AUGMENTING MUSEUM EXPERIENCES WITH MIXED REALITY

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ABSTRACT

Current Mixed Reality experiences focus primarily on training, design and entertainment. This paper presents a very different application, scientific virtualization and its use in informal education. Specifically, we describe a case study that extends an existing museum dinosaur exhibit to include an encounter with ancient sea life. The real world assets and environment are augmented and, in some cases, occluded by the virtual entities that inhabited the seas at the time of the dinosaurs. Achieving this blending of the real and virtual motivated the development of novel real-time computer graphics algorithms and distributed simulation protocols, as well as new conventions in the creation and production of non-linear MR experiences.

KEYWORDS

Mixed Reality, Collaborative Environments, Informal Education

1. Introduction

A Mixed Reality (MR) experience is one where the user is placed in an interactive setting that is either real with virtual asset augmentation (augmented reality as seen in Figure 1), or virtual with real world augmentation (augmented virtuality as seen in Figure 2) [1], [2]. Additionally, in the model proposed in [3], the underlying story must draw on the user's imagination. This latter requirement is needed if the experience is to leave a lasting impression, as is required in training and education.

Most MR experiences are, to date, about the visual domain, with the principal differentiation being between optical [4] and video [5] see-through displays. The primary scientific and technical issues center on tracking, registration and rendering.

Our emphasis is, however, on building multi-sensory, non-linear experiences. Our goal is to give as much attention to the audio, olfactory and tactile senses as to the visual. The current reality, however, is that our experiences achieve a balance between only the audio and visual senses; the worlds we describe here have less of an emphasis on touch and smell. We do, however, include special effects, such as water vapor to simulate steam and smoke, and servo-mechanisms to cause objects to act as if they have been hit, for instance by being bumped by a virtual character.

(a) Real setting

(b) Augmented reality

Figure 1. MR MOUT

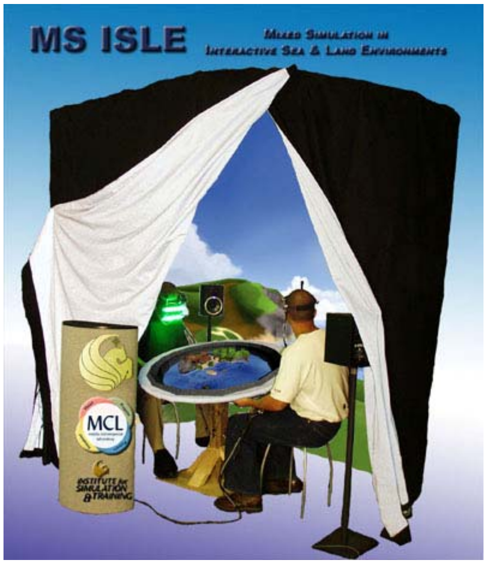

Figure 2. MS ISLE:
Collaborative Augmented Virtuality

2. Underlying Science and Technology

2.1 Visual

The visual blending of real and virtual objects requires an analysis and understanding of the real objects so that proper relative placement, inter-occlusion, illumination, and inter-shadowing can occur. In the system we describe here, we will assume that, with the exception of other humans whose range of movement is intentionally restricted, the real objects in the environment are known and their positions are static.

Other research we are carrying out deals more extensively with dynamic real objects, especially in collaborative augmented virtuality environments. Note, for instance in Figure 2 that two people are sitting across from each other in a virtual setting; each has a personal point-of-view of a shared virtual environment, and each can see the other. In this case, we are using unidirectional retro-reflective material so each user can extract a dynamic silhouette of the other [6]. These silhouettes can be used to correctly register players relative to each other, and consequently relative to virtual assets.

