Display Research at the University of Southern California

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ABSTRACT

The University of Southern California and its collaborative research partner, Fakespace Labs, are participating in a number of research programs to invent and implement new forms of display technologies for immersive and semi-immersive applications. This paper briefly describes three of these technologies and highlights a few emerging results from those efforts.

The first system is a rear projected 300 degree field of view cylindrical display. It is driven by 11 projectors with geometry correction and edge blending hardware. A full scale prototype will be completed in March 2006.

The second system is a 14 screen projected panoramic room environment used as an advanced teaching and meeting space. It can be driven by a cluster of personal computers or low-cost DVD players, or driven by a single personal computer.

The third is a prototype stereoscopic head mounted display that can be worn in a fashion similar to standard dust protection goggles. It provides a field of view in excess of 150 degrees.

1 CYLINDRICAL DISPLAY SYSTEM

In late 2004, the University of Southern California Institute for Creative Technologies was asked to design and deploy a display system for training soldiers in close air support (CAS) tasks. CAS requires a ground-based soldier to guide an aircraft to a target using radio communication. The project called for a minimum 270 degree horizontal field of view and the ability to view aircraft directly overhead. The physical dimensions of the system had to fit within a former vehicle repair garage. Initially, a front projection dome system was considered. However this approach was not feasible due to equipment cost restrictions and long term maintenance concerns.

The final design was a rear projected cylinder with a ceiling screen as illustrated in Figure 1. Our initial specifications provided a twenty foot radius ceiling projection covering an eight foot high vertical screen. These dimensions provided a 300 degree horizontal field of view exceeding the application requirements.

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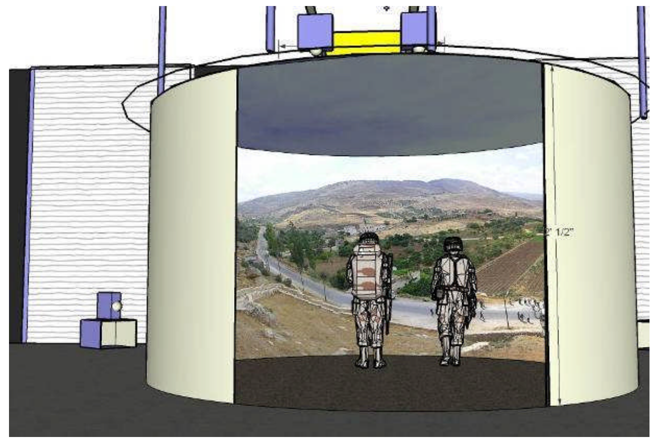

Figure 1: Rendering of final cylindrical display system to be deployed March 2006

1.1 Implementation Process

A significant project challenge involved producing the highest display resolution possible within a somewhat limited budget. To accomplish this goal, we looked to the work of University of North Carolina at Chapel Hill researchers who in the late 1990s developed high resolution displays by blending and warping imagery from multiple projectors [1]. Commercial hardware incorporating these techniques have emerged in the past several years.

Leveraging the availability of these products, we designed our final system to use eleven 1400x1050 resolution DLP projectors. Each projector is equipped with built in geometry correction and edge blending hardware. Seven projection channels provide imagery for the vertical screen and the remaining four channels provide the ceiling sky projection. Each channel connects to a single PC image generator (IG). Imagery on all IG nodes is synchronized via a master graphics client broadcasting global event changes. We chose rear projection to prevent user shadows on the large interior display surface.

The display was developed by first fabricating a small scale prototype, five foot high with an approximately 180 degree field of view (Figures 2-3). This system informed the construction of the final version by allowing us to evaluate projection throws, geometry correction, blending performance, and screen materials.

The rear projected cylinder required a highly specialized frame design. We employed the services of a mechanical design contractor to design a unique solution utilizing a rigid steel frame in combination with suspension cables positioned outside the vast projector throw areas.

