Creating a Visualization PowerWall

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INTRODUCTION

The California Institute of Technology (Caltech) Jet Propulsion Laboratory (JPL) recently made a series of procurements within the Supercomputing Project to create a PowerWall (2 x 2 display) such as the one used at Supercomputing '94 and Supercomputing '95. We have worked closely with the University of Minnesota's Laboratory for Computational Science and Engineering (LCS&E) in configuring our system. Our choices for projector and disk manufacturers were based on a requirement to be compatible with the equipment at the University of Minnesota. This compat-ibility insures that JPL and LCS&E can share and co-develop software. LCS&E's goal is to provide as much resolution as possible in each image while JPL's goal is to produce quality images at animation speeds.

This paper presents the issues of constructing a Visualization PowerWall. For each hardware component, the requirements, options and our solution are presented. This is followed by a short description of each pilot project. In the summary, current obstacles and options discovered along the way are presented.

BACKGROUND

History

When JPL installed its first commercial supercomputer in the summer of 1989, one requirement was that a Supercomputing Visualization Laboratory be established to assist supercomputing users in visualizing their data. The PowerWall Project is an extension of the Supercomputing Visualization Laboratory. At this time, it is a pilot project available only to selected users. If successful, similar facilities may be developed at other JPL locations as general resources.

The Requirements

The parallel graphics computers must have a multi-tasking, multi-user operating system and enough processor nodes, memory and data storage resources to support multiple users simultaneously. Our requirements are based on two specific applications: interactive data exploration through a large database (requiring constant rendering of the data and therefore computing power and large amounts of memory), and time sequence analysis of very large datasets (requiring massive amounts of disk space and high bandwidth from disk to memory). The pilot projects are discussed later in the paper; three projects each require 500 GB of disk for specific, short term purposes.

The facility space, image resolution, frame rate, storage capacity/bandwidth and CPU speed/bandwidth are all important considerations in the construction of a PowerWall. The physical space available for the facility dictates the maximum screen size and the projector throw distance that can be accommodated. The screen and projectors influence the maximum image resolution. The image resolution, in conjunction with the desired frame rate, dictates the minimum disk capacity. The desired image resolution also dictates the memory bandwidth required to play an animation sequence. These components will be examined in the remainder of the paper.

REQUIREMENTS & OPTIONS

The Room

At JPL, as at many other institutions, obtaining space is very difficult. Our laboratory space, 38 feet by 20 feet with an 8 foot ceiling, is minimal for a PowerWall facility. The display unit divides this space into a machine room and a work/viewing area in proportions dictated by projector requirements: 16 feet for the machine room and 22 feet for the work/viewing area.

Ceiling height imposes a restriction on screen size. The bottom of the screen should be at least three feet from the floor. If it extends beyond that, the audience is unable to see much of the display. Ceiling height greater than 8 feet is highly desirable.

The Projectors

Factors influencing the projection system include resolution (ANSI pixel rating), brightness (ANSI lumens), CRT size and throw distance. Additional projector features to consider are edge blending, contrast modulation and liquid coupled lenses. The color sequence of the guns in the projector should be carefully selected in order to obtain the best color balance.

Resolution, brightness, CRT diameters and throw distance are basic characteristics of projectors. Projector specifications often quote two numbers for resolution: the addressable pixels and the ANSI pixels. The addressable pixel rating is the maximum resolution of the projector. The ANSI pixel rating is related to the maximum spatial frequency of line pairs which can be output with a contrast ratio similar to line pairs of lower spatial frequency. (Screens with lower gain require higher brightness specification for the projector than those with higher gain.) The diameter of the CRT impacts hot spots; the larger the diameter, the less problem with hot spots. The throw distance of the projector determines the separation required between the projector and the screen. Folded optics (mirrors) can compensate for the lack of adequate throw distance. However, this may complicate focusing of the projectors.

A P43 green phosphor tube is required for stereo viewing. P43 phosphor has a faster decay time constant which allows 60 frames/second stereo multiplexing without blurring. Contrast modulation adjusts the brightness on the edges of the image to improve color and brightness uniformity across the screen (reducing the hot spot effect). Edge blending allows improved matching of multiple projector installations to provide a more seamless transition between images. Image shifting moves the image slowly over the CRT phosphor surface to reduce the harmful effects of a static image.

