Implementation of a Remote 3D Visualization System

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Abstract

Large-scale displays immerse users in computer-generated graphics and the visualization of detailed data sets creates the illusion of immersion supporting natural interactive collaborations among multiple simultaneous viewers. However, this benefit is limited by located services.

In this paper we describe how a remote visualization system was implemented and configured and the obtained features with this approach.

Keywords: remote visualization, collaborative environments, video transmission, virtual reality, immersive projection technology, distributed VR system, telepresence.

I Introduction

Computational power and Immersive Visualization has become indispensable in the presentation and analysis of high performance computing results. High performance computers (HPC) offer great capability; however, the cost of ownership (i.e. administration, maintenance, and support) of HPC systems is excessive for many organizations. Therefore, many companies are renting CPU hours and high-end graphics by accessing these services remotely. The traditional way to share computer resources has been through telnet access. However, with demanding graphics rendering performed on the user's machine, the high-end graphics capability is not fully used.

The aim of this paper is to describe how to implement and configure a remote visualization system to be used for remote interaction, or for utilizing the high-bandwidth environment for virtual meetings and events. The challenge in this project was to build and use our high performance platform with existing equipments and provides our immersive visualization environments services to our customers.

II Inspiration & Need

The use of immersive environments for collaborative work among remote teams of people shows great potential, especially because they have been proven to be useful at saving company resources, such as time and money. Collaborators at a remote site can share the details of virtual representations, participating actively in the design instead of passively looking at plane graphics.

Our project goal was to link together our powerful virtual reality CAVE with our high performance computers and provide to all our customers with the advantage of using these tools for their particular works at their remote locations. We are providing them with real time assistance from our site to help them build up their tasks without delay. Although our main goal is to establish synchronous collaboration (where more than two teams are working together), we are also considering the impact of asynchronous collaboration (where different teams might be working at different times).

III Background

Nguyen *et al* [4] presented the virtual reality platform for the visualization and control of remote vehicles used in planetary exploration; they designed VEVI as a modular, flexible and distributed for the Mars project. However in their work they did not have to share the virtual world among several teams in different locations.

There are some works were for effective communication among team members it is necessary to observe an image of the different participants in the virtual world, thus avatars technologies have been deployed to represent remote participants in the virtual scene. Works in this direction have been carried out by [1, 3, 7, 8, 9] and others. The X-Room™ is similar in concept to the CAVE™ [10], but based on a PC network with web-based visualization support. Hommes and Pless describe in [11] the networking requirements depending on the virtual reality environment.

IV Existing Platforms

The TACOM-TARDEC HPC graphics environment [5] is a centralized HPC system with 8 graphic pipes supporting 11 remote decentralized display devices, with a total of 31 graphic pipes (see Fig. 1). This architecture was limited to only 2 miles of distance.

Oliveira & Georganas designed VELVET [12], an Adaptive Hybrid Architecture for Very Large Virtual Environments, which allows an unlimited number of users to participate and collaborate in a VE with heterogeneous hardware, but it is mainly focused on sharing areas of interest with virtual avatars. On the other hand, this approach uses a larger number of multicast addresses leading to a large number of entries in routing tables.

One of the main issues targeted in our work was about the latency of signals (conditioning the equipment's output to travel in fast media) and balancing the cost of our solution (not all the signals needed to be sent at high speed, i.e. keyboard's are slower than graphic's output). Other minor issues involved in selecting a wide bandwidth connection and the compatibility and integration of diverse systems to obtain a more advanced solution capable of delivering the throughput needed by all the parties.

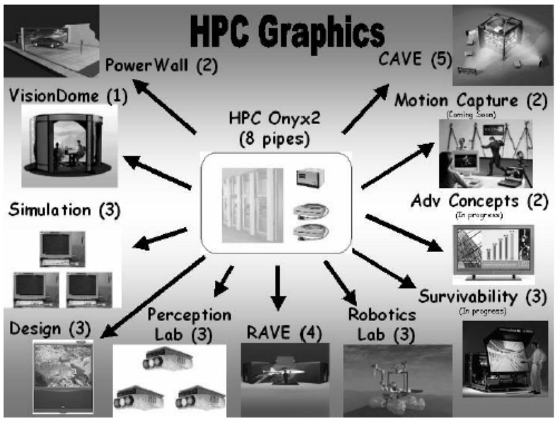

Fig. 1. - Current TACOM-TARDEC HPC graphics environment

V Our solution for Remote Visualization

We are proposing an entire new high-end long distance transmission architecture to accomplish the goals of this project, described in Fig. 2.

