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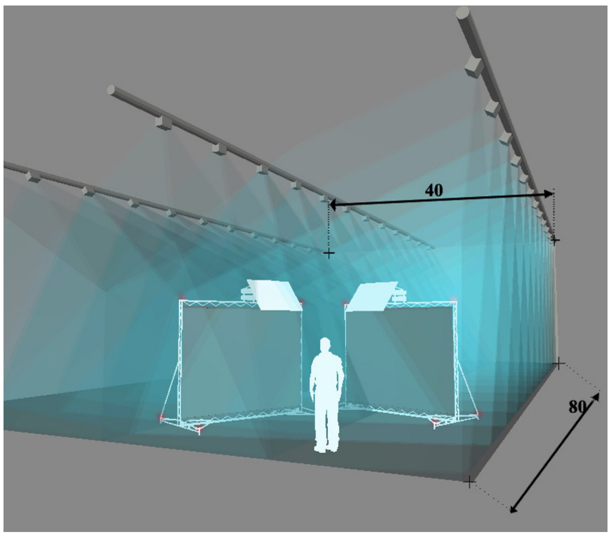
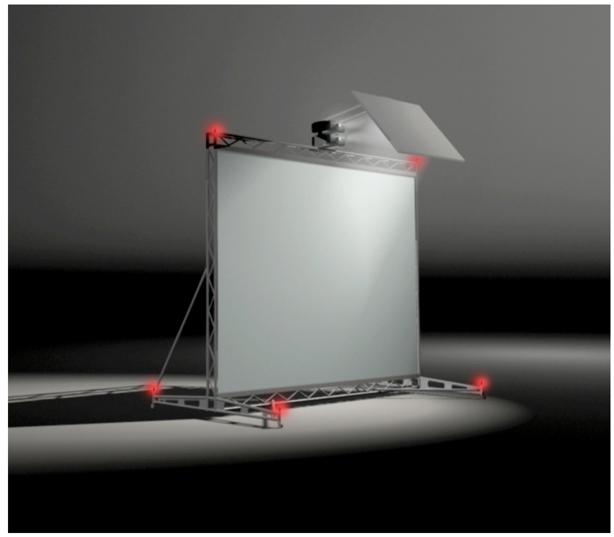
Sharing and Stretching Space with Full Body Tracking

David M. Krum Diane Piepol Mark Bolas
University of Southern California
Institute for Creative Technologies
13274 Fiji Way
Marina del Rey, CA 90292
krum@ict.usc.edu piepol@ict.usc.edu bolas@ict.usc.edu





ABSTRACT
New opportunities emerge when mixed reality environments are augmented with wide field of view displays and full body, real-time tracking. Such systems will allow users see a correctly tracked representation of themselves in the virtual environment, and allow users to "share space" with other virtual humans in the virtual environment. Furthermore, such systems will be able to use tracking data to identify opportunities when a user's perception of the environment can be altered. This would be helpful in situations where redirection or reorientation of the user might be done to "stretch space," i.e. imperceptibly rotating the environment around the user, so that a straight-line walk becomes a curve, preventing the user from ever encountering walls in the physical space. We believe that allowing users to co-inhabit virtual spaces with virtual humans and decoupling physical size constraints from these virtual spaces are two important building blocks for effective mixed reality training experiences.

Categories and Subject Descriptors
H.5.1. Multimedia Information Systems: Artificial, augmented, and virtual realities.

General Terms
Design, Experimentation, Human Factors.

Keywords
Motion tracking, virtual humans, redirected walking, virtual reality, mixed reality.

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1. INTRODUCTION
The Institute for Creative Technologies (ICT) at the University of Southern California is a University Affiliated Research Center (UARC) focused on the development of engaging, memorable, and effective interactive media to revolutionize learning in training, education, and other fields. A major focus of the ICT is the development of training tools and environments for the US military, among other clients. As part of the ICT, the Mixed Reality Lab researches and develops immersive technologies and techniques to build mixed reality environments in support of these applications.