A liquid coupled (LC) lens reduces the scattered light resulting when the light passes from the CRT through air to the projector lens. The liquid has the same index of refraction as glass so that the light does not bend during projection. This option provides a better contrast ratio, causing the blacks to appear blacker and the whites to appear whiter. However, the liquid coupled lens requires additional throw distance.

We chose Electrohome projectors to be compatible with LCS&E. We considered the Marquee 9500LC and the Marquee 8500. The Marquee 9500LC projector with a P43 phosphor tube was selected for the following reasons. The 9500LC has a larger CRT (9 inch diameter) than the Marquee 8500 (8 inch diameter). It is also brighter than the 8500, which is important since we chose a rigid screen with a 1.0 gain (see below). The 9500LC comes with contract modulation, edge blending and image shifting. The disadvantage of the 9500LC over the 8500 in our situation is its longer throw distance. Space in the machine room portion of our facility is very tight and the 9500LC projectors require mirrors to focus properly. Because our projectors are mounted relatively close to the screen, we reversed the color sequence of the guns on the two right projectors. Rather than having those guns mounted red, green, blue, they are mounted blue, green, red. This eliminates the color discontinuity which would otherwise occur between the left and right sides of our 2 x 2 PowerWall.

The Screen

Screen choices include flat vs curved surface, flexible vs rigid surface, one large screen vs several smaller screens and specific surface characteristics.

A front projected curved screen can provide an illusion of dimensionality lacking in a flat screen. For some applications, this is positive; for other applications, such as CAD, the curved screen may not be desirable.

A flexible screen is relatively inexpensive and easy to install but has the disadvantage that any breeze in the room (an Air Conditioner vent, for example) may cause the screen to flutter, distorting the image and distracting the viewer. The rigid screen has a structural support holding the screen motionless.

The projectors can illuminate separate regions of a single large screen or multiple smaller screens arranged in a matrix. Without overlapping the images and blending the edges, the viewer sees highly noticeable and distracting gaps in the overall image. A light background emphasizes these gaps; a dark background helps to mask them. Individual screens in a multiple screen display may be surrounded by mullions; the projection system does not display images over the mullions. Mullions are especially distracting on a 2 x 2 display since the four mullions converge at the center of the display. This is the natural focal point for the viewer and is often the center of scientific interest. Mullions are less obvious on other configurations, such as a 1 x 3 display.

The gain of the screen defines the viewing angle that can be accommodated. The lower the gain, the wider the viewing angle.

Gain	Viewing Angle
1.0	@ 180°
1.3	160°
1.5	120°
2.0	90°

Figure 1: Gain vs Viewing Angle

A person walking from one side of a 1.0 gain screen to the other side will not see a shift in the intensity or in the color of the display. The larger the screen gain, the faster the drop in intensity. A screen with a gain of 5.0 can be viewed easily in a well-lit room. A screen with a gain of 1.0 requires a brighter projector and the room light must be lowered for the image to be clearly seen. Specific screen types have a range in the possible gain; a rigid lenticular screen has a higher gain (4.0-5.0) than a diffuse screen (1.0-2.0).

Based on available screen sizes and our requirement for a 2 x 2 projection display, we initially installed a display consisting of four 50 inch lenticular screens with mullions and 5.0 gain. Most pilot users did not like the effect of the mullions. Reactions were mixed on the gain. Users generally liked the brightness of the display and the fact that they could give demonstrations without dimming the lights. They did not like the chromatic aberrations present in the near field (the color shift and the inability to view individual pixels at close range). We recently replaced this screen configuration with one single screen covering the same area. The new screen has a 1.0 gain.

The Data Issues

The amount of disk space and the speed with which the disk can be read into memory are the two primary issues. Side issues to consider are the backup mechanism and loading/unloading of large datasets.

Computer animation usually displays at 30 frames per second (fps) while film displays at 24 fps. Using film display rates enables the use of commercial film making software that is on the market. JPL is considering purchasing packages such as AVID Illusions, a resolution independent software editing package which allows users to edit images on-line with text and special effects; Alias/Wavefront and SoftImage 3D, for artistic purposes as well as for visualization of scientific data. Movie Player, a package by LCS&E, which plays movies from memory or from disk and is not frame-rate dependent, is currently available.

Twenty-four bit color is preferable; for stereo viewing at these frame rates, eight bit color is required. The following figure gives data storage per minute and bandwidth requirements for various scenarios assuming a 4 panel PowerWall. The disk and the bandwidth in the following figure have been doubled for stereo projection (8-bit color).