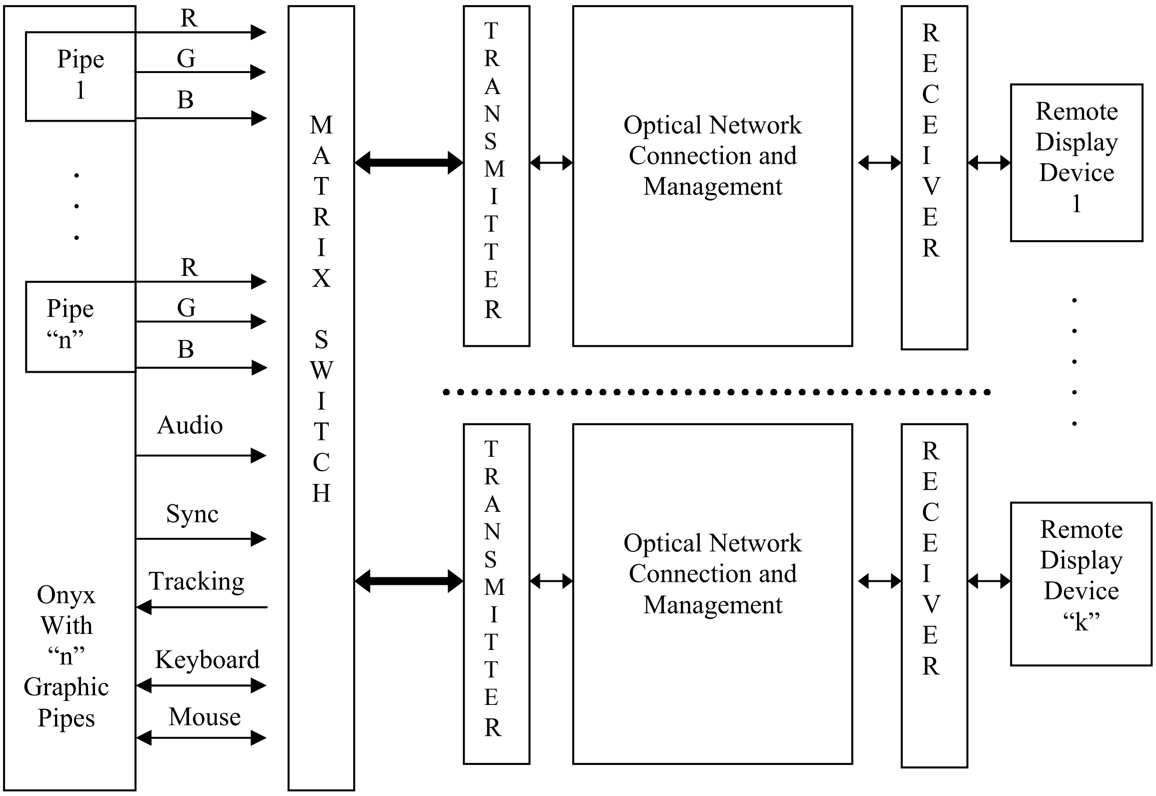

Fig. 2. - Remote Visualization Architecture Diagram

As presented in Fig. 2, a matrix switch, connecting all the video, audio, and control (sync, tracking, keyboard, and mouse) lines, route signals to a particular remote display device. There are multiple outputs from the matrix switch containing video, audio, and control signals through several transmitters to support one remote display device. The RGB analog video signal, audio signal, and control signals are the input of the transmitter, which converts analog signals to digital signals, then multiplexes all the digital signals together and broadcast the new converted optical signal. The number of signal repeaters used will depend on the distance between the host and the remote display device.

Finally the optical signal reaches the receiver at the remote site. The receiver converts the optical signal to the digital signal, de-multiplexes it, converts it back to the original signals, and then sends the signals to the display device. We are expecting to include haptic controllers [6] into this configuration too.

