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FlatWorld: Combining Hollywood Set-Design Techniques with VR

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Despite notable advances over the past decade, current virtual reality systems have numerous drawbacks. For instance, head-mounted displays are hindered by their limited field of view and restrictive cables. The CAVE[1] and other immersive projection systems provide users with a wide field of view, but they can prevent a person from moving about a scene freely, and they often present only a completely virtual scene.

The FlatWorld project at the University of Southern California's Institute for Creative Technologies seeks to overcome these limitations by exploring a new approach to virtual environments (VEs) inspired by Hollywood set-design techniques. Since the dawn of the film industry, movie sets have been constructed using modular panels called *flats*. Set designers use flats to create physical structures to represent various places and activities. For example, we could configure a flat to appear as a room wall, a storefront, or a doorway.

FlatWorld is developing a reconfigurable system of *digital flats*. Using large-screen displays and real-time computer graphics technology, a single digital flat can appear as an interior room wall or an exterior building face. We can also add functional doors and windows to digital flats by constructing physical props that fit and function in the flat system. For example, by placing a doorframe prop in front of a digital flat, a user can open a real door to view a computer-generated view of the world outside (see Figures 1 and 2).

FlatWorld provides a powerful, flexible tool for experiential education, training, and entertainment. The system is cost effective and its architecture is modular, letting us incorporate new VR technologies as they become available. Most importantly, FlatWorld creates an immersive simulation in which a person's entire body is engaged in a space where they can move freely and touch physical objects seamlessly integrated into an interactive VE.

Our approach

The FlatWorld approach creates a mixed reality, blurring the borders between a scene's physical and virtual elements. Recent theme park attractions successfully employ this technique. For example, the "Amazing Adventures of Spiderman" attraction at Universal Studios Islands of Adventure in Orlando, Florida, uses stereoscopic projection screens tightly integrated with physical building facades, props, and other scenery. The props and screens successfully simulate a cityscape, complete with deep alleys and vast building corridors.

Other related work includes the "Being There" project[2] at the University of North Carolina at Chapel Hill. In this system, researchers have arranged walls of white Styrofoam blocks to reproduce a room's basic layout. Imagery is front projected onto the Styrofoam blocks, making these surfaces appear as textured walls with virtual windows and doors. Although users can view exterior scenes through doors and windows, there are no functional props that let them be physically opened or closed.

1 Two digital flats simulating plaster walls in conjunction with real table, window, and door props create a virtual room.

Key features and technologies

FlatWorld incorporates more than a multiscreen visual display system. The system creates a multisensory experience in a space that lets the user move and interact freely

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and naturally. This approach to immersive simulation leverages various technologies that enhance the user's experience and perception of the environment:

- *Scalable wide-area simulation*. Digital flats are modular units that we can assemble in any open area to simulate complex interior and exterior spaces. We can create single rooms, entire building interiors, or city streets using multiple digital flats. By installing additional modules, we can expand a room-sized simulation environment to simulate an entire building. Users can walk or run naturally through these simulated spaces.
- *Combining real and virtual elements*. In FlatWorld, physical props such as real doors, tables, windows, and chairs coexist with virtual objects presented on digital flats. The props present users with physical objects they can touch, open, and close (see Figures 1 and 2).
- *Stereoscopic display*. Each digital flat can display high-resolution stereoscopic imagery (see Figure 3). A 3rdTech HiBall wide-area tracking system provides corrected stereoscopic views for individual users.
- *Reconfigurable*. By interchanging props and digital imagery, we can quickly transform a FlatWorld simulation's appearance. For instance, we can replace a doorframe with a broken concrete prop to create a simulated crumbling wall (see Figures 4 and 5, next page).
- *Immersive sound*. Audio is a critical component of an effective interactive VE. The FlatWorld system supports several immersive audio features. A real-time audio effects programming interface lets VE designers attach sounds to graphic entities. Consequently, the spatial positions of sounds are synchronized with the position of their associated graphical objects. The system can also create reverberation and Doppler effects.
- *Sensory effects devices*. We augment sensory immersion with strobe lighting and tactile floor speakers that simulate the flashes and vibrations of explosions and lightning storms. We can activate a ceiling-mounted fan to provide the sensation of wind gusts from open doors or windows.
- *Smart sensors*. By using electromechanical sensing devices, the FlatWorld system is aware of a user's actions, letting the system respond accordingly. For example, characters and vehicles in the simulated world can react to a user opening a door. Similarly, if a person opens a window during a simulated rainstorm, a sensor can trigger a fan, providing the user with the sensation of a fierce wind.