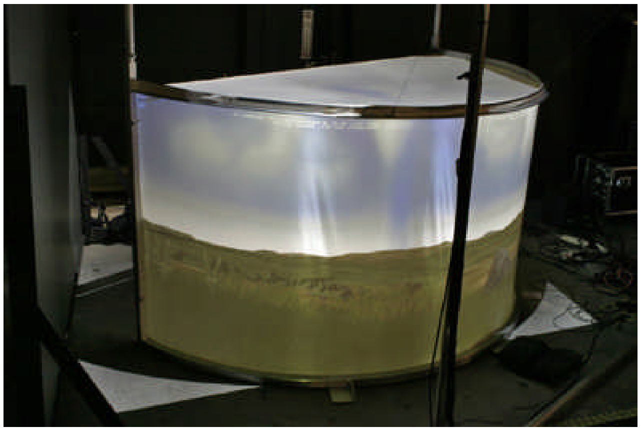

Figure 2: Rear view of small scale cylindrical display prototype with suspension cables and rigid steel frame

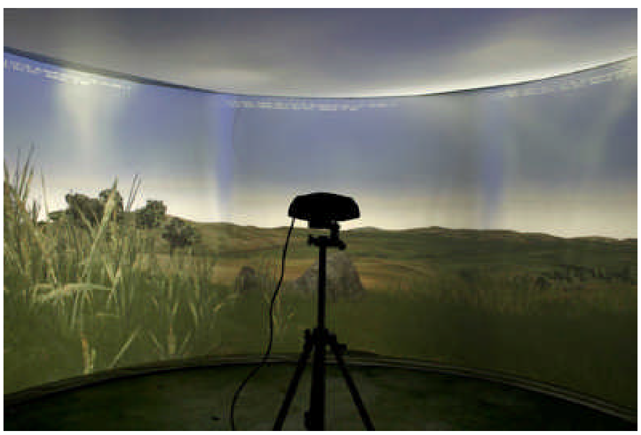

Figure 3: Interior view of small scale prototype

1.2 Project Findings

This effort highlighted the clear advantage of developing prototypes when designing new display systems. With our small scale system we immediately learned that an eight foot screen height provided an inadequate level of presence. We revised our final design by raising the screen height to twelve feet, which completely fills the user's vertical field of view when looking straight ahead.

A key project hurdle involved selecting an appropriate screen material. In addition to covering a large surface area, the screen could not be prohibitively expensive. Initial tests revealed the obvious need for screens with a relatively low gain factor. It was difficult to find a rear projection material of the size we needed without fusing together multiple vinyl segments. This process creates distracting seams in the displayed imagery. After testing several materials and contacting multiple manufacturers, we were ultimately able to identify an affordable vinyl material that could accommodate our twelve foot height and 300 degree field of view.

The construction of the full scale system will be completed in March 2006, and soldiers will begin using the system for close air support training soon afterwards. At that time, we plan to solicit user feedback on the display's effectiveness to guide the design of our future immersive systems.

2 LARGE AREA VISUALIZATION DISPLAY FROM A SINGLE COMPUTER

It is generally agreed that increasing display screen real estate increases a user's productivity and benefits collaboration and communication in classroom and meeting room environments. Until recently, it was impractical - except in very special installations - to provide more than a few screens to most computer users due to the size and cost of the displays themselves. Given recent technological and commercial advances in flat panel and projection displays however, it is suddenly becoming both financially affordable and physically possible. As such, providing large numbers of displays for group presentation environments, and even for individual users, is close to being within reach for general adoption. One limitation remains: driving multiple displays is problematic from both a hardware and application software perspective.

Figure 4: Large area visualization display at USC's Zemeckis Media Laboratory

Some systems, such as NASA Ames' "hyperwall," [2] utilize one computer per display screen, thereby overcoming the problem of bandwidth limitations. Using one computer per display screen, however, is obviously expensive and also requires that custom application software be developed to synchronize a cluster of computers.