The primary visual issues addressed in this paper and of relevance to our museum application are: (a) lighting of real by virtual and *vice versa*, and (b) shadowing of virtual on real and *vice versa*. The details of the real-time algorithms our colleagues and we have developed appear in other papers [7], [8], the latter of which is in part based on [9]. Here we will just note that each real object that can interact with virtual ones has an associated phantom or occlusion model. These phantoms have two purposes. When used as occlusion models, invisible renderings of phantom objects visually occlude other models that are behind them, providing a simple way to create a multi-layered scene; e.g., the model of a sea creature is partially or fully hidden from view when it passes behind a display case. When used for lighting and shadows on real objects, these phantom models help us calculate shading changes for their associated pixels. Thus, using them, we can increase or decrease the effects of lights, whether real or virtual on each pixel.

The specific algorithms we have developed can simply and efficiently run on the shaders of modern graphics cards. It is this GPU implementation as well as careful algorithm design that allow us to achieve an interactive frame rate, despite the apparent complexity of the problem [10].

Figure 4 shows a virtual flashlight directed at several virtual artifacts. The virtual objects are lit by the flashlight and the real box is both lit by the flashlight and darkened by the shadows cast from the virtual teapot and ball. For this simple demonstration, we tracked the box, the "hot spot" on the table and the cylinder using ARToolkit, an image-based tracking system **Error! Reference source not found.**. In general, though, our preferred tracking method is acoustical, with physical trackers attached to movable objects.

Figure 3. Virtual flashlight illuminating
virtual/real objects

Viewing these scenes can be done with a video see-through HMD, a Mixed Reality Window (a tracked flat screen monitor that can be reoriented to provide differing points-of-view) or a Mixed Reality Dome. While the HMD is more flexible, allowing the user to walk around an MR setting, even staring virtual 3d characters in the eye, it is more costly and creates far more problems (hygiene, breakage, physical discomfort) than the MR Window or Dome. Both the MR Window and Dome require an added navigation interface (e.g., control buttons and/or a mouse), since neither is moveable, unlike the HMD whose user can walk around, somewhat freely (observe the minor restrictions imposed by the ceiling tether in Figure 1 (a)). The Window is more flexible than the dome, in that it can be physically reoriented, but it lacks the convenient audience view and the sense of immersion (both visual and auditory) of the Dome. As a consequence, the museum exhibit we describe uses the MR Dome.

2.2 Audio

Ambient audio is an important part of providing a sense of immersion in any interactive simulation. Unfortunately, the standard approach of using sound effects libraries rarely yields believable results due to the lack of spatial depth and acoustic reality.

Our approach to ambient capture utilizes novel techniques in surround sound recording. In creating the ambient audio for MR MOUT (Mixed Reality Military Operations in Urban Terrain depicted in Figure 1), a multi-modal immersive training simulation, we developed a technique whereby two stereo microphones were positioned to record four discrete channels of audio. The stereo microphones were placed back to back in an XY configuration with each capsule in a cardioid pattern (Figure 4).

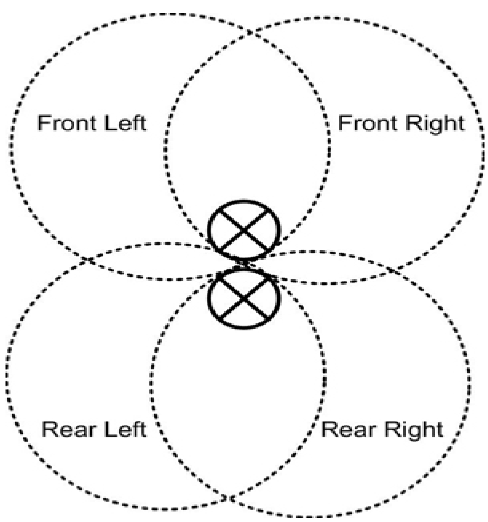

Figure 4. Back-to-back XY surround capture

An acoustic environment similar to the physical set for MR MOUT was located and ambient sounds were captured at several different times of day. This method captured the directional subtleties caused by the unique acoustical signature of the environment and thus produced realistic results when played back through the 7.1 lower tier surround sound installation at the MR MOUT site.

