Going Beyond Reality: 
to Create Extreme Multi-Modal Mixed Reality for Entertainment

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Media Convergence Laboratory
University of Central Florida

A Partnership of

Institute for Simulation and Training
School of Computer Science
College of Arts and Science
We wish to thank our partners

Sea Creatures
Going Beyond Reality

Session I: Achieving Next Generation Extreme MR

- Objective: Extreme MR
- Mixed Reality Continuum for Entertainment
- Evolution of Mixed Reality through history
- Art of Extreme MR
- Case Studies: Cross Industry Transfer Projects
  - MR MOU
  - Sea Creatures
  - Experiential Movie Trailer
Experiential Marketing

Going Beyond Reality

Session II: Achieving Next Generation Extreme MR

- Engine of Extreme MR
- Science & Technology of Extreme MR
- From invention to innovation
- Future Research Directions
The Art and Science of Experiential Entertainment

Cave Painting

Diorama

Theater

Cinemagic

Animation
MR Research:  
Convergence of Media

As immersive as Military Simulation
As intuitive as Play
As visceral as a Theme park
As Meaningful as education
As interactive as video games
As compelling as motion pictures

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Painting with the Audience’s Imagination...

Universal Studios Islands of Adventure
1. UIOA: video of theme park screams
Inventing the Technology of the Imagination
The Power of Entertainment

3D Video Games

Pong: Video Games

MTV: Music Video

Quake: Virtual Reality

Orson Wells: Radio

D.W. Griffith: Film

Sid Caesar: Television

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The Power of Imagination

“What is in the (text) book is only one fourth of the story. It is like an iceberg where three-quarters of the story you don’t see, it is beyond the page.”

Earnest Hemingway
Milgram’s Reality-Virtuality Continuum

REALITY

Augmented Reality

Hybrid Simulation

Live Simulation

Virtual Simulation

VIRTUAL

Augmented Virtuality
Redefining Mixed Reality

“Magic is behind the eyeballs”

Augmented Reality

Augmented Virtuality

REALITY

VIRTUAL

IMAGINATION

Rides

Dark Rides

Video Games

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Mixed Fantasy Continuum

(adding imagination)

Milgram’s Reality-Virtuality Continuum

Augmented Virtuality (AV) — Augmented Reality (AR)

Physical Reality (Interface)

Virtual Reality (Media)

Compelling Mixed Reality (The Play)

Imaginary Reality (Story)

Film

Novel

Traditional Theme park

Magic Show

P.T. Barnum Reality-Imagination Continuum

Aristotle’s-Media-Imagination Continuum
Making Memories for a Lifetime

Amusing

Training

Learning
Power of Mixed Reality
Melting the Boundaries

Real-time, immersive, 3D, visceral multi-modal
Art and Science of MR
Melting the Boundaries

Augmented Reality
Imaginary Reality
Live Simulation
Virtual Reality
Augmented Virtuality

MIXED REALITY
Art and Science of MR

Filling in the Gaps

- Real-Time
- Visual
- Audio
- Haptic
- Synthetic
- Captured
- Adaptive
- Displayed
- Non-Linear
- Perceived
- Performance
- Networked
- Integration

MIXED REALITY

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Case Study: TRAINING

Richly Layered Experiences

- All Dimensions
- All Modalities
- All Domains
- Anytime
- Any Where
Combat Reality

Blood, sweat, tears, life and death
Live Simulation

Physical, immersive, multi-modal
Virtual Reality

Dynamic, flexible, on-demand
Immersion Beyond the projection screen
Cinemagic
Imaginary Reality

Compelling, emotional, memorable
Real Training vs. Entertainment

Real MOUT Training at MOUT McKenna

Clip from the Columbia Pictures Film - Black Hawk Down

Are these embedded?
If not, cut them.
Dynamic Virtuality
Melting the Boundaries

Dynamic Virtuality

Compelling Reality

Constructive Intelligence
Melting the Boundaries

All Dimensions
All Modalities
All Domains
Anytime
Anywhere

Dynamic Virtuality
Compelling Reality
Constructive Intelligence
Mixed Reality in Military Operations in Urban Terrain

Dynamic Virtuality

Compelling Reality

Constructive Intelligence
Mixed Reality in Military Operations in Urban Terrain
Power of Mixed Reality

What is Mixed Reality?

