# Going Beyond Reality:
# Creating Extreme Multi-Modal Mixed Reality for Training Simulation

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## ABSTRACT

Nothing replaces the importance of the sweat, blood and tears of a live simulated training experience in which all your senses (visual, audio, haptic, olfactory, gastronomy, etc.) play into a physical, mental and emotional life-and-death scenario in a fully three dimensional, real-time world. When Virtual Reality is provided as an alternative, it can pale in comparison, as it is a disembodied experience no matter how much artistry has been applied to the aesthetic display and emotional thrill. This statement is applicable even to military simulations that drive complex and intricate training, and yet rarely cause trainees to break a sweat. There is a need for systems that integrate training scenarios into physically responsive live environments, enhanced by compelling entertainment techniques. Such systems must support the delivery of a wide range of simulation applications including vehicular, dismounted and constructive simulation planning.

This paper covers recent developments in integrating multi-modal functionality into Mixed Reality (MR), the blending of real and virtual sight, sound and special effects. More specifically, we present an overview of an MR research project and the multi-modal training engine (versus game engine) produced as a consequence of this research. This engine composes real and synthetic sensory stimulations into an interactive, multi-sensory, non-linear, immersive experience.

One application of this MR system is to create a MOUT (Military Operations in Urban Terrain) environment that blends real assets, such as buildings or building facades, with virtual assets including neutrals and combatants, both friends and foes. The entire system (software and hardware) is designed to be deployed into the field to transform any site into a MOUT for use in military training, homeland security, emergency response, informal education and entertainment. It can adapt core content experiences to custom environments providing in-the-field lush, compellingly, interactive and non-linear group experiences.

## ABOUT THE AUTHORS

**Scott Malo** is the Digital Production Supervisor for the Media Convergence Laboratory. He has a Bachelor of Arts in Digital Media from the University of Central Florida and was one of the first graduates of that program. His interests include production research that defines the mixed reality production studio and working with video production techniques such as digital filming, editing, compositing, and DVD authoring.

**Christopher Stapleton** is the Director of the University of Central Florida's Media Convergence Laboratory and a faculty member in the UCF School of Film & Digital Media. His previous positions have been in developing experiences for entertainment companies such as Universal Studios, Nickelodeon, Disney and Sanrio. His present work is developing creative and scientific research for the next generation experience-based digital media for art, entertainment and education. His education consists of a Master of Fine Arts in Film and a Bachelor of Fine Arts in Theater from New York University.

**Charles E. Hughes** is Professor of Computer Science in the School of Computer Science at the University of Central Florida. After receiving his PhD in computer Science in 1970, he served on the faculties of Computer Science at Penn State University and the University of Tennessee prior to joining UCF in 1980. His research interests are in mixed reality, distributed interactive simulation and models of distributed computation. He has authored or co-authored over 100 refereed research papers and six books. He is a senior member of the IEEE.

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## INTRODUCTION: COMBAT REALITY

Nothing replaces the importance of the sweat, blood, and tears of a live simulated training experience with all your senses (visual, audio, haptic, olfactory, gastronomy, etc.) driving the physical, mental and emotional life-and-death scenario in a full three-dimensional, real-time world.

The importance of training soldiers is to prepare them for the hell of war so that, when the time comes, they will react on instinct and not on fear. Training needs to have the same impact of chaos and fear as exists in real war. The term the "fog of war" applies here because the training needs to simulate that situation (see Figure 1). If the training does not impact the soldier, then the training has failed. How can simulation-based training get the heart pounding, the blood running, and the fear level up to actually cause the "fog of war?" The answer is that the experience must stimulate the entire body and all of its senses and create in a real sense the hell of war. Our contention is that Mixed Reality training is the answer to producing this emotional response (Stapleton and Hughes, 2003).

**Figure 1.** Training in MR/MOUT

## THE POWER OF ENTERTAINMENT

When Virtual Reality is provided as an alternative to a real experience, it generally pales in comparison, as it is a disembodied experience no matter how much artistry has been applied to the aesthetic display and emotional thrill. By combining the worlds of video games and theme parks, training can be taken to a whole new level (Stapleton et al., 2002). The video game industry has been improving their craft for the past 30 years, yet in all of their artistry and exciting game play the technology is still not compelling enough to simulate the "fog of war." On the other hand the theme park technology of today adds the thrilling nature of full body stimulation and activity. So what if theme parks and video games combined their strengths? We want to have a multi-modal, compelling, interactive story to tell. Change the entertainment aspect into simulation for training soldiers and we have a heart pounding simulation that stimulates the body and imprints vivid memories into the brain of the soldier. If these vivid memories are repeated enough times, they will turn into instinct.

