Wide-View Visual Systems for Flight Simulation

Dubravko Miljković
Hrvatska elektroprivreda
Vukovarska 37, 10000 Zagreb
dubravko.miljkovic@hep.hr

Abstract - **Immersive virtual environments necessary for realistic flight simulations need wide view visual systems that cover large horizontal visual angle and consist of multiple video channels. Methods for achieving this task in flight simulator are presented: use of displays and projectors, most common types of visual systems, use of multiple graphics cards and multihead graphic cards, single graphic card with graphic expansion modules and surround display using PC clusters. Integration of visual system with rest of simulator is described. Implementation of flight simulator with three channel visual system on PC cluster is described.**

I. Introduction

Computer generated image system is important part of the flight simulator. Ability to show multiple views on more than one display at a time creates a more realistic cockpit environment. Visualization systems that support multiple-display viewing can greatly enhance user perception. The visual systems must be of a high resolution and a wide field-of-view, so that the person sitting in the simulator can be fully immersed into the flying experience. After review of available solutions, realization of a relatively simple multichannel flight simulator is described. Reviewed solutions also leverage new PC based image generation and display technologies.

II. Display Devices

Display device convert electronic signal into a visual image, [1]. Today there exist a large number of display choices for training simulators based on a variety of different display methodologies. Display devices may be classified as (conventional) displays and video projectors.

A. Displays

1) Cathode Ray Tube (CRT) display: Use a beam of electrons to stimulate phosphors and thus make the image. Offer high contrast, can be viewed from almost any angle, flexible resolution. However today are mostly obsolete technology and bulky.
2) Liquid Crystal Display (LCD): LCD flat panel is made up of color or monochrome pixels filled with liquid crystals and arrayed in front of a light source (backlight) or reflector. Offer satisfactory contrast, reasonable luminosity and response. They are suitable for small to medium displays (e.g. glass instrument panels).
3) Plasma Display: Plasma Display Panels stimulate phosphor cells individually with electrodes. Plasma Display technology provides several key advantages over conventional CRTs and LCD panels, high luminosity, contrast and very fast response. They are suitable for medium to large displays.

B. Video Projectors

Projectors are used for creating very large views. Main technologies are:

1) CRT Projector: Use cathode ray tubes as a light source. Provide the largest screen size for a given cost. Offer high contrast ratio.
2) LCD Projector: Use LCD light gates and is the simplest system, making it one of the most common and affordable. Projector needs a light source (bulb).
3) Digital Light Processing (DLP) Projector: This technology uses one, two, or three microfabricated light valves called digital micromirror devices. Advantages are high resolution and excellent color accuracy. Just as LCD projectors DLP projector needs a light source.

III. Visual Systems

A visual system combines display devices like direct-view monitors, CRT projectors or light valves with optics and other components to form a complete visual system that can be used as the image presentation part of a training simulator.

A. Types of Visual Systems

Various methods have been used in the pursuit of a quality visual system. Most common types of visual system are listed here:

- Domes
- Collimated Display Systems - Projected & Monitor Based
- Head Mounted Displays
- Eye tracking devices
- Head slaved projectors
- Real time photo realistic, textured graphics
- Virtual Reality
- Retinal displays

In real world distant objects move along with normal head movements. Parallax is an apparent displacement or difference of orientation of an object viewed along two different lines of sight. When using projector system with distant screen surface, due to parallax, slightly different image is seen from different viewing positions, Fig. 1. This distant image can be achieved by collimation. Collimated display means that the light rays are coming out parallel instead of radiating out in the normal way. Here are listed some most important methods for achieving illusion of image depth

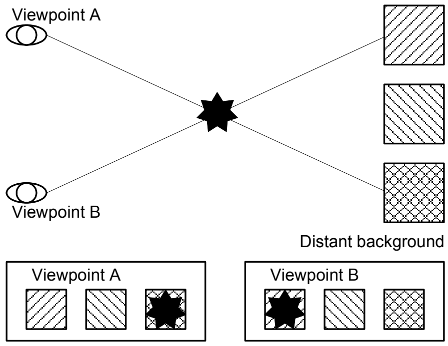

Fig 1. Illustration of parallax

using collimated images combined with CRT display and projector.