Mixed Reality is the blending of the real world and the virtual world and the combination is seamless

2. MR MOUT 2.0 Video

MR MOUT 2.0 Scenario – Mixed Reality vs. Reality Views
MRMOUT 4.0
Situational Awareness to Command and Control
The Art of Mixing Reality

Artist Rendition of the MR MOUT “visor” HUD

Future: MR Backlot and Previsualization for filmmaking
Case Study: Entertainment

Experiential Movie Trailer

- Looks like a film
- Plays like a game
- Immersed like a theme park
- Embedded in Retailtainment
Eyes on the Prize

A. Previsualization
Benchmarks

B. Borrow from the best
Creating the Story Assets

C. Characters, Environments, Events
MR Mini MOUT

D. Venue Reality
(Scenography)
Designing the SFX:

E. Special Effects (SFX)
(Punctuation)
Designing the Lighting

F. Illumination, Shading, Shadows Palettes
(Blending the seams)
Layers of Illusion

G. Real-time Compositing

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## Building Each Layer

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Hybrid Audio Engine

3D display

3D Capture

H. Sensory Synchronization
Animatic

1. Timing & Juxtaposition

Story boards

Captured Mock-up
Augmentation

3. Time Portal Animatic (on-line) start in middle at,

‘this is a composite video of animatic…etc.’”

K. Integrating Reality
Points of View

REALITY

Augmented Reality

VIRTUAL

Augmented Virtuality

Embedded Display

Immersive Display

Head Mount Display

Virtual Display

L. Multi-player (Diverse Displays)
Case Study: Entertainment

Extending and Enhancing Educational Exhibits

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Experiential Learning

- **Compelling Experiences**
  There is greatly increased competition for both leisure time and leisure dollars.

- **Repeatable Experiences**
  Repeat visitors demand changing experiences to keep them coming back.

- **Throughput of Content**
  New experiences are needed for growth in membership revenue, marketing opportunities and sponsorship dollars.

- **Cross-generational Experiences**
  Museums are visited by families and others representing multiple generations, different learning styles, and varying levels of existing knowledge.
Museums

- The 16,000 American museums average approximately 865 million visits per year, or 2.3 million visits per day.

- Museums are a $16 billion dollar/year industry in America.

- 1997 Census and AAM Statistics
Experiential Learning Test

A. Does the exhibit know that I am here?

B. Do I impact the Exhibit in any way?

C. Does the Exhibit Impact me in any way?
Permanent Display

Limited learning, Static, Never Changing, Mostly reading, No Direct bridge to school or home.
Dino Digs Transformation

Repeat experiences (visits), Changing content, Social, Physical, Interactive, Responsive, Extended depth.
MR Sea Creature @ OSC

Creatures, Environment come alive

MR ROVER
Virtual Scientific Tools

Reality triggers Virtuality, Virtuality triggers reality
Sea Creatures: Dino Digs Transformation

4. Insert Sea Creature Video
Power of Experiential Content

Story
Power of Experiential Content

Story
Exposure
Question
Museum
Power of Experiential Content

Story

Exposure

Question

Play

Understanding

Create

Home
Power of Experiential Content

- **Story**
- **Exposure**
- **Question**
- **Understanding**
- **Play**
- **School**
- **Share**
- **Game**
- **Expression**
- **Create**
Power of Experiential Content

- **Story**
- **Exposure**
- **Question**
- **Understanding**
- **Play**
- **Memorable Experience**
- **Game**
- **Expression**
- **Create**
- **Share**
Experiential Learning Landscape

