in a virtual environment that is seamlessly enhanced by computation and large databases. When participants are tele-immersed, they are able to see and interact with each other and objects in a shared virtual environment.

Tele-immersion can be of immense use in medical industry and it also finds its application in the field of education

THE HISTORY

It was in 1965 that, Ivan Sutherland, proposed the concept of the 'Ultimate Display'. It described a graphics display that would allow the user to experience a completely computer-rendered environment. The term Tele-immersion was first used in October 1996 as the title of a workshop organized by EVL and sponsored by Advanced Network & Services, Inc. to bring together researchers in distributed computing, collaboration, VR, and networking. At this workshop, specific attention was paid to the future needs of applications in the sciences, engineering, and education. In 1998 Abilene, a backbone research project was launched and now serves as the base for Internet-2 research. Tele-immersion is the application that will drive forward the research of Internet-2.

There are several groups working together on National Tele-Immersion Initiative(NTII) to make this wonderful technology available to common man.

FIRST FEEL OF TELE-IMMERSION

A swift investigation revealed that three researchers, led by UNC computer Scientists Henry Fuchs and Greg Welch, in May 2000 opened a pair of portals connecting Chapel Hill with Philadelphia and New York. Through these portals, they could peer into the offices of colleagues hundreds of miles away, in life-sized three dimensions and real time. It was as if they had teleported distant chunks of space into their laboratory. The experiment was the first demonstration of Tele-immersion, which could radically change the way we communicate over long distances. Tele-immersion will allow people in different parts of the world to submerge themselves in one another's presence and feel as if they are sharing the same physical space. It's the real-world answer to the StarTrek Holodeck, the projection chamber on the Starship Enterprise where crew members interact with projected images as if they were real.

May's experiment was the culmination of three years' work by the National Tele-Immersion Initiative (NTII), a project led by virtual pioneer Jaron Lanier. The test linked three of the members of the group:UNC Chapel Hill, the University of Pennsylvania in Philadelphia, non-profit organisation called Advanced Network and Services in Armonk, New York, where Lanier is chief scientist.

At Chapel Hill, there were two large screens, hung at right angles above desk, plus projection cameras and head tracking gear. The screens were flat and solid, but once the demo was up and running they looked more like windows. Through the left-hand screen, Welch could see colleagues in Philadelphia as if they were sitting across the desk from him. The right-hand screen did the same for Armonk. When

Welch changed point of view, the images shifted in a natural way. If he leaned in, images got larger, if he leaned out they got smaller. He could even turn his neck to look round the people.

To make it work, both target sites were kitted out with arrays of digital cameras to capture images and laser rangefinders to gather positional information. Computers then converted the images into 3D geometrical information and transmitted it to Chapel Hill via Internet2. There, computers reconstructed the images and projectors beamed them onto screens.

The images were split and polarised to create a slightly different image to each eye, much like an old-fashioned 3D movie. Welch wore glasses differently oriented polarising lenses so his left eye saw one image right eye the other, which his brain combined to produce 3D images.

A head-mounted tracker followed Welch's movements and changed the images on the screens accordingly. Like the first transcontinental phone call, the quality was scratchy, also jerky, updating around three times a second rather than 10, the minimum speed needed to capture the full range of facial expressions. It only worked one-way: the people in Armonk and Philadelphia couldn't see Chapel Hill.

All this may sound like conventional videoconferencing. But Tele-immersion is much, much more. Where videoconferencing delivers flat images to a screen, Tele-immersion recreates an entire remote environment.

SCIENCE OF TELE-IMMERSION

Tele-Immersion has an environment called TIDE. TIDE stands for Tele-Immersive Data exploration Environment. The goal of TIDE is to employ Tele-Immersion techniques to create a persistent environment in which collaborators around the world can engage in long-term exploration and analysis of massive scientific data-sets. When participants are tele-immersed, they are able to see and interact with each other and objects in a shared virtual environment. Their presence will be depicted by life-like representations of themselves (avatars) that are generated by real-time, image capture, and modeling techniques. The environment will persist even when all the participants have left it. The environment may autonomously control supercomputing computations, query databases and gather the results for visualization when the participants return. Participants may even leave messages for their colleagues who can then replay them as a full audio, video and gestural stream.