1. Large CRT Monitor-Based Display System

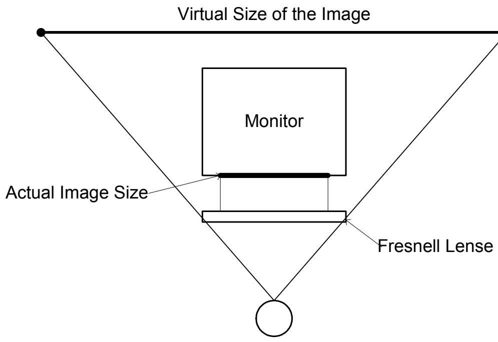

Fig 2. Fresnell Lense

The use of a Fresnell lens reduces image quality. They tend to be used only where quality is not critical, Fig. 2.

2. Collimated display using spherical mirror and a beamspliter

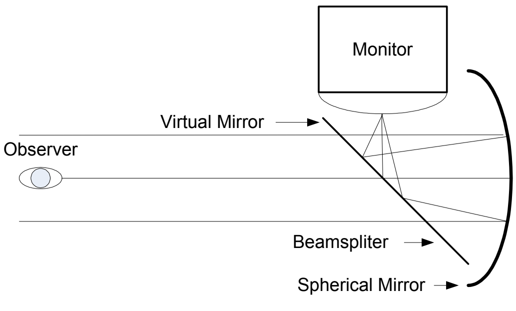

Fig. 3. Collimation

The display is collimated, using a spherical mirror to view the image on a digital projection monitor at optical infinity. A display system comprises a high performance monitor, an optical quality beamsplitter and a precision front-surfaced collimating mirror and is shown in Fig. 3.

3. Multichannel Projection Display System

An effective way to extend the total field-of-view capability of a display is to use multiple projectors with a curved screen surface, Fig. 4 (adopted from [1]).

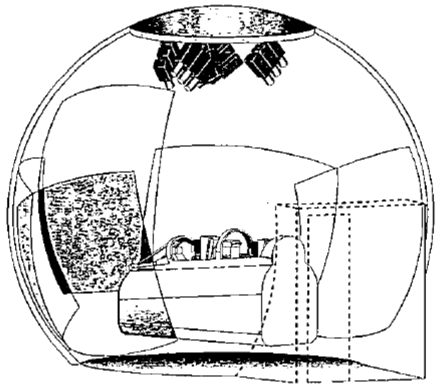

Fig. 4. Dome system, adopted from [1]

Domes are visual system of choice when a 360 degree field-of-view is needed, [1, 2]. There are many types of domes - some which use external projectors, others with internal projectors and combinations of the two. In all cases, the display surface is independent of the user's head position. The major drawback to this approach is the cost involved in providing resolution over the entire area of the dome. The surrounding space around watcher is spherical. Spherical perspective is the most natural display of a surrounding ambience. Described dome system doesn't use collimation.

4. Wide-Angle Collimated Display System

Monitor Based Collimated Display Systems (also known as W.A.C. - Wide Angle Collimated window displays) are designed to provide the user with an "out-of-window" display. Their purpose is to display a scene with realistic depth of field cues for the pilot/operator.

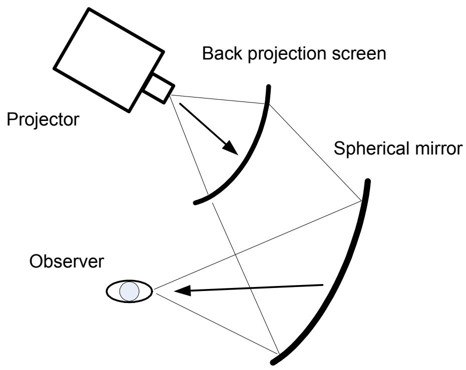

Fig. 5. Wide-Angle Collimated Display System

The mirror is made from a reflective plastic film, held in shape by a vacuum. The image itself is projected on to a back projection screen above the pilot's head, by the several projectors which can just be seen on the roof of the simulator, so the pilot is actually looking at a reflection of the image, Fig. 5. This reflection seems to be infinity, i.e. it does not look as though it is only a reflection of a picture on a screen just a few feet away.