In trying to overcome this challenge, it is instructive to realize that much of the data on a computer display changes less often than 60 times a second, thus the video channel has redundancy that can be reduced to drive more displays without increasing the channel bandwidth. For example, there is little need to update the visual data for fairly static images, such as spreadsheets, text documents, or the like, at 60 Hz. In addition, a user looking at a bank of computer displays typically concentrates on a single display at a time, thus offering an opportunity to further reduce the overall required bandwidth.

2.1 Implementation:

Our system (Figures 5-6) synchronizes the video output from a single personal computer using a freeze-frame buffer that is a standard feature of the 14 DLP projectors (NEC Model LT260K) we use. A PC routes its single video output signal to a distribution amplifier that relays the signal to the projectors. The PC then uses a USB port to convey commands to our custom-developed 'freeze box' to either freeze or un-freeze the projected video on selected projectors. In this way, a single PC can drive multiple projectors. The freeze box consists of a simple micro-controller that interfaces to the projectors via 14 remotely located infra-red LEDs which it drives to mimic standard remote-control commands - including 'freeze frame'.

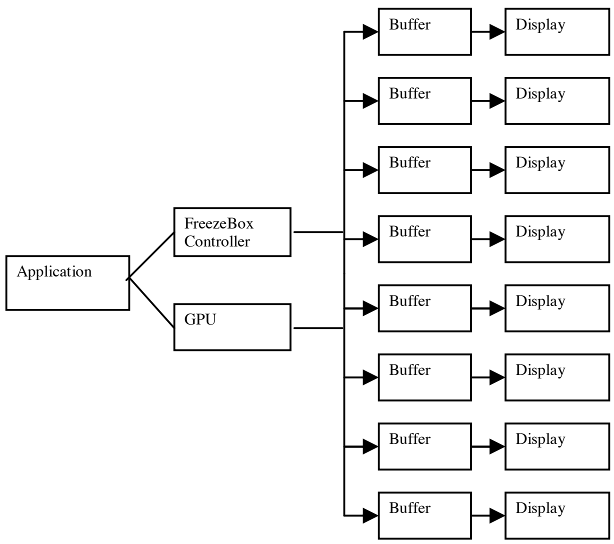

Figure 5: System architecture

For example, the PC can be programmed to sequentially display 14 full screen JPEG images, with each image displayed for 2 seconds before cycling to the next image. As it cycles between the images, a different projector is commanded to freeze its image. In this way, 14 unique images will be displayed at the end of the cycle. The 2 second delay is required to ensure proper timing given the projectors' characteristics and the open-loop control architecture.

2.2 Discussion

The system has been used for a number of applications including presenting panoramic imagery [3] and allowing for massive amounts of imagery to be simultaneously viewed. A proof of concept test with extremely detailed imagery from Clifford Ross's R1 camera system [4] was implemented and highlighted the need for such tiled systems to meet the demand of the human eye for resolution.

Although it would be interesting to pursue alternative architectures that allow for multiple applications and GPUs to directly address each display's buffer, we have been struck by the value of limiting the system to a single PC and GPU. The ease with which applications can be modified to work with the approach is quite valuable. It requires only that software be modified to drive multiple displays from a single application, rather than trying to synchronize multiple instances of an application distributed across a cluster.

3 Fast Action Wide Field of View Head Mounted Display

Humans use peripheral vision for spatial orientation and motion cues, while central vision is useful for detailed imagery and color perception. In many ways, central vision can be thought of as telling one 'what' is in an environment, while peripheral vision informs the user about the 'where' of an environment. Early HMDs focused on providing a sense of presence through the power of peripheral vision. In the quest for crisp central imagery, many modern HMDs have reduced their fields of view to the point of eliminating their ability to provide a feeling of immersion, or have grown bulky to the point of interfering with natural head motions.