This approach, while unique in MR environments, is commonly used for non-directional capture in major motion picture production. The practice is called the recording of “silence” in order to provide both realistic acoustical presence and continuity to a film. In reality, there is never true silence. The recording of the acoustical signature of the space is able to provide a neutral and consistent background to put into context the disjointed cuts and effects that are introduced from synthesized or pre-recorded sounds.

Adapting this process for MR SEA CREATURES was a challenge as the primary activity is underwater. To capture underwater ambience requires the use of “hydrophones” – hermetically sealed transducers. Hydrophones can be used in any form of underwater environment.

We made a custom designed “XY” mount to position four hydrophones that enable us to capture four discrete channels of audio for surround sound play back. Ocean ambience was captured at New Smyrna Beach, Florida using a multi-channel mobile recording unit. The turbulence created by crashing waves made for a realistic ambience that closely matches the violent seas of the Cretaceous period. We captured additional sound effects by moving objects through a swimming pool past the underwater hydrophones.

2.3 Production Pipeline

While creating the Timeportal MR experience for SIGGRAPH 2003 (Figure 5), our team devised a Mixed Reality Production Pipeline for developing content for scenarios. Taking our cue from the pipeline used in the film industry, we devised a system that allows both the artistic team and the programming team to move forward in parallel steps, going from the concept to the delivery of a Mixed Reality scenario.

Figure 5. Timeportal at SIGGRAPH 2003

The process starts with the written story and a rapidly produced animatic. The animatic is a simple visual rendering of the story from a single point-of-view. Its purpose is to communicate the vision of the creative team. This allows the art director, audio producer and lead programmer to effectively exchange ideas and determine each team's focus.

Once the animatic is presented and the behaviors are agreed upon, the artists can begin creating high quality virtual assets (CG models, textures, animations, images, and videos). Concurrently, the programmers implement a first-cut virtual experience using the preliminary models developed for the animatic. Similarly, the audio producer creates and/or captures appropriate ambient, 3d and point-source sounds. Typically these tasks take about the same amount of time to produce as does the development of the professional quality virtual assets.

The next step is to enhance the virtual world with the new artistic creations, producing a purely virtual version of the scenario. This is where we view and hear the scene from many angles and positions. Using this "bird's eye view" provides us with the equivalent of a virtual camera that can move around the environment in real-time to see every aspect and interaction point in the scenario. This allows the teams to see problems and solve them now, rather than after the full MR experience is created. The content and story are evaluated and decisions are made that improve the scenario's playability. The art, audio and programming teams then continue to work on their respective areas addressing the issues that were raised at this stage.

The next step is the interactive scenario. This is a version of the scenario implementation, which is interactive and non-linear, but is still completely virtual. All assets are being finalized. This is the final step in making minor changes and tweaks to the story and technology.

The last step is integration. If all of the previous stages have been followed, there should be no major surprises. This is the step in which the entire team needs to be involved, from the programmers to the artists to the audio engineers. All the pieces (audio, graphics, special effects and story) of the Mixed Reality scenario come together now.

2.4 Story Delivery

A newer version of the Mixed Reality System reported in [6] is our delivery platform. This consists of many components, such as graphics, physics, behavior, audio, special effects, and story engines (Figure 6). Each of these controls a different part of the overall MR System. The story engine, in consort with a story script, is the most important component of the MR system, as it is the one that controls the story, the behaviors of agents, and communicates semantic-based actions to each of the other engines.

The key technologies used in the MR System are Open Scene Graph and Cal3D for graphics, Port Audio for sound and a DMX chain for talking to special effects devices. Our network protocol is built on top of TCP/IP. Authoring of stories is done in XML, with a visual interface that allows non-technical members of the team to create and edit scripts, although the rudimentary nature of our current system still means that the programmers must be available as consultants, debuggers and fine-tuners. Hopefully, we will break that dependency by the end of this year.