5. Head-tracked and eye-tracked displays

Head tracking is slaving the imagery to the head position. It is generally used together with head mounted displays.

Head-mounted displays may also be used with tracking sensors that allow changes of angle and orientation to be recorded. When such data is available in the system computer, it can be used to generate the appropriate computer-generated imagery (CGI) for the angle-of-look at the particular time.

6. Simple wide-angle solution

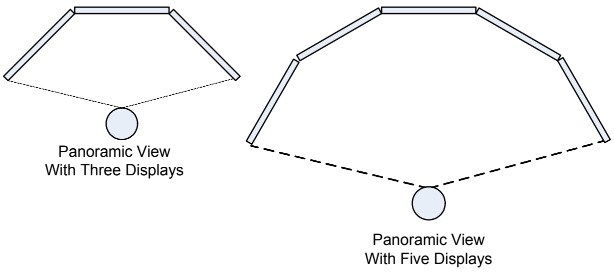

Fig. 6. Wide angle solutions with multiple planar displays

Simple solution includes integration of several planar views separated by some angle, as shown in Fig. 6. It is not a perfect solution, but is quite popular because it is easier to implement with commodity hardware.

B. Image Distortion and Correction Techniques

Projector system distorts the image, [2, 3]. Distortion is introduced by the lens, the non-planar dome, and possibly the CRT projector's electronics and CRT itself. When building a wide angle image on the sphere, it is necessary to use adaptive visual algorithms for synthesis of spherical expression, Fig. 7, [2]. Projected image distortion can be attributed to following causes:

1. Distortion due to spherical screen

With distortion correction software, the system is capable of displaying life size, stereoscopic, distortion free images on the screen with a wide field of view. The image distortion software correction, as shown in Fig. 8, [2], can be performed in real time.

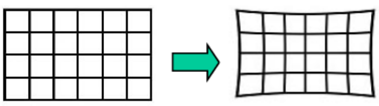

Fig 7. Plane image represented on a spherical screen

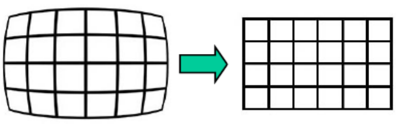

Fig. 8. Presentation of pre-distorted image

2. Distortion due to projector's position.

The image distortion caused by the projector shift (rectangle distorted to trapeze) shown in Fig. 9 could be corrected using lens shift feature of the projector.

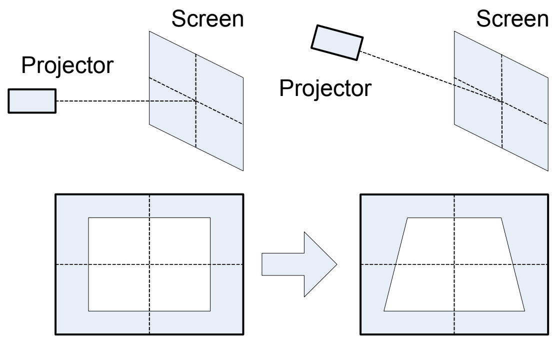

Fig. 9. Distortion due to projector position

C. Blending

Each projector is restricted to render only one portion of the whole image. However there obviously will be an overlap at the boundary of each rendered portion, Fig. 10.

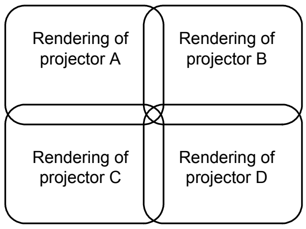

Fig. 10. Overlapping of images from several projectors

Smooth blending near these boundaries can be also achieved by software.