All users are separated by hundreds of miles but appear collocated able to see each other as either a video image or as a simplified virtual representation (commonly known as an avatar). Each avatar has arms and hands so that they may convey natural gesture such as pointing at areas of interest in the visualization. Digital audio is streamed between the sites to allow them to speak to each other.

TIDE will engage users in CAVEs, ImmersaDesks and desktop workstations around the world connected by the Science and Technology Transit Access Point (STARTAP) - a system of high speed national and international networks. TIDE has three main parts:

- ✓ TELE-IMMERSION SERVER (TIS)

- ✓ TELE-IMMERSION CLIENT (TIC)

- ✓ REMOTE DATA AND COMPUTATIONAL SERVICES

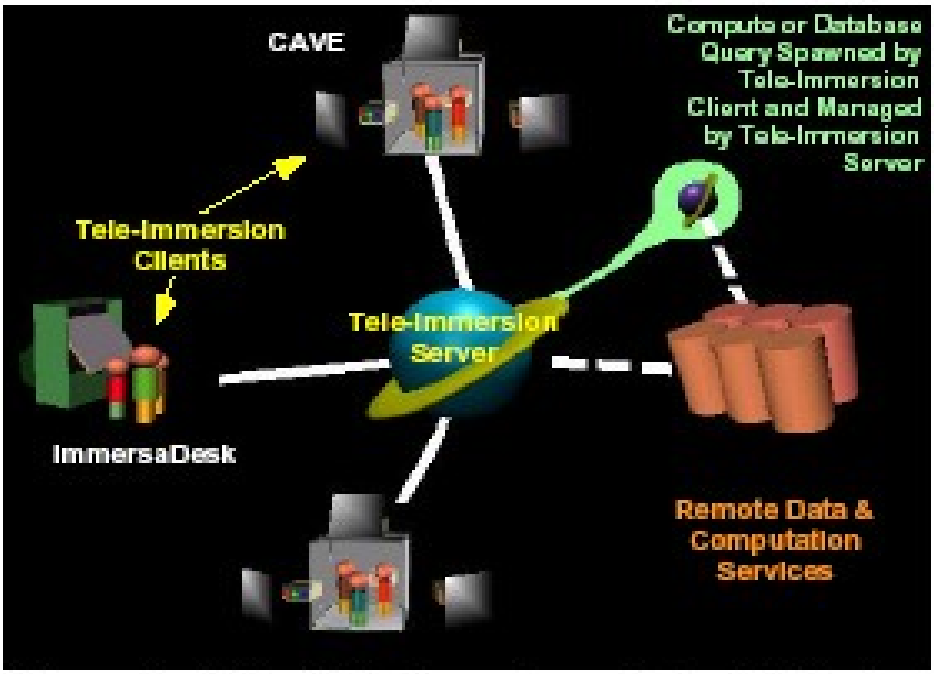


Figure 1. The Tele-Immersion Data Exploration Environment

TELE-IMMERSION SERVER:

The Tele-Immersion Server's primary responsibility is to create a persistent entry point for the TICs. That is, when a client is connected to the TIS, a user can work synchronously or asynchronously with other users. The environment will persist even when all participants have left it. The server also maintains the consistent state that is shared across all participating TICs. Finally the TIS stores the data subsets that are extracted from the external data sources. The data subsets may consist of raw and derived data sets, three dimensional models or images.

TELE-IMMERSION CLIENT

The Tele-Immersion Client (TIC) consists of the VR display device (either CAVE, ImmersaDesk, etc) and the software tools necessary to allow "human-in-the loop computational steering, retrieval, visualization, and annotation of the data. The TIC also provides the basic capabilities for streaming audio and video, and for rendering avatars to allow participants to communicate effectively with one another while they are immersed in the environment. These capabilities come as part of EVL's Tele-Immersion software framework called CAVERNsoft.