REALITY

Physical Reality

Augmented Reality

Training

Augmented Virtuality

Virtual Reality
Experiential Learning Landscape

**REALITY**
- Physical Reality
- Augmented Reality
- Virtual Reality

**LEVEL**
- National Standards
- Regional Focus
- Augmented Virtuality
- Virtual Reality

- Training
- Class
- Individual
Experiential Learning Landscape

REALITY
- Physical Reality
- Augmented Reality
- Virtual Reality

LEVEL
- Command
- Institution
- Learning
- Team
- Individual
- Augmented Virtuality
- Virtual Reality

LEVEL
- Just in Time
- Retro-fit
- Planning
- Long Term
- Evaluation
Next Generation Challenge

- More depth and diversity
- Content validation through real-time evaluation
- MR as a critical bridge forward to formal education
- MR conduit from Scientific Virtualization to Experiential Learning Centers.
SECTION II: Achieving Next Generation Extreme MR

- Engine of Extreme MR
- Science & Technology of Extreme MR
- From invention to innovation
- Future Research Directions
SCI ENCE & TECHNOLOGY
Mixed Reality Displays

REALITY

Augmented Reality

VIRTUAL

Augmented Virtuality

IMAGINED

Embedded Display

Immersive Display

Virtual Display

Head Mount Display

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The Engines

- Story
- Graphics
- Audio
- SFX / DMX
Story / Scripting / Master

- Agent architecture
- XML-based scripting
  - behaviors with guarded cases, triggers, guarded reflexes
- AI Plug-ins
- Basic physics engine
- Pluggable-interface protocol
- Procedural scripting
Graphics Engine

- OSG Open Scene Graph
- Cal3D
- Agent peers
- Occlusion
  - Impostors
  - Matte support
Audio Engine

Fully 3D Peripheral Sense

- Ambient, point, dynamic (3d moving)
- Constrained based on speaker placement
- Agent peers
Audio Capture

Acoustical Situational Awareness

- Two stereo mics placed back-to-back in XY configuration with cardioids pickup patterns
- Ambience was captured in courtyard near busy road at various time during the day and evening
- Captured tracks were panned to front left, front right, rear left, and rear right within the MR Sound Engine
- Virtual ambient sounds were added in post (e.g. distant explosions, gunfire, helicopter flybys, etc.)
- Virtual sounds have an increased sense of validity when mixed with real world ambient surround capture
Hybrid Audio Display
3D audio beyond Headphones

- Surround
- Embedded
- Point Source
- Environmental
- Haptic
- Hypersonic
- Asymmetrical Displays
Network Protocol

- Simple, efficient
- Command stream (show, hide, …)
- Control stream (position, orientation, …)
  - Can attach control stream to trackers, physics engine, other agents
Contributing Science
Melting the Boundaries in real-time
Illumination and Shadows

Sumanta Pattanaik
Erik Reinhard
Blending the Real and the Virtual

- Use color-transfer for ambient lighting (ER)
- Lighting (SNP)
  - Virtual light on real/virtual objects
  - Real light on virtual objects
- Shadows
  - Cast by virtual objects on real/virtual objects
  - Cast by real objects
- Fire
  - Creating light and shadows on real/virtual objects
Why Virtual Lighting

- How do you give a real flashlight to a virtual object?

- Certain effects, such as the overall luminance of the scene (such as changing the time of day), may be cheaper to implement virtually. Useful for dynamic simulation applications.

- In entertainment applications, sometimes physically incorrect lighting may be necessary to create the desired dramatic effect.
Shadows

Sumanta Pattaniak
Importance of Shadows

- Shadows are an important part of lighting simulation:
  - Lights should cast shadows on real objects even though the light sources are virtual.
Importance of Shadows

- Helps with suspension of disbelief.
- Helps us understand:
  - Relative virtual-to-real object position and height in space.
  - Shape of a virtual shadow receiver’s surface.
  - Position of nearby virtual objects that are occluded or outside the field of view (virtual enemy in hiding).
Our Contribution

- We demonstrate two ways to inject virtual light into a scene in the context of two practical MR applications.