IV. MULTICHANNEL IMAGE GENERATION ON ONE COMPUTER

Multiple video channels could be generated using just one computer. These channels could stretch the same (e.g. forward view) or generate new additional individual views (e.g. left, forward and right view), Fig. 11. In the former case there is not significant drop in a frame rate, in later drop in frame rate is quite large and depends on a number of individual views. If one wants just to stretch the same view onto three monitors, generally speaking, one will not significantly loose performance. If the same equipment is used to create three independent views, with a specific view

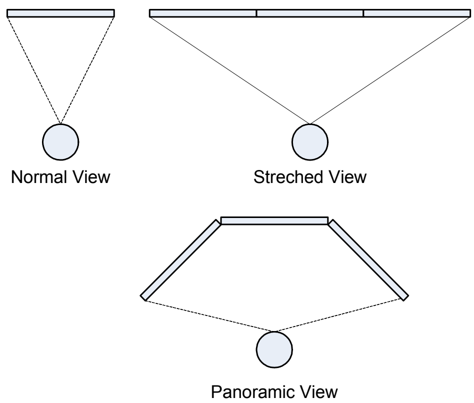

Fig. 11. Normal, stretched and panoramic view

angle assigned to each monitor, computer may be about three times slower because it has to handle three different views. Considering this, multichannel images generated on one computer are generally limited to multiple display instrument panels that don't require too much processing power. Further text regarding multichannel images in this section is mainly oriented toward PC computers (commodity hardware).

A. Multiple graphics cards

Some PC motherboards support multiple PCIe (PCI Express) graphic cards. Otherwise one can use AGP+PCIe or PCIe + PCI combination of display adapters (i.e. one graphic card use AGP and another PCI slot) but this solution doesn't offer the same performance at each card due to different interface bandwidths.

B. Multihead graphics cards

There exist numerous multihead (multi-output) graphic cards that can provide multiple video channels at the same time. Two heads are required for a dual-screen, three heads for a triple-screen and four-heads for four screens.

C. Single graphics card with graphics expansion modules

Graphics Expansion Modules (like Matrox DualHead2Go and TripleHead2Go) are small black boxes that let you connect two or three monitors to one video card. Graphic Expansion Module truncate video signal from one line in two or three sections and type it out from separate buffers again, but this time in duration of one line of video signal, Fig. 12. They connect to the VGA or DVI output and use your system's GPU to provide high-quality 2D, 3D and video across all monitors.

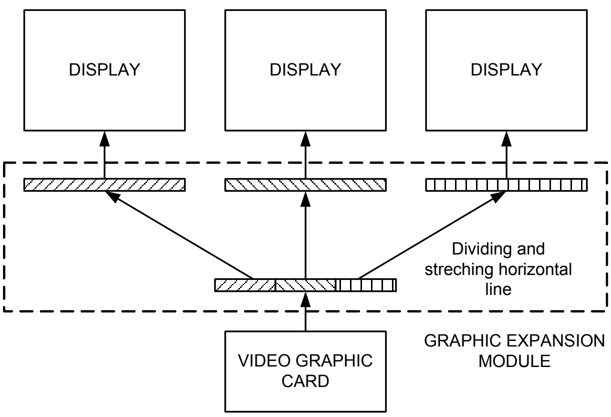

Fig. 12. Graphic Expansion Module

V. SURROUND DISPLAY USING PC CLUSTER

Several PC computers can be networked together via a local network to form a "graphic cluster", Fig. 13. Such arrangement allows multiple display and multiple computer nodes to interact. Each node has graphical capability and provides visual output, [4, 5, 6, 7, 8,]. Specific view angle is assigned to each monitor which is the only way to actually make view angle wider and create a true panoramic view, [9, 10].

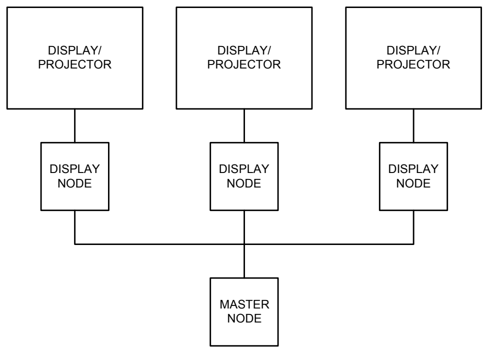

Fig. 13. Graphical cluster with three video channels

A. Basic approaches

Two basic approaches for setting up graphic clustering communication software architecture are: Client/server and Master/slave.