2 Users view the exterior virtual world through a physical door or window.

3 FlatWorld uses stereoscopic graphics to provide a compelling sense of depth. Objects can even appear to pop out of the screen and float in the middle of the room. (Simulated image.)

High-performance PC graphics accelerators and digital projectors are available at affordable prices. Researchers are now able to build extremely high-performance, multinode, projection-based VE systems at a relatively low cost. Wherever possible, the FlatWorld system exploits low-cost, commercial, off-the-shelf technology. PC-based graphics technology provides the imagery presented on each digital flat, and the passive polarized stereoscopic display system uses standard conference room projectors.

Proof of concept system

We completed construction of a single-room FlatWorld system in November 2001 in a small warehouse space

4 **Using interchangeable props, we can quickly transform a space.**

5 **Broken concrete props and digital flats simulate crumbling room walls.**

near the Institute for Creative Technologies in Marina del Rey, California. This prototype consists of two digital flats and two real walls (see Figures 1 and 2). Movable door, window, and broken-wall props can reconfigure the room's appearance (see Figures 4 and 5). The physical walls and props were constructed by Paramount Studios. The 3/4-inch thick acrylic rear projection walls were fabricated by the Stewart Filmscreen Corporation.

We also developed a demonstration scenario to illustrate the system's key features and capabilities. The demo uses real-time stereoscopic graphics, immersive audio, and numerous other effects in conjunction with a movable set of physical props. Since November 2001, we've shown the system to more than 200 visitors.

A custom stereoscopic rear-projection system provides imagery for each digital flat. Digital projectors are mounted with passive polarizing filters and driven by Pentium 4 PCs equipped with Nvidia graphics accelerators. We developed the system's real-time audio–visual content using OpenGL and the DirectSound3D programming library. Strobe lights, overhead fans, and other multisensory effects devices are controlled using the X10 home-automation protocol.

Applications

Our single-room prototype illustrates the viability of the FlatWorld approach to immersive simulation. An expanded version of this prototype could be appropriate for a number of educational and training applications. For example, FlatWorld could offer museums a wide range of applications such as an array of historic places and events:

- *An ancient Roman villa*. Visitors could walk onto a real balcony to view a photorealistic recreation of ancient Rome bustling with people and activity.
- *Benjamin Franklin's laboratory*. While peering through actual windows, visitors could interact with a virtual Benjamin Franklin as he conducts his famous lightning experiment on a nearby hilltop.
- *The Wright Brothers' workshop*. Museum patrons could open windows and doors to view Wilbur and Orville conducting flight tests on the dunes of Kitty Hawk.

FlatWorld also has potential applications for simulation and training. Digital flats are an ideal VE technology for training groups of security and emergency services personnel. They're capable of presenting a variety of training scenarios based on decision-making tasks. Several digital flats could even simulate close quarters, building interior spaces in which groups of trainees could freely run or walk.

Future directions

We plan to upgrade FlatWorld system components as new immersive techniques and display solutions emerge. For example, our first-generation digital flat was built by projecting wall textures and stereoscopic, real-time 3D imagery onto rear-projection screens. A future digital flat could use organic LED (OLED) or another flat-screen display technology that would reduce or eliminate the rear-projector throw distances—an inconvenience inherent in our current digital-flat implementation.

In a FlatWorld simulation, the VE'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 Graphics Lab, we plan to incorporate recently developed photorealistic rendering techniques into the FlatWorld real-time graphics software infrastructure. Our goal is to create FlatWorld VEs that are indistinguishable from their real-world counter parts.

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

In the future, we aim to expand our prototype system to simulate a multiroom space with both interior and exterior environments. We intend to fabricate the system's components as a series of modular units to enable rapid physical and electronic setup. Our goal is a system that could be dismantled, packed, and moved among multiple sites. ■

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