Mixed reality is a term that describes environments and experiences that combine elements that are real with elements that are virtual. For example, a user could be immersed in a virtual reality system displaying a virtual automobile engine model which can be disassembled with real tools. Other mixed reality experiences might be provided by physical rooms where windows are simulated by display screens, or by head mounted displays (HMDs) which use cameras and graphics engines to overlay virtual objects over a view of the real world.

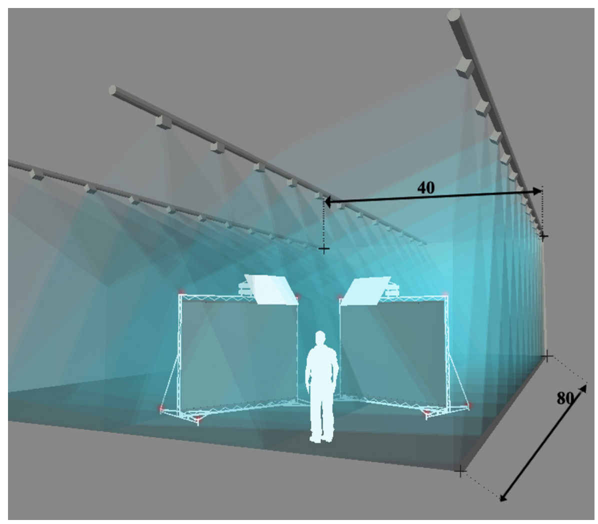

Figure 1: Conceptual diagram for the IR STAGE which tracks users, props, and projection screens.

To create effective mixed reality training scenarios, it is important to immerse users in simulated experiences that convincingly replicate the mental, physical, and emotional aspects of a real world situation. Our research in replicating those aspects have recently centered on the use of full body tracking systems and wide field of view displays in order to support realistic physical locomotion and strong engagement with virtual human characters.

We are building the *Intelligent Reality Sizable Tracked Augmented Graphics Environment*, or IR STAGE, which is a full motion capture stage 40 feet wide and 80 feet long (see Figure 1). This stage will allow real-time tracking of users, props, projection screens, and head mounted displays. These capabilities will enable us to bestow upon users the ability to "share space" with virtual human characters, giving users the strong impression that they are immersed in the same virtual space inhabited by a compelling virtual human. We also wish to "stretch space," allowing users to physically walk around a virtual space that is larger than the physical space available, without the users knowing that their spatial perception is being manipulated.

In disseminating this paper, our intent is to share our research directions with the research community in order to garner feedback and invite collaborators who may be able to employ our software and hardware facilities and help advance the state of the art in mixed reality experience design.

2. PREVIOUS WORK

Our current research directions have evolved from several bodies of prior work, including efforts related to large tracked spaces, redirected walking, and our group's own work with mixed reality environments and virtual human characters.

The Department of Defense (DoD) has long tried to find a way to provide soldiers within CAVE virtual environments or wearing HMDs with the ability to physically move around in an unlimitedly large environment. Omnidirectional treadmills, unicycles, large hamster-ball contraptions, and techniques for walking in place have been tried [4, 14, 2, 1, 12, 7]. However, true physical locomotion, like walking and running, is a compelling feature in training environments because there is a direct correspondence to the locomotion and physical coordination required in real world tasks. Furthermore, true physical locomotion can provide better spatial cognition since it provides spatial cues missing from simulated movement techniques [13].

Thus, a variety of researchers have experimented with large tracking spaces to facilitate user motion over a large area. [5, 15]. While these large spaces are conducive to physical locomotion due to their size, these spaces have finite limits and boundaries which may differ from the virtual environments which are being portrayed. A group of techniques have been initiated to address this issue. Redirected walking is one technique used to subtly rotate the virtual environment, preventing users from encountering walls [11, 6]. Distracting objects can help make these redirections less noticeable [10].