## THE ADVANTAGES OF MIXED REALITY

With a Mixed Reality training system, soldiers can be placed in an environment that tests their mental and physical stamina. MR can create an experience that forces the trainee to make critical decisions in split seconds under fire and in the heat of battle.

Mixed Reality can achieve the sweat and focus of training by controlling the interplay between the virtual assets and the real world. At anytime the computer and/or trainer can change the level of the scenario, creating more complex and rigorous training sessions. The trainee can be pushed to high levels of multi-tasking that can stress the subject and cause poor decision making. By pushing the soldier to these extreme levels of chaos, the training increases the awareness of the soldier in extreme situations. The soldier is better trained and has more strength, fewer weaknesses and a better opportunity to survive a real encounter.

VR training applications do not allow for free range of movement by the trainee and do not sufficiently train the soldiers in tasks in a precise and accurate manner (Knerr, 1998). Mixed Reality allows for real

movement and interactive passive haptic feedback with the physical surroundings to provide more realistic warfare movements for dismounted soldiers. It also gives us the ability to allow the soldier to use a real weapon whose position and orientation can be tracked. For these reasons, we contend that the training acquired from mixed reality is more precise and real than that of VR training applications.

Critical decision-making and situational awareness issues are an important part of MOUT training and are not fully integrated in current training applications (Phillips, 1998 and Matthews, 2000). MR MOUT provides more complex scenario variations in a richly layered realistic situation and 3D multi-modal world. This allows the training to have critical decision-making and situational awareness by the trainee during a time of high stress and fear. MR MOUT can create the "fog of war" and then place the soldier in a position to make decisions that may cause fellow soldiers or civilians to come in harm's way.

## MR MOUT TEST BED CONCEPT

There is a need for systems that deliver training scenarios in physically responsive live environments. Such systems need to employ compelling entertainment techniques and incorporate highly dynamic training components that can adapt to the range of simulation interface applications from vehicular to dismounted to constructive simulation planning.

The MR MOUT test bed developed at the University of Central Florida is a training simulation using the latest in mixed reality technology. The simulation consists of a video see-through HMD (Uchiyama, 2002), real Hollywood-style facades that represent a 360 degree mini MOUT site, computer generated environments, characters, and props, a prop gun or other interface device with tracking, and real lights, crates, and walls. Standing inside the mini MOUT creates the view of a death trap as the soldier is open for attack on all sides and from high up.

The mini MOUT uses the real pieces of set and props and combines them with virtual characters and environments to create an outdoor courtyard with surrounding buildings and a water tower all inside a real building within a 20'x20'x20' space. Using a combination of bluescreen technology and occlusion models the real and virtual elements are blended into one complete MOUT site. The trainee has the ability to move around the courtyard and hide behind objects in the courtyard. The most effective and powerful result of this mixed reality training is the fact that the virtual character can occupy the same space as the trainee. The trainee can literally walk around a FFW soldier and see the computer generated character standing in the courtyard with them.

Figure 2 shows the mini without virtual assets. Figure 3 shows a virtual version of this facility, along with environmental models (sky, clouds and buildings in the distance). The models that match physical assets are not displayed, but are used for occlusion (they clip the rendered images of characters inside the buildings, allowing us to see only those parts that are visible through portals). The environmental models are displayed, thereby completing the visual landscape.

**Figure 2.** Real World Mini MOUT

**Figure 3.** Virtual Mini MOUT

By using show action control effects known as Macro-Stimulators, we can create scenarios where the real world around the trainee feels physically responsive. This is done by using computers to control lights, doors, window shutters, blinds, and other types of on/off or modulated actions. The computer can monitor the trainee by an interface device such as a special gun with tracking and then change the real

environment based upon the user's behavior. Along the same lines the story itself can trigger environmental changes that can startle the trainee such as a CG enemy character kicking open a real door. The macro-stimulator can add the excitement and realism that helps blend the real and the virtual.