REMOTE DATA & COMPUTATION SERVICES

Remote Data and Computation Services refer to external databases and/or simulations/compute-intensive tasks running on supercomputers or compute clusters that may be called upon to participate in a TIDE work session.

The databases may house raw data, or data generated as a result ofcomputations. In most cases the data-sets contain too many dimensions and are much too large to visualize entirely. However data mining may be employed to clean the data, to detect specific features in the data, or to extract trends from the data. In some cases as the data mining processes may generate models of the data, the models can be used to make predictions on missing data points. Furthermore the models can be used to determine which attributes in a multidimensional data-set are the most significant. This is particularly valuable for visualization because the ability to fill missing data points means a more accurate estimate of the missing data can be made than by simple graphical interpolation. In addition by being able to isolate the most significant attributes, a viewer can prioritize the attributes that they assign to visual features (such as hue, intensity, shape etc) in the visualization. For example Nakayama and Silverman have shown that stereoscopic depth is the most powerful, pre-attentively detected visual feature as compared to other features such as intensity and hue (the features most commonly used in scientific visualizations.) This is a particularly interesting finding for VR because the medium in which VR resides is inherently stereoscopic. In TIDE the approach taken is to employ data mining algorithms where appropriate as a means to partition space non-isotropically; to exclude attributes with low significance; to “smart” average attribute values to “summarize” a number of attributes into a single attribute (as

a means to reduce dimensionality); and to decimate the data based on the limits of the VR visualization system.

Initially many of these processes will be controlled on desktop interfaces of PSEs and the resulting decimated data is distributed amongst the collaborators via the Tele-Immersion server. However over time we will gradually allow an increasing number of these functions to be controlled directly from within the Tele-Immersion environment using three-dimensional interfaces.

VIRTUAL REALITY (VR) DISPLAY DEVICES

As stated earlier VR display devices are mainly four in number. They are listed below

- ✓ CAVE
- ✓ Immersa Desk
- ✓ Desktop workstation
- ✓ Desktop Workstation

CAVE

The CAVE virtual reality system is a 10 foot-cubed room that is projected with stereoscopic images creating the illusion that objects appear to co-exist with the user in the room. The CAVE™ is a multi-person, room-sized, high-resolution, 3D video and audio environment. Graphics are projected in stereo onto three walls and the floor, and viewed with stereo glasses. As a viewer wearing a location sensor moves within its display boundaries, thecorrect perspective and stereo projections of the environment are constantly updated, so the image moves with and surrounds the viewer to achieve immersion.

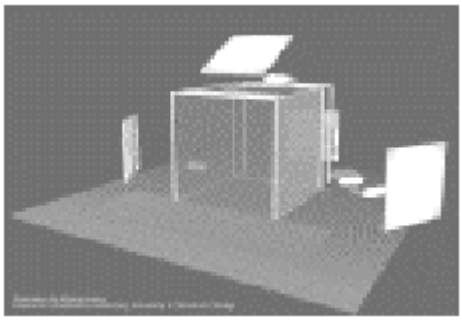


Figure of CAVE

IMMERSA DESK

The ImmersaDesk™ is a drafting-table format version of the CAVE. When folded up, it fits through a standard institutional door, and deploys into a 6’ x 8’ footprint. It requires a single graphics engine of the SGI Onyx or Octane class, one projector, and no architectural modifications to the working space. The Immersa Desk is software compatible with the CAVE library.

figure

DESKTOP WORKSTATION

The desktop workstationdisplays a data-flow model that can be used to construct the visualization that is shared between all three display devices. The participants in the VR displays can use three-dimensional tools to directly manipulate the visualization.