The ICT Mixed Reality Lab has developed a variety of software and hardware infrastructures to support mixed reality experiences. In the FlatWorld project, we augmented flats, which are mobile scenery structures derived from film and theater stagecraft, with the addition of projection screens [9]. The resulting digital flats can be easily positioned and projected upon to simulate walls or viewports, such as windows, doors, or other openings. They can also be combined with the standard flats, representing solid walls, to create rooms, alleyways, and other structures. The mixed reality environments are then enlivened with the addition of 3D computer generated content, 3D spatial sound, rumble effects, and set dressings such as rugs, curtains, and other physical props. While very compelling environments can be created from this infrastructure, there is little ability to track users, set pieces, digital flats, and props. Tracking these elements can be useful during the initial configuration of an environment as well as while the training experience is running.

The ICT has also produced a variety of experiences involving virtual human characters [8]. One notable example, co-developed by the Mixed Reality Lab, is SGT Star, an information guide employed by the US Army Accessions Command to provide information about Army careers at public events. SGT Star is often presented on a transparent screen (see Figure 3), providing a para-holographic, or simulated 3D appearance. However, since users cannot walk past the character (into the screen) and the character and cannot emerge from the screen, users may perceive that the character inhabits a different space which is unreachable and virtual. User tracking and wide field of view displays may provide some techniques to unite the world in front of the screen with the character's world behind the screen.

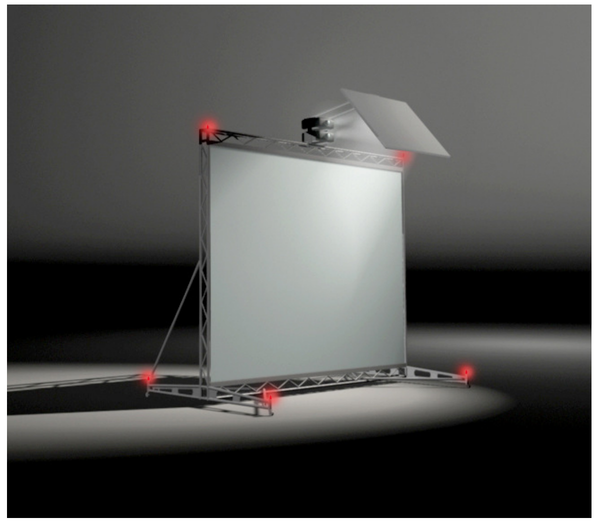

Figure 2: A mobile digital flat developed for the FlatWorld project, combining stagecraft and 3D digital projection. This digital flat carries an integrated projector and mirror.

3. SHARING SPACE WITH VIRTUAL HUMANS

Characters in virtual reality environments often appear to be two dimensional or distant (either perceived or real). These shortfalls may weaken engagement, and thus the efficacy of training. By incorporating a wide field of view HMD and full body tracking, we aim to convince users they are sharing the same volumetric space with virtual humans. This will help enhance the illusion that the virtual human is a sentient entity with whom the user can socially relate. Humans have a strong drive to relate socially with items that display only a glimmer of what can be ascribed as personality. In fact, while many humans may not consciously perceive that they are interacting with unintelligent objects in a social fashion, they often still fall into the human tendency to ascribe personalities and emotions to things, like animals, computers, cars, and other machinery. Removing barriers to this tendency can elicit more realistic responses to virtual human characters, making them more effective in supporting roles in training scenarios.

By employing wide field of view displays, like one of the new generation of wide HMDs (providing up to 150 degrees), we may be able to create uniquely compelling experiences with virtual humans. Peripheral vision cues, not previously available in standard HMDs, engender a variety of spatial cognition and pre-attentive behaviors that are important in engaging users into a situation. For example, some photographers anecdotally mention that they feel as if they are detached observers of real world events. While some of that disengagement comes from their journalistic role, the limited field of view of a camera lens may play a part by lessening the immersion that photographers feel with the real world. If a camera's limited field of view can stifle real world immersion, a narrow field of view HMD certainly could limit virtual world immersion.