Resolution (Pixels)	Color (Bits)	Frame Rate (fps)	RequiredDisk (GB/min)	Required Bandwidth (MB/s)
1280 x 1024	24	24	22.6	338
1280 x 1024	24	30	28.3	472
1600 x 1200	24	24	33.2	554
1600 x 1200	24	30	41.5	692
1280 x 1024	8	24	15.0*	252*
1280 x 1024	8	30	18.8*	316*
1600 x 1200	8	24	22.2*	368*
1600 x 1200	8	30	27.6*	460*

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* Rates for stereo projection

Figure 2: Disk requirements for 4-panel PowerWall

The need for 500 GB of disk is justified on specific project requirements. However, those requirement are for very limited amounts of time. Figure 2 shows that four 1280 x 1024 panels require approximately 23 GB storage for a one minute animation sequence (24 fps, 24-bit color). During the development cycle, disk usage of three times the final product size is not unusual. Assuming that the average developer is using 75 GB of disk, the 500 GB we have should accommodate 5 developers or, more likely, one user giving a large demo and two or three developers.

The transmission rates required to view an animation sequence is another justification for disk space. The transmission rate required for four 1280 x 1024 panels (24 fps, 24-bit color) is approximately 338 MB/sec. In order to achieve this transmission rate, we looked briefly at SCSI disk characteristics. A sustained transfer rate of 5-10 MB/s per disk and 20 MB/s for each port (3 disks to the port) told us that we needed 108 disks and 36 ports in addition to assorted SCSI boxes, I/O cards and Mezzanine cards.

We then looked at fiber channel to reduce the number of disks required. A fiber channel supports 100 MB/s and each fiber channel RAID-3 disk sustains 70 MB/s. Therefore, 5 RAID systems are required to sustain 338 MB/sec. For optimum performance while minimizing cost, the memory to frame buffer bandwidth should match the total disk I/O bandwidth for each system. Therefore support for some of the largest scenarios in Figure 2 (for example, 1600 x 1200 resolution at 30 fps and 24 bit color) cannot be implemented.

We purchased 8 RAID-3 systems; each system has eight 9 GB disks plus a parity disk for a total RAID storage of 576 GB. An STK Silo attached to a CRAY J90 via HiPPI is the backup device. In addition to the RAID disk, which is split evenly between our two Power Onyx systems, each system has 36 GB of non-RAID disk that serves as system and home directory space. We automatically and routinely backup users' home directories and system areas. Users must backup (or unload) files residing in temporary disk space. In addition to network access to the Silo, users have available CD ROM, DAT tape, 8 mm EXABYTE tape and an optical reader for transporting data between systems.

The Compute Servers

One decision in the PowerWall design is whether to use the RE2 or the IR graphics board. This decision is critical because of the memory to frame buffer transfer rate. The RE2 graphics board can support 12 fps at 24 bit color and resolution of 1600 x 1200 or 20 fps at 24 bit color and 1280 x 1024. Adding a second raster manager board to the RE2 allows it to support a second display at the same resolution. The IR can support 30 fps at 24 bit color and 1600 x 1200 resolution.

Our two Power Onyx systems control the PowerWall. Each system has two infinite reality (IR) engines with 64 MB of texture memory and four R10000 CPUs each with 2 MB secondary cache. Each Power Onyx has 2 GB of memory and 324 GB of disk (288 GB of RAID-3 disk plus 36 GB of SGI disk). Each system has two Dual Port Prisa Fiber Channel Controllers to service the RAID-3 disks.

PILOT PROJECTS

The pilot projects are described very briefly in this section. Each was chosen because of its extensive experience with visualization and its interested in testing the concept of a multiple purpose, high quality visualization laboratory. Each project has contributed equipment for the success of the laboratory.

Synthetic Aperture Radar,
N-Body Project,
Remote Interactive Visualization & Analysis
Dave Curkendall, Principle Investigator

Each of the three separate projects for this principle investigator claim the need for 500 GB of data to meet specific project goals.

The SAR project must demonstrate the ability to process large scale SAR data. One quarter terabyte of raw data must be processed in order to meet a project milestone. The raw and processed data require approximately one half terabyte of disk during the milestone demonstration.