Audio is another key way to making the virtual and real become more compelling. By placing audio with CG elements and moving them around the environment, the trainee will become more immersed in the scenario. Good audio can make the difference between a heart pounding thrill ride and a ho-hum simulation. In a Mixed Reality experience, audio creates the ambience, the realism and the surprises that make the experience seem real. In military training, audio is a key element in creating the sensory overload associated with the "fog of war" that prepares the soldier for the worst that could happen on the battlefield.

## MR SYSTEM

The Mixed Reality System (Hughes et al., 2004) is the core of the mixed reality simulation. The MR System can drive diverse and interoperable systems to blend real and synthetic sensory stimulations into an interactive, non-linear, immersive, multi-modal training engine (versus game engine). It is designed to drive compelling experiences that combine advances in real-time computing with entertainment techniques.

The system is comprised of many components, such as graphics, audio, special effects, and story engines (Figure 4). Each of these engines 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 each of the other engines. The key to the MR System that is different from a game engine is that it blends the real world with virtual assets (characters, props, etc.) to provide a mixed setting. This blending is not strictly at the visual level; it includes mixing real and synthetic audio, and real and simulated haptic feedback. These capabilities combine to create a compelling experience that can simulate an under-fire training scenario.

The MR System we have developed 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 team scenarios. In this context, users see each other as real people in a common setting, while interacting with virtual characters and objects.

## MR MOUT: ANYTIME ANYWHERE

The system is designed to be deployed into the field to transform any site into a MOUT site for use in military training, homeland defense, emergency response, informal education and entertainment. The hopes for the future are that mixed reality can be easily set up in any location, from the inside of an office building to an entire town. The locations could be filled with virtual additions to the real environment and then populated with virtual enemies, civilians, and soldiers. This could then turn any location into a training situation, without affecting the people or location to any major degree. This makes mixed reality training a valuable tool for anytime, anywhere training. Figures 5 and 6 show our demonstrations of this evolving science and technology at I/ITSEC 2002 and 2003, respectively. These demonstrations are examples of the systems' anytime, anywhere capabilities.

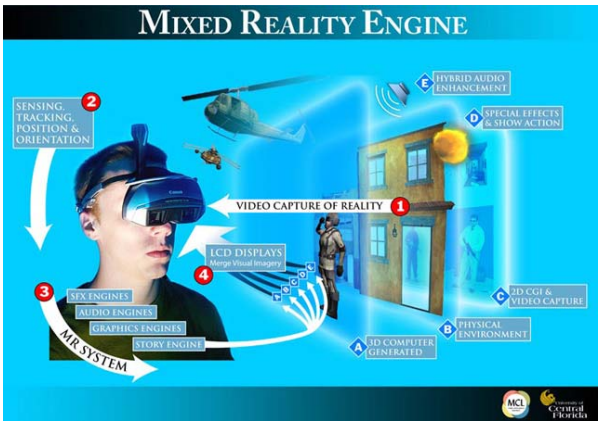


**Figure 4.** MR Engine Diagram

The technology is not only able to be used anytime or anywhere, but it also can be changed to represent anytime, anywhere. By inserting different behaviors, models, and a new script, the experience could take place in a new hot spot in the world. Mixed Reality could let soldiers relive old battles to learn from the mistakes made before them, or soldiers could step into a future battle and test the latest concepts in military gear and technology. Either way this system can handle changes in location and time. Having an ever changing system is one thing that makes the MR System an effective tool for training simulation.

The flexibility of mixed reality allows for almost unlimited possibilities. This is the type of training that can be used by the military, homeland defense, police, and even special agencies like the FBI just by changing the mixed reality training scenarios to fit their needs. By creating a backlot or library of CG content and

scenario scripts the mixed reality training application could be a valuable tool for different types of training, anytime and anywhere.