Figure 3: A virtual human character who uses spoken dialogue to understand and answer questions about military careers.

Additionally, in many virtual environments, user avatars are either invisible, incomplete, or do not correctly follow the movements of the user. Full body tracking will allow a correct representation of the user's own body in the virtual environment, increasing the level of self-immersion and placing the user on the same level as the virtual human. There will no longer be a projection screen, separating the space of the user from the space of the character. The user and the virtual human can freely move around and past each other. Furthermore, the user will have a stronger sense of personal space, which can overlap with the virtual character's personal space, allowing non-verbal social interactions.

We believe that these features will make the virtual humans elicit stronger responses from the user, potentially making the characters seem more lifelike, persuasive, and equally more likeable or imposing, depending on the design and behavior of the character.

4. STRETCHING SPACE IN VIRTUAL ENVIRONMENTS

Physical locomotion (walking, running, etc.) has been recognized as essential for individual combatant simulations in which the soldier interacts directly with the surrounding environment. Spatial cognition and other processes of understanding an environment are weakened when only virtual locomotion is provided (i.e. through a joystick or button press) [13].

Furthermore, virtual locomotion could result in negative training in scenarios involving dismounted soldiers, like urban combat, where precise physical locomotion and coordination are important. Unfortunately, most virtual environments are limited in physical size and thus cannot allow unbounded physical locomotion.

Redirected walking can enhance the perception that users are in an unlimited virtual space. The virtual environment is subtly rotated and shifted around the user, without the user noticing. In this way, a large tracked space can be used to trick users into thinking that they are walking on an infinitely long straight road–when they are actually walking in a circle, or following an object rotating around them while the virtual world rotates at a faster rate.

Full body tracking will allow us to determine body and head poses that signal when a user is distracted, otherwise engaged, or in some way, less attentive to the environment. These are likely opportunities to shift and rotate the environment even more, allowing stronger guidance away from walls and other obstacles.

The ultimate goal of system would be to create a seemingly infinite urban area through which the soldier can navigate streets, alleyways, etc. The chaotic nature of urban simulation and the need for soldiers to find a physical protection behind objects and in alcoves affords a unique domain where there are many opportunities to employ user redirection (e.g. when a soldier blinks, covers his/her face, dives behind cover, etc.) With a large tracked area, we will be able to identify more opportunities to manipulate the perceived size of a virtual environment to a walking user.

There are also additional benefits that result from the capability to track props and bodies with a high level of detail and quality. Digital flats and other scenery could be placed in various configurations for different training purposes. Tracking these items would allow the system to recognize the topology of these elements and adjust the virtual world to correctly reflect this. Furthermore, scenario designers could be tracked and might demonstrate the desired behaviors of various computer controlled agents and vehicles, "directing" in theater parlance, or "programming by demonstration" in computer science parlance [3]. Finally, virtual environments could use the tracking data to display physical dynamics that respond to user movements like brushing against foliage, kicking open a door, or casting shadows.

5. CONCLUSION

The construction of the IR STAGE will allow a variety of experiments which examine how humans perceive virtual environments and virtual human characters. By employing wide field of view displays and full body tracking, we can determine how humans respond to virtual humans when several barriers between their worlds are dissolved. We hypothesize that this will lead to opportunities for more believable characters, better rapport, improved assessment of intent, and better non-verbal communication.

Furthermore, analysis of real-time tracking data will allow systems to multiply the physical space available for locomotion. Redirection and other techniques might be applied to full effect when users are distracted and unable to see manipulations of the environment that steer them away from walls. It may become feasible to create training scenarios that are longer and more elaborate when users can roam freely while completely immersed in their virtual world.

We feel that the IR STAGE and related infrastructure will be a valuable scientific apparatus that can provide the means to answer a variety of questions in immersion, interaction, and human perception. Thus, we welcome suggestions and collaborators in our research efforts.

6. ACKNOWLEDGMENTS

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