The 10 million byte dataset (minimum resolution) of the n-body project cannot reside anywhere but on disk. A complete simulation consists of 40 bytes/particle, 18 million particles and 1000 time steps.

The Remote Interactive Visualization and Analysis (RIVA) project is an interactive data explorer which allows scientists to explore NASA's largest scientific datasets using high speed networking and parallel supercomputing technology. This project uses an SGI Onyx for the user interface and a HiPPI frame buffer connected to the CRAY T3D via a HiPPI network (100 MB/s peak and approximately 50 MB/s sustained). Once an image of 1280 x 1024 pixels is displayed on the HiPPI frame buffer, the SGI Power Onyx, using the reality engines, allows the user to display the image on the PowerWall at four times the resolution.

Product Development Center
Information Systems Development
Meemong Lee, Principle Investigator

This project will attempt to use the PowerWall by remote access. The codes will execute on the Power Onyx systems co-located with the PowerWall but, through the use of the network dual-head software daemon (ndsd), will display the output and control the interactivity from a different building within the JPL campus. That building has duplicated the display and projection systems, relying on the Power Onyxes for the computing power and an ATM network for communication speed. If the PowerWall demonstrates its usefulness to management, the computational power may be duplicated in that location at a later time.

Visualization of Planetary Surfaces and Atmospheres
Erik DeJong, Principle Investigator

This project generates simulated flights over planetary surfaces. It will also be controlled through remote access. This project is currently able to use the Power Onyxes as their primary computing power for displays that are being channeled to their recording lab for production film recording.

Process Millennia
John Peterson, Principle Investigator

This project, which shares the physical lab space and the compute engines but does not use the PowerWall, will design a prototype virtual reality system for use in spacecraft and mission design. It uses a JPL design program within the framework of a commercial 3-D virtual reality system called MUSE. This project uses a single Electrohome 8500 projector in front projection along with a Fakespace boom, sound system and joysticks.

SUMMARY

The following miscellaneous information contains known problems or data that may prove useful. It also notes some of the uncertainties we are still experiencing with our current implementation.

The Room

Room scheduling during the pilot project phase is done through Meeting Maker XP, the JPL scheduler of choice. Having several diverse and high visibility projects already leads to conflicting schedules. By using the Meeting Maker software, all users will have up-to-date access to the room schedule via a Macintosh or a PC.

The Projectors

We are working under the assumption that our Marquee 9500LC projectors will focus down to a 50" diagonal. Although this is NOT within the written specifications, engineers have indicated that it should work. If they cannot focus down, a larger screen will be installed in spite of the consequences of moving the screen closer to the floor and reworking the custom scaffolding that holds the projectors.

The projectors are very sensitive and easily get out of physical and/or color alignment. Re-alignment is a very time consuming task. To save wear and tear on the projectors, we built a "Monitor Wall" for development work. This wall is composed of 4 SGI Onyx monitors mounted in a configuration similar to our 2 x 2 PowerWall. These monitors are movable to allow one user to develop on the complete set or to allow users to share in a 2 x 1, 1 x 2, or 1 x 1 configuration.

Panaram Technologies III Screen Blender (a commercial product) may be needed to augment blending effects of the Marquee 9500LC projectors. This product is currently available for a 1 x 3 screen configuration and works very well; it is expected to be released in October 1996 for a 2 x 2 display. This company also makes a complete ready-to-go PowerWall package consisting of a 1 x 3 curved screen with supporting structure, 3 front projectors and the Screen Blender.

The Screen

A retractable cloth screen is installed in front of the PowerWall for presentations. The cloth screen is motor-driven to lessen the chance that raising and lowering it might scratch the PowerWall. This is the only possible location in the room for this screen.

The Compute Servers

Under OpenGL, it is not possible to open a viewport that covers the complete display of 3200 x 2400. This is a hardware limit caused by the size of the registers and arithmetic units used for rastering polygons. To produce a gigantic image, you must break the image into tiles that are smaller than the maximum viewport dimensions and render each tile. For many applications this is easily done but for some applications it is difficult.

Because we are using two Power Onyxes to drive the PowerWall, we have a problem with asymmetric I/O caused because gangdraw (the capability to have multiple CPUs issue synchronized commands) does not work correctly with OpenGL 6.2. Since each Power Onyx drives two projectors, each pair of projectors are in sync.