Figure 6: Prototype Fast Action HMD (FAHMD)

The Virtual Technologies and Environments program at the Office of Naval Research sponsored the development of novel approaches for the design and development of Head Mounted Displays that can meet the requirements of training for close quarters battle (CQB) requirements. Such a display system must be capable of providing spatial and situational context to the soldier, thus it requires a very wide field of view that can display imagery to fill the user's peripheral vision. Additionally, CQB requires rapid head and body motions, thus demanding a very lightweight display solution and innovative mounting configuration.

Fakespace Labs and its STTR research partner USC have recently developed an HMD to meet these requirements and have just begun to qualify the capabilities and experiences that can be created with the prototype HMD called the Fast Action HMD (FAHMD).

3.1 Discussion

The FAHMD employs a canted optical approach similar to the Cyberface II [5] to achieve a 160 degree field of view. It provides a generous exit pupil that eliminates the need to adjust the IPD for different users and is light enough to allow for reasonably rapid head motions.

While we have only recently completed the prototype system, our initial experiences were significant, although strictly qualitative. The handful of users that have tried the system typically had over 10 years experience with immersive display systems and technologies. They reported a sense of presence on par or beyond that of most previous immersive system experiences.

Designing environments for the FAHMD has proven to be more difficult than expected, as the users are surprisingly finicky about what looks “right” in the environment. In many ways, we feel that the field of view is providing a sense of presence strong enough to begin to evoke reactions similar to those described by Masahiro Mori in his theory "The Uncanny Valley" [6]. As the environments get closer to “real”, users begin to relate to the virtual environment in a natural fashion, thus deviations from natural become increasingly objectionable.

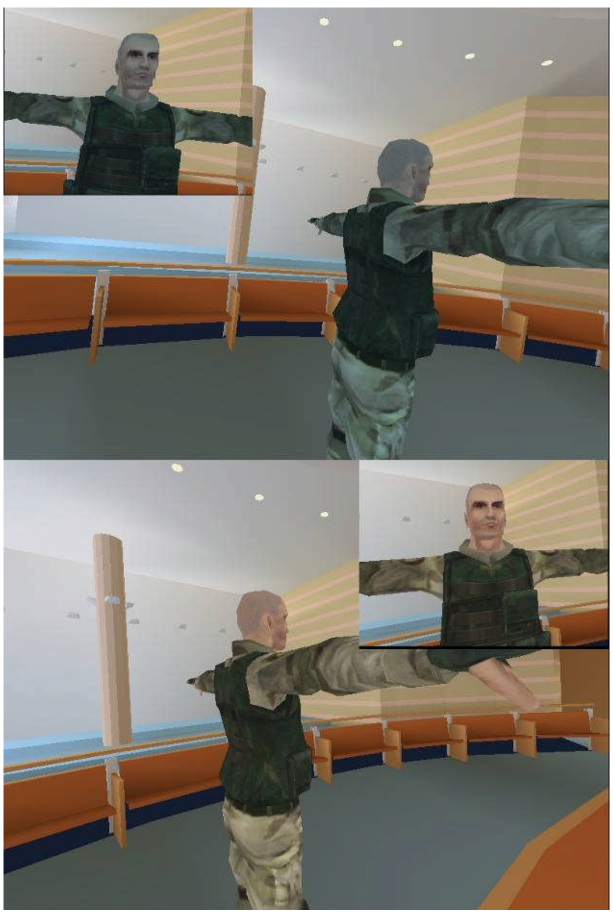

Figure 7: Virtual human models used in room lighting tests

An anecdotal example of this concerned the color of virtual human models in a room environment (Figure 7). Users commented that the color of a particular character's skin appeared too gray, and as a result the model looked like a corpse. When a graphical mask was used to crop the field of view to 60 degrees diagonal, the virtual human's tint did not immediately appear wrong. We theorize that the larger field of view was allowing the user to consider the overall lighting model of the room, with respect to which the virtual human's tint was incorrect. With the 60 degree field of view, it was not possible to be close enough to the human model and simultaneously explore the room's lighting conditions to make such an observation

We expect to begin testing how this ability to visually determine context affects a user's experience of color, size, and motion, and hope to then explore the effect on presence.

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