FLATWORLD: A MIXED REALITY ENVIRONMENT FOR SIMULATION AND TRAINING

Jarrell Pair* and Diane Piepol
Institute for Creative Technologies
University of Southern California
13274 Fiji Way, Suite 600
Marina del Rey, California 90292
Phone: +1-310-574-7818
E-mail: pair@ict.usc.edu, piepol@ict.usc.edu,

ABSTRACT

The FlatWorld project at the University of Southern California’s (USC) Institute for Creative Technologies (ICT) is developing a virtual reality environment which allows users to walk and run freely among simulated rooms, buildings, and streets. The system integrates Hollywood set construction techniques with state of the art computer graphics and immersive display technology. FlatWorld provides a powerful, flexible tool for experiential simulation and training. The system is cost effective, and its architecture is upgradeable allowing the incorporation of new virtual reality technologies as they become available.

1. INTRODUCTION

This project merges the art of cinematic stage production with the science of virtual environment design. In film and theatrical productions, sets are constructed as modular components called “flats”. Using flats, set designers strive to produce actual physical, tangible structures that convey a sense of place or activity. (See Figure 1) Virtual environment designers seek similar results using electronic displays and programmable 3D graphics.

Current virtual environments have severe limitations that have restricted their use. For example, users are often required to wear bulky head mounted displays that restrict a person’s freedom to physically move as they would in the real world. Furthermore, a person cannot touch or feel objects in the virtual world.

1.1 A New Approach: The Digital Flat

FlatWorld is pursuing a research and development program that addresses these limitations by creating a system of “digital flats” along with customized training scenarios. A digital flat is effectively a large screen display. A single digital flat has the ability to appear as an interior room wall or an exterior building face. When physical props are used in conjunction with digital flats, doors and windows can be simulated. Users can touch and open these portals to view an exterior virtual world. Because of their modular characteristics, several digital flats can be rapidly assembled in any open space to simulate multiple situations in a variety of geographic locations. This approach of using physical props within a virtual environment creates a “mixed reality” world where the physical and the virtual seamlessly coexist.

2. RELATED WORK

FlatWorld fuses together two somewhat established capabilities – one is the practice of building stages and theatrical sets (stagecraft) and the other is the development of interactive virtual environments. Each area has limitations that FlatWorld addresses. The following activities are relevant to some portion of the overall research and development problems FlatWorld presents.

Figure 1: Traditional Hollywood Flat at Paramount Studios
2.1 Theme park attractions

Though they are not interactive experiences, recent theme park attractions illustrate the effective use of many of the key technologies and techniques used in the FlatWorld project.

The “Terminator 2 3D” attraction at the Universal Studios parks is regarded by many as one of the most impressive uses of stereoscopic 3D cinema in the world. Traditional film projection is used in tandem with theatrical lighting to transform building walls into windows providing a view of a stereoscopic 3D world. A 24+ channel spatial audio system enhances the immersive effect.

The “Amazing Adventures of Spiderman” ride at Universal Studios Islands of Adventure in Orlando, Florida illustrates how stereoscopic projection screens can be used to convincingly simulate alleys and urban corridors. The screens are tightly integrated with physical building facades, props, and other scenery. Both Terminator 2 3D and the Spiderman attraction illustrate how the borders between the physical and the virtual elements of a scene can be blurred.

2.2 Immersive Projection Systems

Since the early 1990’s, virtual environments researchers have built immersive display systems consisting of multiple front and rear projection screens. The most well known system is called the CAVE (CAVE Automatic Virtual Environment), initially developed at the University of Illinois-Chicago’s Electronic Visualization Laboratory (Cruz-Neira et al., 1993). The CAVE and other immersive projection systems provide users with a wide field of view, but they can prevent a person from moving about the scene freely.

2.3 Commodity Based Virtual Reality Systems

High performance PC graphics accelerators and digital projectors have recently become available at very affordable prices. Researchers are now able to build extremely high performance multi-node, projection-based virtual environment systems at a relatively low cost. For example, The NAVE (Non-expensive Automatic Virtual Environment) project at the Georgia Institute of Technology illustrated how a three screen stereoscopic immersive virtual environment could be built for under $60,000.00 (Pair et al., 2000). Stanford’s WireGL architecture has demonstrated how commodity PC’s can be clustered into a powerful, multi-node real-time graphics rendering system (Humphreys et al., 2001).

2.4 “Smart” Rooms

Work at the Massachusetts Institute of Technology (MIT) Media Lab in perceptually aware computing has explored the concept of “smart” rooms (Maes et al., 1995). These systems use computer vision and other sensing techniques to create projected virtual environments within physical spaces which react to a user’s actions. The “KidsRoom” project is of particular relevance to FlatWorld because of its use of story driven, educational content.