Conclusions

Figure 3 identifies the maximum frame rates that we are able to sustain with the PowerWall and computer system that we currently have.

View	Resolution (pixels)	Color (bits)	Frames per Second
Mono	1280 x 1024	24	30
Stereo	1280 x 1024	8	30/30
Mono	1600 x 1200	8	30
Stereo	1600 x 1200	8	24/24

Figure 3: Maximum frame rates for our system

A diagram of our system is shown below.

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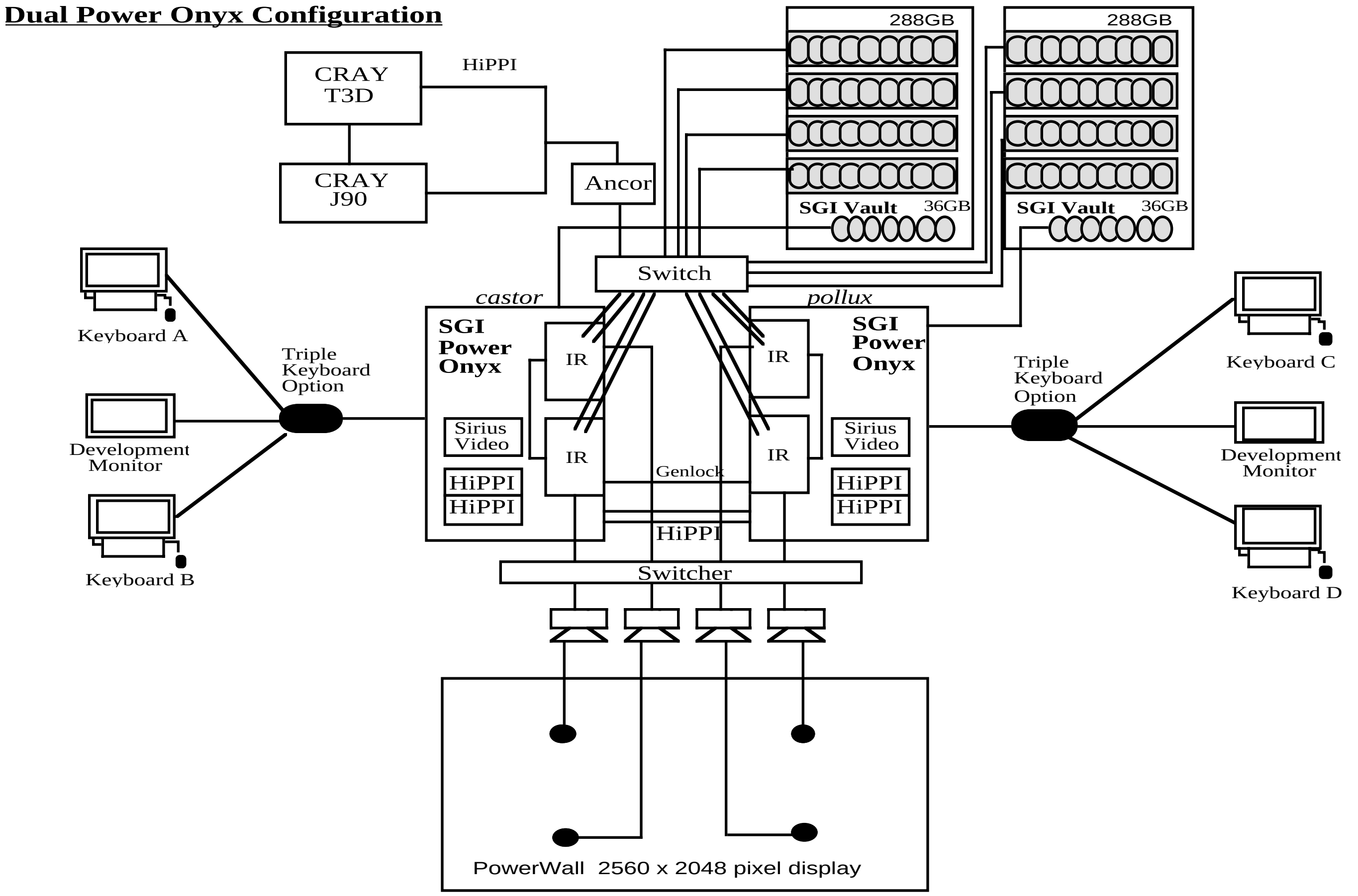

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