1. Client/Server

The Client/Server approach consists of a single master node that serves data to the graphic rendering clients. Server sends primitives to be rendered and rendering client nodes do the rendering process.

2. Master/Slave

The Master/Slave approach consists of multiple nodes, where each node of the graphic cluster locally store and runs an identical copy of the graphics application. Only application status variables are communicated from master to slaves. Based on imported status variables application instances running on slaves generate necessary visual views.

B. Synchronization

Whenever technical and financial resources are available multiple channels should be synchronized, [4,11], Fig. 14. Lack of synchronization between channels can be particularly easily detected in fast turns. Broken horizon line appears because one of the computers stays a frame behind another. Multi channel synchronization provides following benefits:

- Adjacent Channel Matching
- Optimum and Consistent Frame Rates
- Reduce System Latencies
- Monitor Interactions
- Reduce Simulator Sickness

Synchronization is generally implemented in hardware, but can be software as well, [11, 12, 13]. Client/server or master/slave graphic cluster can include following levels of synchronization:

- Data Locking: Process of synchronizing the views to maintain the consistency across the screen

- Genclocking (video synchronization - at pixel, line and frame level)
- Swap Locking (video synchronization - at frame level, i.e. changing prepared frames across all video channels at the same time)

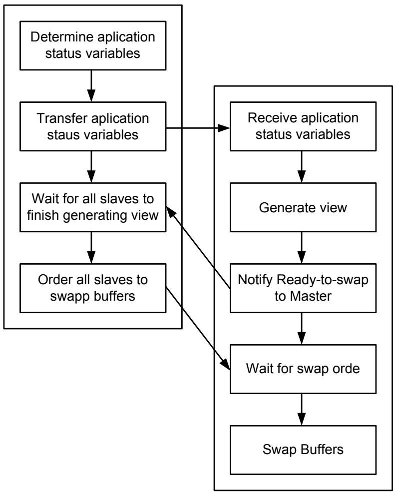

Fig. 14. Synchronization process between master and slaves

In real use minimal frame rate should always be above 30 fps (frames per second), but can be 120 fps for demanding applications. High frame rates generally decrease latency of a system (delay between issued command and appropriate change in visual).

VI. EXAMPLE ON FLIGHT SIMULATOR

Following example describes realization of wideview visuals using FS2004 simulator and Wideview broker.

A. Basic description of a FS2004 simulator

Main elements of the simulator are: aircraft, scenery, gauges, sound, modules, effects and weather that interact together. Logical structure of the simulator corresponds well to main folders of the simulator.

B. Basic description of aircraft model

Each aircraft within FS2004 consist of aircraft.cfg file and model, (instrument) panel and sound folders (Fig.15).

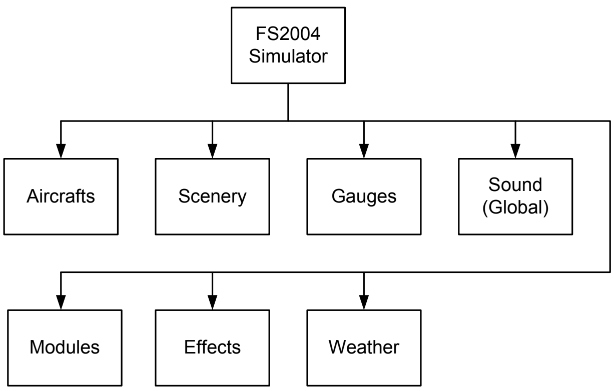

Fig. 15. Structure of FS2004 flight simulator

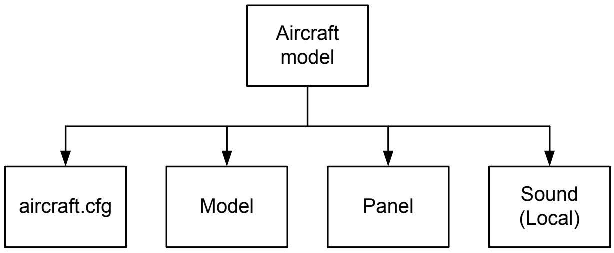

Fig. 16. Structure of FS2004 aircraft model

Model includes aircraft flight dynamics. Sound includes various .wav files that are combined for producing engine and environment sounds (wind, runway friction etc.). Panel consists of numerous gauges. Gauges are organized in windows (panel can have more windows, Fig. 16).