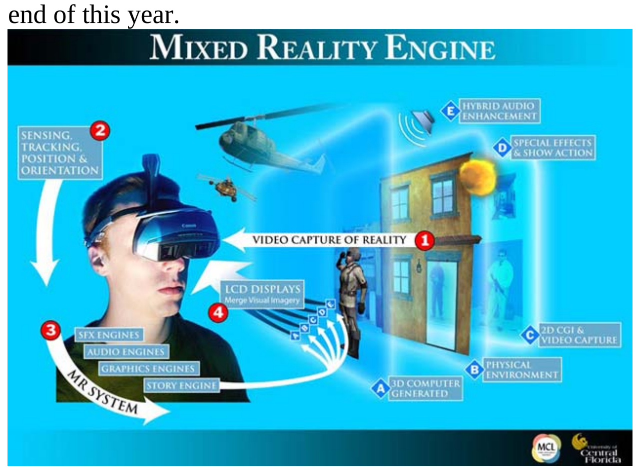

Figure 6. MR Engine diagram

The MR System can run stand-alone (one user) or in combination with multiple MR Systems (each managing one or more users). Thus, the system can be configured for collaborations. In this context, users see each other as real people in a common setting, while interacting with virtual characters and objects.

3. MR Sea Creatures

The experience begins with the reality of the Orlando Science Center's DinoDigs exhibition hall – beautiful fossils of marine reptiles and fish in an elegant, uncluttered environment. As visitors approach the MR Dome, a virtual guide walks onto the screen and welcomes them to take part in an amazing journey. While the guide is speaking, water begins to fill the "hall" inside the dome. As it fills, the fossils come to life and begin to swim around the pillars of the exhibit hall! The dome fills with water and visitors experience the virtual Cretaceous environment (Figure 7). The visitors will be able to navigate a Rover through the ocean environment to explore the reptiles and fish. The viewing window of the Rover is what the visitor sees in the Heads-Up Display (upper right corner of Figure 8) of the MR Dome.

Figure 7. Cretaceous life at Orlando Science Center

As the experience winds down, the water begins to recede within the dome, and the unaugmented science center hall begins to emerge again. At about the point where the water is head high, a pterodactyl flies overhead, only to be snagged by a tylosaur leaping out of the water. (Fgure 8) Holding the pterodactyl in its mouth the tylosaur settled back down to the ocean floor. When all the water drains, the reptiles and fish return to their fossilized reality at their actual locations within the hall. A walk into the exhibit space (the real exhibit) will reveal that the tylosaur was trapped in time with the pterodactyl in its mouth. This connection of the MR experience back to the pure real experience is intended to permanently bond the experiences together in the visitor's mind.

Figure 8. Tylosaur captures a pterodactyl

The purpose of an informal education experience is to inspire curiosity, create a positive attitude toward the topic, and engage the visitor in a memorable experience that inspires discussion long after the visit. One of our research initiatives is in creating Experiential Learning Landscapes, where the currently harsh boundaries between learning in the classroom, learning at a museum, and learning at home become blurred. MR SEA CREATURES is our first MR museum installation intended for this purpose. We have, in fact, already experimented with a non-MR installation that supported extended experiences to the home and school [12]. Its success, though on a small scale, has helped to strengthen our convictions.

4. Conclusions

There are clearly many problems remaining in MR, especially in the areas of user interfaces, rendering, registration, audio, olfactory, haptics and story creation/delivery. We attack all of these, with a particular emphasis on multimodal interfaces, real-time rendering, MR audio and a continuing effort to create an easier-to-use, more robust authoring and delivery system.

However, science and technology, while central to our research agendas, are not the ultimate product that we aspire to deliver. Our goal is to help support the maturation of wise, not just smart children. We firmly believe that experiential learning is necessary to make this leap. Such experiences need to be safe, but full of impact, as in walking through a virtual forest whose health is dependent upon your establishing intelligent forest management policies [13].

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