Using images, lighting, sound, and computer vision action recognition technology, a child's bedroom was transformed into an unusual world for fantasy play. Objects in the room became characters in an adventure, and the room itself actively participated in the story, guiding and reacting to the children's choices and actions. Through voice, sound, and image the KidsRoom entertained and provoked the mind of the child. The children's positions and actions were tracked and recognized automatically by computer and used as input for the narration control system. Computer vision techniques were tightly coupled to the narrative, exploiting the context of the story in determining both what needed to be seen and how to see it. Moreover, the room affected the childrens' behavior (e.g. coaxing them to certain locations) to facilitate its own vision processes (Bobick et al. 1996).

2.5 Projected Textures/Projection-Based Augmented Reality

At the University of North Carolina (UNC) Chapel Hill, researchers have been using video projectors to create color and limited geometric detail on simple or arbitrary surfaces (Raskar et al., 1998, 2001). Effectively, the projector paints synthetic textures on rudimentary physical objects. The challenge presented is to simulate color and geometry on surfaces that have neither of these properties. Projected texture research is often categorized into the broader field of augmented/mixed reality that deals with the integration of artificial objects into real scenes. Notable work in this area is seen in the “Being There” project (Low et al., 2001). Projectors transform flat Styrofoam panels into brick walls with windows and doors.
3. FEATURES AND TECHNOLOGIES

FlatWorld is far more than a multi-screen visual display system. The system creates a multi-sensory experience in a space that allows the user to move and interact in a free and natural manner. This approach to immersive simulation leverages a variety of technologies that enhance the user’s experience and perception of the environment.

Wide-area (rooms – building – city block) mixed reality simulation: Single rooms, entire building interiors, and city streets can be simulated using multiple digital flats. The mechanical design of individual digital flat units will emphasize modular scalability. By installing duplicate hardware, a room sized simulation environment can be expanded to simulate an entire building. The first generation digital flat was built by projecting wall textures and stereoscopic, real-time 3D imagery onto rear projection screens. A second-generation digital flat could use electronic ink or organic LED (OLED) technology.

Haptic features of barriers and portals: In FlatWorld, physical props such as real doors, tables, windows, and chairs coexist with virtual objects. These real structures and props are utilized in conjunction with digital flats to present trainees with physical objects they can touch, open, and close.

Transportability: The FlatWorld system will be designed to enable rapid physical and electronic setup. The system can be dismantled, packed, and moved among multiple sites.

“Smart” sensing spaces: By using a variety of electro-mechanical and optical sensing devices, the FlatWorld system is perceptually aware of a user’s actions, and it can respond accordingly. For example, characters and vehicles in the simulated world can react to a person opening a door. Similarly, if a trainee opens a window during a simulated rainstorm, a sensor can trigger a fan, providing the sensation of a fierce wind.

Flexible range of realistic, programmable environments: A variety of geographic locations and environmental conditions can be simulated using real-time 3D graphics. Users can view and interact with these locations through doors, windows, and other portals simulated with digital flats.

Group participation at one or more distributed sites: FlatWorld will ultimately incorporate distributed simulation capabilities. Multiple FlatWorld sites could be linked for large-scale training exercises.

Cost Effective Components: Wherever possible, the FlatWorld system exploits low cost, common off the shelf technology (COTS). For example, PC-based graphics technology drives the imagery presented on each digital flat.

Immersive Audio Technology: Audio is an important component of an effective interactive virtual environment (Davis et al., 1999). The FlatWorld system supports a number of immersive audio features. A real time audio effects programming interface allows virtual environment designers to attach sounds to graphic entities. The spatial positions of sounds are synchronized with the position of their associated graphical objects. The programming interface is capable of reproducing real world phenomena including reverberation and doppler effects. Sensory immersion is further augmented by strobe lighting and tactile floor speakers which simulate the flashes and vibrations of explosions and lightning storms.

4. CURRENT PROTOTYPE SYSTEM

In November 2001, a single room prototype FlatWorld system was constructed in a two thousand square foot warehouse near the Institute for Creative Technologies.

The prototype system consists of two digital flats and two real walls. Movable door, window, and broken wall props can be used to reconfigure the room’s appearance. (See Figures 2-6) The physical walls and props were constructed by Paramount Studios. A basic demonstration was developed to illustrate the system’s key features and capabilities. The demo utilizes real time stereoscopic graphics, immersive audio, and a number of other effects in conjunction with a movable set of physical props. Since November 2001, we have shown the system to over 200 visitors.