In an experiment TinMouse freeware simulator add-on model of Boeing 737-200 Advanced was used, [14]. The aerodynamics for the package has been praised (those who have flown the real -200 say that the numbers and performance are spot on). The panel is quite detailed with many windows (panel views). Following instrument panels (panel views) are implemented: main panel, overhead, radio communication and navigation, throttle panel, TAWS and EGWPS.

The aircraft model, aerodynamics, and sound are top notch as well, but the panel is what makes this package one of the best freeware packages.

C. Block diagram of a multiple node setup

Block diagram of a multiple node setup is presented in Fig. 17. Same instance of flight simulator application is installed on the local hard drive of every node (PC), both master and slaves. On all nodes the same scenery and the same texture are also installed, otherwise the outside view would differ on some nodes. Scenery replication is accomplished from master to slave nodes via replication software. Same degree of realism and the same aircraft, scenery and graphic options are set within simulator application installed on every node. Master node is used for running simulation (this is the node where flight dynamics of an aircraft and flight trajectory is calculated) and distribution of application status variables

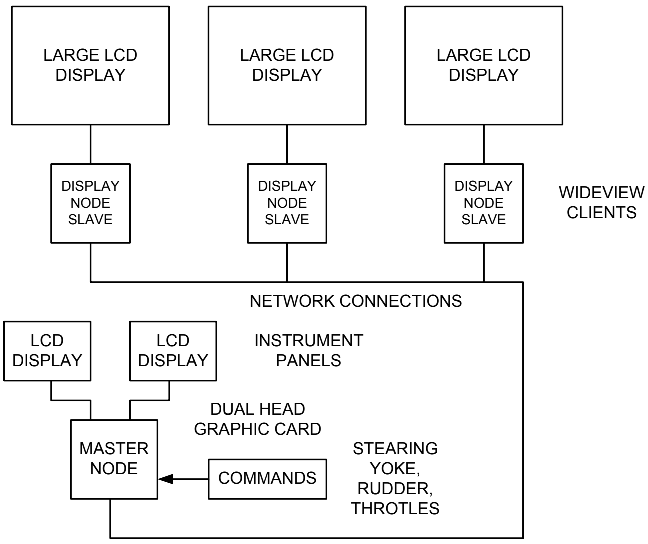

Fig. 17. Simulator setup

(via Wideview agent) and instrument panels only. It has one dual-head graphic card that drives two LCD monitors for aircraft instrument panel (several panel views), [16]. The panel gauges are generally not power-hungry like the external scenery and one computer is sufficient for several panel views (they are pretty static, e.g. radio communication panel). Scenery views are delegated to slaved nodes that are dedicated just for generating quality scenery views at sufficiently high frame rates. When using graphical cluster with multiple monitors, following recommendation should be fulfilled:

- The monitors should be placed all at the same level
- The monitors should be of the same size or better of the same brand / model
- The resolution and refresh rate should be the same
- The size of the external view's window must be identical on the monitors
- The angle formed between the monitors should meet the actual view orientation used in simulator

D. Wideview agent

Master node and slave nodes communicate via network using Wideview broker agent, [16]. Wideview allows several PCs to be networked together and run Microsoft Flight Simulator in a coordinated fashion. It is a set of special gauges which can be installed in any aircraft's panel and than can be used to create virtual cockpits with multiple outside views, using networked PCs. Different type of agent is used on master node (Widewiew server gauge) and different on slaved nodes (Wideview client gauge). Wideview handles the aircraft's position, orientation, pitch, and bank, the taxi lights, landing lights, the calendar (date/time) and the weather. Moving parts (gear, flaps, spoiler, and engines) are also supported. On each slave node different view angle (for left, forward and right view) is set in Wideview agent configuration settings. The master node, (the node where flight simulation takes place: flight dynamics and flight trajectory), runs the WidevieW server module which passes aircraft position data, weather, date and time and other parameters to the slave nodes running simulator in a special slew or pause mode. This data is updated many times per second and client nodes very accurately and fluently follow the master node. WidevieW puts the clients in SLEW mode automatically each time it starts.