For example in the CAVE a user is changing the isosurface value in the data-set. These changes are automatically propagated to all the other visualization

displays. In the meantime the ImmersaDesk user, noticing an anomaly in the data-set, inserts an annotation in the data-set as a reminder to return to more closely examine the region. Closer examination of the region is achieved by instructing a remote rendering server consisting of multiple giga-bytes of RAM and terabytes of disk space, to render the images in full detail as a stereoscopic animation sequence. These animations will take some time to generate and so the users continue to examine other aspects of the dataset. Eventually the rendering is complete and the remote server streams the animation to each of the visualization clients for viewing.

INFINITY WALL

The Infinity Wall is derivative of the Power- Wall, a research effort of Paul Woodward at the University of Minnesota. The PowerWall achieves very high display resolution through parallelism, building up a single image from an array of display panels projected from the rear onto a single screen. High-speed playback of previously rendered images is possible by attaching extremely fast disk subsystems, accessed in parallel, to an Onyx. The Infinity Wall is a simpler Power Wall that has tracking and stereo; it is CAVE library compatible.

figure

APPLICATIONS OF TELE-IMMERSION

The list of applications of tele-immersion is very large. Some of them are:

- Interacting with friends miles away in a simulated holographic environment.
- Tele-immersion can be of immense use in medical industry.
- Tele-immersion also finds its application in the field of education.

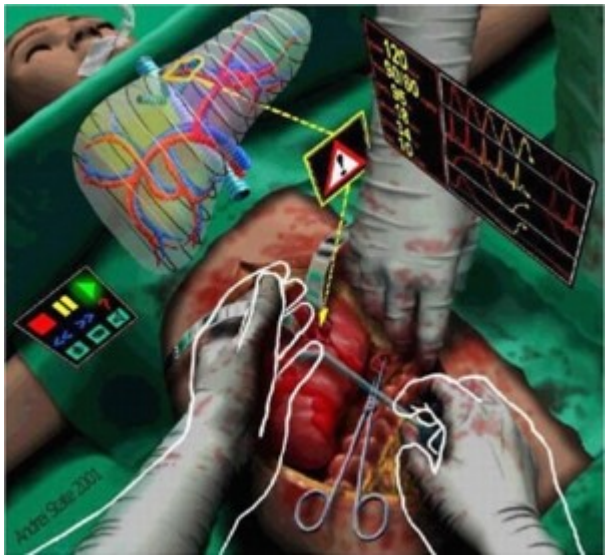
A large set of applications can be managed, depending on the position of infinity wall:

1. Full scaled model preview in industrial application (aircrafts, cars, …) when all three modules are lined up (180°)

2. Flight simulation scenarios visualization when side-modules are in 135° layout;

3. Immersive simulations when side-modules are in the "room setup" (90°)

MEDICAL APPLICATIONS



3D surgical learning for virtual operations is possible using this technology.

In future real surgery can be carried out on real patients.

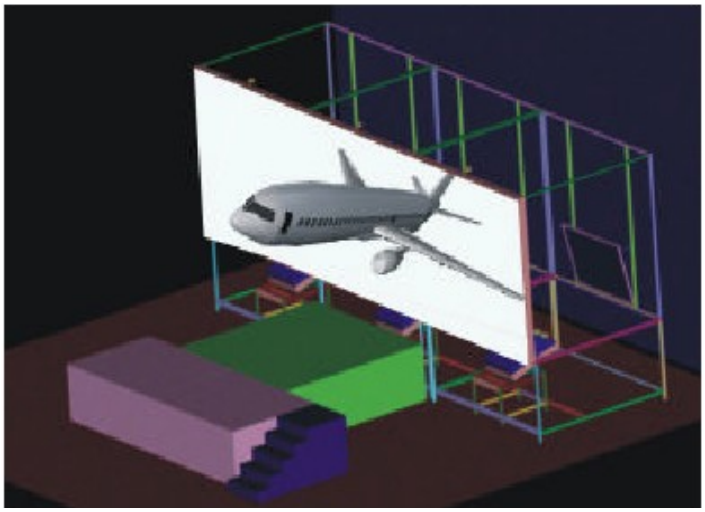
It could be life saving if the patient is in need of special care.