VI Technical approach

To transmit video, audio, tracking, control, and other signals to remote sites within 100 feet from the computational and visualization resources (the maximum recommended cabling distance before signal degradation) is technically feasible as presented by [5]. However because operational requirements may dictate remote display devices be hundreds or even thousands of miles away, a whole new high-end long distance transmission technique is needed. In this section we look into the data and network requirements to accomplish our project and we analyze the two possible alternatives to tackle this problem.

VI.1 Data Transfer Requirements

In order to calculate the network bandwidth requirement, the following assumption is made: an Onyx3400 machine supporting a 4-Wall CAVE 1000 mile away. The stereoscopic 3D image requires a resolution of 1280X1024 pixels per display surface. A high definition 3D visualization uses a refresh rate of at least 48 frames per second for each eye, resulting in total frame-refresh rates up to 96 frames per second. Furthermore, each pixel's R, G, B color is represented by 8 bit each, resulting in a total of 24 bits. Thus, the total transmission bit rate will be:

(1) Graphic data
1 screen size: 1280X1024

Component: RGBA, however A is not used, and sync is on Green, 8+8+8=24 bits
Refresh rate: 96Hz:
Bit rate per screen:
1280X1024X24X96 = 3019898880 bits per second (bps) = 2880 Mbps = 2.8125 Gbps

This result in an uncompressed video stream in the range of 2.8 gigabits per second.

4-Wall total:
4X2.8125 Gbps = 11.25 Gbps

(2) Audio data
ADAT optical Audio: 44100 bps

(3) Control data
Sync signal: 96 bps
Tracking signal: 115200 bps
Keyboard: up to 9600 bps
Mouse: up to 9600 bps

Total uncompressed data needed to be transmitted is about 11.25 Gbps.

VI.2 Network Bandwidth

The following chart Table 1 shows all the line speeds used in Internet backbones, LAN, and WANs.

Line Type	Bandwidth (Speed)
OC-255	13.21 Gbps
OC-192	10 Gbps
OC-96	4.976 Gbps
OC-48	2.488 Gbps
OC-24	1.244 Gbps
OC-12	622.08 Mbps
OC-3	155.52 Mbps
Fast Ethernet LANs	100 Mbps
OC-1	51.84 Mbps
T-3, DS-3	44.736 Mbps
Token Ring LANs	16 Mbps
Thin Ethernet LANS	10 Mbps
Cable Modem	10 Mbps
T-1, DS-1	1.544 Mbps
DSL	1.544 Mbps
IDSL (DSL over ISDN)	144 Kbps
ISDN	128 Kbps
DS-0, one Ch. of a T-1	64 Kbps
V.34, Rockwell V.Fast Class Modems	28.8 Kbps
V.32bis Modems, V.17	14.4 Kbps
Modem Speeds in 1990s	9600 bps
Modem Speeds in 1980s	2400 bps

VI.3 The alternatives for Remote Transmission

There are two possible options to accomplish the project we are addressing: option 1 uses uncompressed data transmission and option 2 uses compressed data before transmission. Both solutions use the same matrix switch.

VI.3.1 Option 1: Uncompressed data transmission

<u>The Matrix Switch</u>

For uncompressed or compressed data transmission a matrix switch is needed. Lantronix [14] has 2 models of matrix switch, Matrix-Hub 1000 and Matrix-Hub 3000. Since the Matrix-Hub 3000 has a maximum refresh rate of 85 Hz that is below our requirement 96 Hz, we selected the Matrix-Hub 1000 as the matrix switch that is rated at a maximum resolution and refresh rate of 1900X1200@180 Hz.

Figure 3. Matrix-Hub 1000

The Matrix-Hub 1000 is a multi-interface 10X10 (maximum) matrix switch for high performance graphics environments. This model gives the users the ability to route up to 10 different computer sources among 10 different console destinations. It can route and switch video, keyboard, mouse, and serial peripherals quickly and easily to optimize operational productivity in any graphics environment. The high performance video capability makes the Matrix-Hub 1000 a perfect choice for visualization, postproduction or scientific applications.

The Matrix-Hub 1000 is controlled through a serial (RS-232) port, either directly via dumb terminal or remotely through a networked computer. User-friendly menus and commands make controlling and programming the Hub simple tasks. The Matrix-Hub 1000 allows four different levels of control, giving users a variety of access and control privileges.

The Matrix-Hub 1000 operates transparently so any keyboard conversions take place outside of the switch. Source (input) cards and destination (output) cards are available for PS2 and Sun keyboard/mouse types.