E. Synchronization

Described system doesn't employ video synchronization between channels and exploit persistence of LCD monitors for producing multichannel views of acceptable quality. However, frame rate is adjusted by frame rate lock option and most of the time system produce same frame rate across all video channels. Frame rate lock simply limits frame rate at predetermined value despite that some channels within system at some moments could produce considerably higher frame rate. This way frame rates between channels are equalized and differences in human perception of various channels are minimized.

VII. CONCLUSION

Main approaches toward realization of wide-view visuals for flight simulations have been reviewed. Some approaches produce better visuals, other use commodity hardware and are financially feasible for wider audience. Proposed solutions apply new PC based image generation and display technologies. When medium to high frame rates and panoramic visuals are required graphical cluster with nodes dedicated to generation particulars scenery views is the solution. Application instances running on slaved nodes must be synchronized with master node which periodical broadcast application status data to all slaved nodes.

REFERENCES

1. P. C. Lyon, "Choosing the Right Display System for a Flight Training Simulator", Proc. of SIMTECT 96, Melbourne, Australia, March 1996
2. N. Shibano, P. V. Hareesh, H. Hoshino, R. Kawamura, A. Yamamoto, M. Kashiwagi and K. Sawada, "CyberDome: PC Clustered Hemi Spherical Immersive, Projection Display", Proc. of ICAT 2003, December 3-5, Tokyo, JAPAN
3. M. Song, S. Park and Y. Kang, “A Survey on Projector-based PC Cluster Distributed Large Screen Displays and Shader Technologies”, Proc. of International Conference on Computer Graphics and Virtual Reality 2007, June 25-28, 2007, Las Vegas, Nevada, USA
4. Nirnimesh and P. J. Narayanan, “Scalable, Tiled Display Wall for Graphics using a Coordinated Cluster of PCs", Proc. of 14th Pacific Graphics Conference, October 11-13, 2006, Taipei, Taiwan
5. D. B. Maxwell, A. Bryden, G. S. Schmidt, I. Roth and J, E. Swan II, "Integration of a Commodity Cluster into an Existing 4-Wall Display System", Proc. of Workshop on Comodity-Based Visualization Clusters, IEEE Visualization 2002, October 27, 2002, Boston, Massachusetts
6. J. D. Choi, K. J. Byun and B. T. Jang, "A Real Time Surround Display using PC Clusters", Proc. Software Engineering and Applications 2002, Cambridge, USA, November 4 – 6, 2002.
7. G. Tudor, "An Enhanced Bridge Simulation Training Facility for the Royal Australian Navy", Proc. SIMTECT 97, Canberra, Australia, 1997
8. J. F. Horn, D. O. Bridges, C. Sharma. L. V. Lopes and K. S. Brenter, "A Multi-Disciplinary Rotorcraft Simulation Facility Composed of Commodity Components and Open Source Software", Proc. of American Helicopter Society 60th Annual Forum, Baltimore, MD, June 2004
9. VRSG as a Multi-Channel Image Generator, MetaVR, http://www.metavr.com/products/vrsg/multichannel.html
10. MetaVR Visuals Used in NASA T-38N Program, MetaVR, http://www.metavr.com/casestudies/t-38.html
11. "Multi-Channel Synchronization in Visual Simulation Systems", Quantum 3D, 2001
12. A. Griesser and L. V. Good, RTSyncNet, "A flexibile Real-Time Synchronization Network for Cluster based Vison and Graphics Architectures", Proc. of IEE International Conference on Visual Information Engineering (VIE 2005), Glasgow, UK, 4-6 April 2005
13. M. Waschbüsch, D. Cotting, M. Duller and M. Gross: WinSGL, "Software Genlocking for Cost-Effective Display Synchronization under Microsoft Windows", Proc. of Eurographics Symposium on Parallel Graphics and Visualization, 2006
14. TinMouse B737-200 Adv. Project, http://www.avsim.com
15. Using Multiple Monitors (in FS2004/FSX), www.fsinsider.com
16. L. Napolitano, Wideview, http://www.wideview.it