It gives surgeons the ability to superimpose anatomic images right on their patients while they are being operated on. Surgeons get a chance to learn complex situations before they actually treat their patients.

USES IN EDUCATION

It can be used to bring together students at remote sites in a single environment. With tele-immersion students can access data from remote locations. Internet2will provide access to digital libraries and virtual labs.

Exchange of culture is possible without travel.



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FUTURE OFFICE

CHALLENGES OF TELE-IMMERSION

Tele-immersion has emerged as a high-end driver for the Quality of Service (QoS), bandwidth, and reservation efforts envisioned by the NGI and Internet2 leadership. From a networking perspective, tele-immersion is a very challenging technology for several reasons:

- The networks must be in place and tuned to support high-bandwidth applications.
- Low latency, needed for 2-way collaboration, is hard to specify and guarantee given current middleware.
- The speed of light in fiber itself is a limiting factor over transcontinental and transoceanic distances.
- Multicast, unicast, reliable and unreliable data transmissions (called “flows”) need to be provided for and managed by the networks and the operating systems of supercomputer-class workstations.
- Real-time considerations for video and audio reconstruction (“streaming”) are critical to achieving the feel of telepresence, whether synchronous or recorded and played back
- The computers, too, are bandwidth limited with regard to handling very large data for collaboration
- Simulation and data mining are open-ended in computational and bandwidth needs—there will never be quite enough computing and bits/second to fully analyze, and simulate reality for scientific purposes.

In Layman's language the realization of tele-immersion is impossible today due to

1. The non-availability of high speed networks
2. The non-availability of supercomputers
3. Large network bandwidth requirements

SOLUTION

The first two basic problems can be overcome when Internet-2 will come into picture later and third problem can be overcome by the fast development of image compression techniques.

ABOUT INTERNET-2

- Internet2 is not a separate physical network and will not replace the current Internet. It is not for profit consortium consisting of 200 US universities, Industries and is directly under the control of US govt..

- Internet2 is for developing and deploying advanced network applications and technology, accelerating the creation of tomorrow's Internet.

- Internet2 enables completely new applications such as digital libraries, virtual laboratories, distance-independent learning and tele-immersion

- A key goal of this effort is to accelerate the diffusion of advanced Internet technology, in particular into the commercial sector.

FUTURE DEVELOPMENTS

The tele-immersion system of 2010 would ideally:

- Support one or more flat panels/projectors with ultra-high color resolution (say 5000x5000)
- Be stereo capable without special glasses
- Have several built-in micro-cameras and microphones
- Have tether-less, low-latency, high-accuracy tracking
- Network to teraflop computing via multi-gigabit optical switches with low latency
- Have exquisite directional sound capability
- Be available in a range of compatible hardware and software configurations
- Have gaze-directed or gesture-directed variable resolution and quality of rendering
- Incorporate AI-based predictive models to compensate for latency and anticipate user transitions
- Use a range of sophisticated haptic devices to couple to human movement and touch
- Accommodate disabled and fatigued users in the spirit of the Every Citizen Interface to the NII [2]

CONCLUSION

Tele-Immersion is a fast developing technology and it is going to benefit the common man once Internet-2 comes into picture. It is of immense use in the field of

- ✓ Medicine
- ✓ Education and numerous other fields

It also helps in reducing business travel.

Tele-Immersion is a technology that is certainly going to bring a new revolution in the world and let us all hope that this technology reaches the world in its full flow as quickly as possible.