<u>Transmitter</u>

The transmitter used was the V2O-S25 system from TeraBurst [15]. It is designed for real-time bi-directional transport of high-quality stereoscopic video images, fully synchronized with audio, control and data signals, over any distance in private networks. The V2O-S25 system provides the best image quality by transporting uncompressed high-resolution video from a wide variety of formats and refresh rates, over a single high-bandwidth optical connection. Additionally, real-time audio, remote control of keyboard and mouse as well as third-party video conferencing and data file sharing are synchronized onto the same optical signal. This allows fully interactive collaboration between visualization centers across a campus, across town or around the globe over a private network.

The V2O-S25 takes an RGB analog video signal, audio signal, and all the control signals as input, and then output a synchronous optical network (SONET)/synchronous digital hierarchy (SDH) optical signal.

<u>Optical Network Connection and Management</u>

Qwest [16] offers an OC-192 optical wavelength dedicated private line adequate to connect computers and remote visualization sites. Qwest QWave service is based on the multiwave (MW) CoreStream™ system from Ciena®. This dense-wave division multiplexing (DWDM) system provides optical transport. The system can multiplex up to 96 discrete OC-48 optical carriers at 50 Ghz spacing or 48 OC-192 optical carriers at 100 Ghz spacing over one fiber. It operates with existing SONET/SDH fiber optic transmission systems (FOTS). The system channel plan conforms to the International Telecommunications Union (ITU) 50 Ghz and/or 100 Ghz spaced frequency channel plans. The frequency range extends from 191.50 to 196.25 THz.

Qwest QWave™ service is based on its state-of-the-art backbone network. The wavelength transport equipment deployed is high-reliability carrier class. The network is monitored and managed on a 24/7/365 basis with multiple network control centers. In the event of a fiber cut or an electronic failure the mean time to repair (MTTR) objective is four hours and eight hours respectively.

Qwest QWave provides high capacity bandwidths of OC-48 and OC-192. Customers requiring a protection path need to purchase a second wavelength and implement protection switching on the customer's equipment. Route diversity between the working and protection wavelength circuits may be available - subject to confirmation. Qwest QWave provides transparency for network management purposes. This is a fully managed service. Customers are relieved of the burden of managing their own fiber and repeater stations - as in dark fiber solutions. Also Qwest QWave can provide a viable alternative where dark fiber is not available. The QWave network footprint spreads all across the United States.

<u>Receiver</u>

Identical to the Transmitter V2O-S25, there is a receiver at the other end of our system to receive the data from the computing site. This receiver, however, has the input and output reversed. So the receiver will take the optical signal as an input and convert it back to the original signals, such as RGB analog video signals, tracking signals, control signals, etc.

VI.3.2 Compressed data transmission

As we mentioned before the same matrix switch described for the uncompressed system would be suitable for this approach. However the following equipment would differ.

<u>Transmitter</u>

TeraBurst has another product, the V2O-C150; its functionality is the same as V2O-S25, however it operates with an OC-3 (155 Mbps) optical connection. It is designed for real-time bi-directional transport of high-quality stereoscopic video images, fully synchronized with audio, control and data signals over any distance in public networks. The system uses visually lossless compression on large graphical data sets to enable low bandwidth requirements for cost-effective optical wavelength transmission over public networks without compromising signal quality. Additionally, real-time audio, remote control of keyboard and mouse as well as third-party video conferencing and data file sharing are synchronized onto the same optical signal. This enables fully interactive collaboration between visualization centers across a campus or over public networks around the globe.

VI.4 Comparing Alternatives

These two options have their own strength and weakness. Option 1 offers high quality graphic imaging, however since the transfer bit rate is very high (about 2.8Gbps), we will likely experience dropped frames. In addition, the cost is much higher than option 2. Although Option 2 is more economical, the graphic quality is lowered since data is compressed.

VII Conclusions & Final Remarks

An efficient way to share HPC systems is to use centralized computational and visualization resources to streamline modeling and simulation efforts to the remote specialized display device, such as PowerWall, Cave, RAVE, VisionDome, etc.

This paper presented the architecture designed at Delta Search Labs to provide remote 3D visualization and supercomputing services to distant customers. We discussed the issues and trade offs in this project and how they were addressed.

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