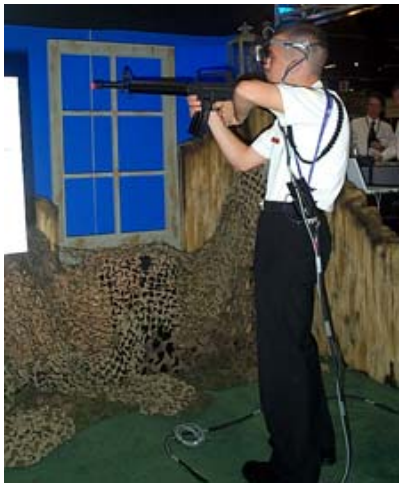

**Figure 5.** I/ITSEC 2002 MR MOUT Demonstration


**Figure 6.** I/ITSEC 2003 MR MOUT Demonstration

## MR EXPERIENTIAL TRAILERS

The idea behind a Mixed Reality experiential movie trailer is that the fantasy and adventure of a movie are brought to life in a mixed reality scenario. This interactive scenario would place the player(s) into their favorite movie, not just as observers but also playing the role of one of the movie's characters. By taking the best aspects of film and placing this super realistic fantasy into a full-bodied simulation, mixed reality can be as real as a film like Black Hawk Down or Saving Private Ryan. A training simulation could stay true to the realism of war, yet be more compelling than a movie by taking the best features from those movies and combining them with the best from video games and theme parks.

The important concept here is "experiential." The experience of mixed reality can have much more impact than any one media that currently exists. Mixed Reality can combine the different aspects of various digital mediums and use them in new and unique ways. All of this forms a new and thrilling simulation experience that cannot be easily replicated by other game or simulation systems. Combining the real and virtual worlds brings together the best of both worlds: the virtual reality simulation experience and the real world training exercises.

With the creation of the Experiential Trailer for the SIGGRAPH 2003 Conference (Figure 7), the Media Convergence Lab formed a Mixed Reality Production Pipeline for developing content for scenarios. By taking a cue from the pipeline used in the film industry, we have devised a system that allows both the artistic team and the programming team to move forward in parallel steps to go from the concept of the scenario to the deliverable of a Mixed Reality scenario.

**Figure 7.** Animatic Frame from SIGGRAPH '03

It starts with the written story and a quick animatic. The animatic is a simplistic visual rendering of the story from a single point of view. Using this rendering as a communication tool allows both the artist and the programmer to grasp the ideas that each team needs to focus on. This type of visual tool works best to communicate the vision of the creative crew to the entire team. Programmers get a sense of the tasks needed to make the technology ready for the story or to let the creative team know of limitations.

Once the animatic is presented and the behaviors are agreed upon by the team, the artists can go away and begin creating the virtual assets (CG models, textures, animations, images, and videos). The programmer can then begin building new components to the technology (if necessary) and implementing a first-cut virtual experience using the preliminary models developed for the animatic. Typically this takes 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 the scene from many angles and positions, unlike in the animatic where only a single viewpoint was provided. 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 team 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. Both 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 and technical components are being finalized. This is the final step in making minor changes and tweaks to the story and technology. After this step, the teams prepare for the final integration into the MR system.

The last step is the integration. If all of the previous steps have been successful, 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.

This process is one that works for both creative and technical. At each step the team as a whole will view and comment on the problems that need to be solved. Once the whole team agrees on that step, the area teams move forward. This process, combined with close communication between the artistic and programming teams, allows Mixed Reality projects to be successful.

## FUTURE WORK

The future of Mixed Reality, both in scientific advances and creative applications, is so promising that we contend it will become a stable fixture in the world of entertainment, museums, and training venues around the world, and that this future will happen in the next decade. The potential applications for MR are so numerous and the experiences so exciting and immersive that it's not a matter of whether, but of when it will attain its destiny.

Today's gaming world is thriving in military simulation games. The US Army has also jumped on board with America's Army. Even the video game world is acknowledging the fact that gaming will move towards a future like Mixed Reality (MacDonald, 2004). The industry sees Holodeck-style game chambers, body tracking, and VR headsets in the future of gaming. MR MOUT is representative of the future of MR, from the creative process to the technology to the systems architecture to the production pipeline. In many senses, it is the future.

As MR technology matures and research discovers the best uses of this technology, Mixed Reality will become the preferred platform for training simulation. It will prepare the soldier for battle. It will clear away the "fog of war" by subjecting soldiers to the hell of war before they are actually in war. By sending a soldier to battle having already faced the worst in training, that soldier will be more prepared than the enemy on the battlefield and will win.

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