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IT magazine August 2003

APPENDIX

writers-readers	description	distribution	example
1 – 1	point-to-point connection, with data streamed for a single writer to a single reader	socket, stream	HPC resource streams simulation results to a VE server, which transforms them to a polygon representation for use by end-user display machines
1 – m	single writer to multiple readers	multicast, broadcast	Audio stream from a single person in a VE. Any number of participants may choose to listen to the stream, to hear what the person is saying
m - n (m < n)	privileged writers to multiple readers. A small group of writers cooperate to maintain a data structure which is read by many	DSM, multicast, RPC/RMI	Two workgroups of users cooperate with a VE. Each group has its own local server. The two servers run time services used to sync clocks on local machines
m - n (m = n)	peer-to-peer sharing of data	DSM, mobile object, RPC/RMI	Complex CAD model being manipulated by multiple users within a VE. Individual components of the model may be changed by any user. Multiple users may change separate components simultaneously. Model is stored within a distributed shared memory, which all users can access
m – 1	multiple writers accessing a common data structure	RPC/RMI	A simulation running on a remote HPC resource. Elements of the simulation may be directed by any participant

Table 1: Access patterns for Teleimmersive data

Tele-Immersion Data Flow Types							
Type	**Latency**	**Bandwidth**	**Reliable**	**Multicast**	**Security**	**Streaming**	**DynQoS**
Control	< 30 ms	64Kb/s	Yes	No	High	No	Low
Text	< 100 ms	64Kb/s	Yes	No	Medium	No	Low
Audio	< 30 ms	Nx128Kb/s	No	Yes	Medium	Yes	Medium
Video	< 100 ms	Nx5Mb/s	No	Yes	Low	Yes	Medium
Tracking	< 10 ms	Nx128Kb/s	No	Yes	Low	Yes	Medium
Database	< 100 ms	> 1GB/s	Yes	Maybe	Medium	No	High
Simulation	< 30 ms	> 1GB/s	Mixed	Maybe	Medium	Maybe	High
Haptic	< 10 ms	> 1 Mb/s	Mixed	Maybe	Low	Maybe	High
Rendering	< 30 ms	>1GB/s	No	Maybe	Low	Maybe	Medium

The columns represent flow-type attributes:

- **Latency** is the sum of all delays in the system, from the speed of light in fiber, to operating system overhead, to tracker settling time and screen refresh
- **Bandwidth** is the bits/second the system can transmit
- **Reliable** flows are verified and retransmitted if bad
- **Multicast** flows go to more than one site at once
- **Security** involves encryption overhead that may or may not be warranted or legal
- **Streaming** data is a constant flow of information over time, as with video, audio and tracking
- **Dynamic QoS** can provide ways to service bursty high-bandwidth needs on request

The rows indicate the data flow types:

- **Control information** consists of data that is used to manage the tele-immersion session, to authenticate users or processes, to launch processes, to control the display or tracking systems, and to communicate out of band between the world servers and VR systems.
- **Text** provides simple communications capability within collaborative sessions for simple note taking and passing. Text can also command Unix processes driving the environments.
- **Audio** gives ambient auditory cues, allows voice communications among users, and is used to issue commands via voice recognition and speech synthesis. A typical application may use multiple audio streams.
- **Video** can allow teleconferencing or remote monitoring displayed within the virtual world. Synthetic 2D animated bitmaps in video format have application as well.
- **Tracking** is achieved with location and orientation sensors, and captures the position and orientation of the user. Typically this data is streamed to the computer responsible for computing the perspective of the scene. Tele-immersion requires tracking data to be shared among sites. Most VR systems only head and hand track; future systems will have many more sensors to track more complex posture and body motions.
- **Database** is the heart of a tele-immersion application world. The database contains the graphical models of virtual scenes, objects, and data, and since the database is used to provide the

models that are rendered, it must be maintained in a coherent state across multiple sites. Databases might be as simple as shared VRML files or as complex as multi-terabyte scientific datasets, VR extensions of video serving, or even Virtual Director recorded sessions. (Virtual Director is a joint EVL/NCSA development project. [29])

- **Simulation** provides the basis for dynamics behaviors, like responding to the users' actions. Small-scale simulations often run on the computer also generating the VR experience, but frequently the simulation will need a dedicated supercomputer. [28] User input is captured and transmitted to the simulation via the network and the simulation will generate an update, which is then propagated to each user site for local

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