Imagery for each digital flat is provided by a custom stereoscopic rear projection system. (See Figure 5) Digital projectors are mounted with passive polarizing filters and driven by Pentium 4 PC’s equipped with NVIDIA graphics accelerators. The system’s real time audiovisual content was developed using OpenGL and the DirectSound3D programming library. Strobe lights, overhead fans, and other multi-sensory effects devices are controlled using the X10 home automation protocol.
5. CONTENT DEVELOPMENT

In creating content for the FlatWorld environment, we intend to borrow techniques used in the gaming industry where appropriate. For example, in a first person 3D game, the extent of the virtual world is often intentionally restricted. To optimize the computer’s rendering capabilities, the outside environment viewed through a window or other portal is not fully modeled. This technique presents a problem. If a player were to wander into this exterior world, they would find themselves trapped in a partially rendered space consisting of incomplete polygonal structures and partially applied textures.
Similarly, in FlatWorld, we must prevent users from walking into the projected virtual environment through the physical door and window props. Otherwise, users could find themselves colliding into the digital flat’s rigid rear projection screen. By looking to game design, we are presented with a possible solution. From games we learn that collision detection, story parameters, and blocking enemies can be used to restrict a player’s movement. These techniques can prevent players from walking into a half-rendered void, in the case of a 3D game, or a rigid projection screen, in FlatWorld’s context.

However, FlatWorld scenarios are not simply video games shown on a large screen. The system’s distinctive characteristics demand the development and testing of specialized software and computer generated content. In games, the user interacts using a keyboard, joystick, or other device. In contrast, FlatWorld users interact with physical objects as they would in the real world. To view an exterior virtual scene, the user touches and opens a real window. The FlatWorld experience emerges from the integration of smart sensors, physical props, projected walls, immersive audio, and stereoscopic visuals. These features are coupled with the user’s ability to physically walk or run.

6. FUTURE WORK

The FlatWorld system architecture can easily incorporate hardware and software enhancements. We plan to upgrade the system’s components as new immersive technologies and display solutions become commercially available.

6.1 New Display Technologies

We have considered developing a second-generation digital flat using an emerging display technology such as electronic ink or organic LED’s. This type of flat would eliminate the need for projector beam throw distances, an inconvenience inherent in digital projection based flats.

Initially developed at the Massachusetts Institute of Technology, electronic ink promises to provide paper-thin display surfaces using micro-droplets. The theoretical maximum resolution of electronic ink is very high making it a potential flexible display material for use in digital flats. Based on discussions with other researchers, organic LED (OLED) technology could emerge as another ideal digital flat display technology. OLED’s have the fast response time and high resolution needed to support real-time 3D graphics display. If tiled, OLED display segments could create a wall-sized digital flat.

6.2 Graphics, Sound, and Tracking

In a FlatWorld simulation, the virtual environment’s graphics must be extremely convincing. Otherwise, FlatWorld’s mixed reality illusion fails and the system’s effectiveness is significantly reduced.

By collaborating with researchers at the Institute for Creative Technologies (ICT) Graphics Lab, we plan to incorporate recently developed photo-realistic rendering techniques into the FlatWorld software infrastructure. For example, we are planning to develop a real time rendering system which utilizes image based and pre-computed global illumination lighting techniques. Our goal is to create FlatWorld virtual environments which are indistinguishable from their real world counterparts.

We also intend to enhance the FlatWorld immersive audio system. Our current one room prototype will be modified to utilize components of a 10.2 channel audio system used in other ICT projects. The enhanced system will be capable of creating highly convincing threedimensional audio effects that vary based on the user’s position and orientation.

Accurate stereoscopic viewing requires position tracked camera perspectives for all users. Currently, there are no widely accepted solutions for providing tracked stereoscopic imagery for more than two individuals. We plan to investigate and prototype the use of new display and tracking technologies that could provide unique stereoscopic viewpoints to several FlatWorld users.

6.3 Expanded Modular Prototype

As the project progresses, we are aiming to expand our prototype system to simulate a multi-room space with both interior and exterior environments. (See Figure 7)

We intend to fabricate the system’s components as a series of modular units to enable rapid physical and electronic setup. As needed, it could be dismantled, packed, and moved among multiple sites in a relatively short period of time.
7. CONCLUSION

FlatWorld provides a powerful, flexible tool for experiential simulation and training. The system is cost effective and upgradeable. Most importantly, FlatWorld creates an immersive simulation in which the entire body is engaged in a space where a person can move freely and touch physical objects seamlessly integrated into an interactive virtual environment.

ACKNOWLEDGEMENT

This paper was developed with funds of the Department of the Army under contract number DAAD 19-99-D-0046. Any opinions, findings and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the Department of the Army.

REFERENCES