Virtual Fire

Virtual Flashlight
Occlusion Models

- Our algorithms make use of the occlusion models of real objects which are common in MR applications.
- Occlusion models describe the geometry of all real objects in the scene. They can be pre-measured or automatically generated.
- Model position relative to camera is tracked.
- Usually used for determining which parts of virtual objects are hidden by real objects closer to the camera.
- Having this geometry available lets us adapt many algorithms from computer graphics.
Occlusion Models

Example of the occlusion model for a notebook (approximated by a single polygon).

- No occlusion model
- With occlusion model
- Tracking model’s position

Tracked by a marker.
Tracking

- Need to know position relative to camera of every interactive real object.
- Any object that is allowed to move independently of others must also be tracked independently.
- Several methods of tracking:
  - Sensor-based (InterSense, Polhemus, GPS)
  - Image-based (ARToolkit)
Tracking

- **ARToolkit** is an image-based tracker which derives camera position relative to a particular marker based on its location and tilt in the video frame.

- Developed by University of Washington’s Human Interface Technology Lab.

- We chose **ARToolkit** for this demo for several reasons:
  - Light-weight
  - Free
  - Easy to set-up
Tracking

- Not necessarily great for larger projects:
  - Poor tracking quality of far-away objects.
  - Done in software = slow
  - Markers everywhere!
  - Marker must be visible in video frame

- Luckily the tracking problem can be easily isolated from the rest of the system and thus the method of implementation can be changed easily.

Virtual Fire

- Our virtual fire application simulates a real environment light by computer-generated fire.
- The process works by calculating how the intensity of each pixel covered by an occlusion model is increased by the virtual flames.

Unmodified frame  Virtual illumination only  Illumination + flames
Virtual Fire

- Thanks to occlusion models, this calculation can be done with many known computer graphics lighting algorithms and can be accelerated by graphics cards. The calculation can be simple or complex depending on the requirements of the application.
- The original intensity of the pixel is scaled up based on the result of the computation. Finally, virtual flames are drawn onto the image.

Unmodified frame  Virtual illumination only  Illumination + flames
Bonus: Virtual Wind

A separate marker tracks the position of a non-existing fan. Lighting on ground shifts with flame’s position.
Virtual Flashlight

Artificially make a room darker, and restore it to its original intensity with a virtual flashlight. Done in multiple steps.
Virtual Flashlight

Step #1: Scale down intensity of pixels that are **not** covered by tracked occlusion models by some constant factor.

*Untracked pixels assumed to be unlit by virtual light*

**Partially darkened frame**

**Final processed frame**
Virtual Flashlight

Step #2: Calculate shadows from virtual objects falling on real objects. 

*Using a version of the shadow volume algorithm from computer graphics adapted for MR.*

Virtual shadows on real objects  Final processed frame
Virtual Flashlight

Step #3: Artificially darken occlusion model-covered pixels, and simulate virtual light by darkening virtually “lit” pixels less. *Modified intensity is determined by the spotlight algorithm from computer graphics.*

**Full virtual lighting applied**

**Final processed frame**
Virtual Flashlight

Step #4: Composite virtual objects and compute shadows from real and other virtual objects falling on them.

*Use same basic algorithm as in Step #2.*

Final processed frame
Video

(click image to play)
Color Transfer

Erik Reinhard
Computer generated images

Can be very realistic, but color selection is sometimes a problem.

Not so with holiday snaps.
Fool the human visual system into accepting ‘realistic color schemes’
Van Gogh’s Holiday Photos
The Process

- Reinhard et al., 2001
  - Compute mean and variance of color attributes of pixels in source and target
  - Impose mean and variance of source on target
  - Requires source and target be similar in composition; hard to control in dynamic MR

- Chang et al., 2004
  - Name colors and maintain each pixel in its color group
  - Avoids swatches but may be hard to maintain frame rate; will try to optimize
Color Space

- RGB’s dimensions are correlated, making analysis a 3-d problem
- Can get three 1-d problems by using $L\alpha\beta$ space (independent in practice)
Extending to MR

- Get example from real; target is virtual
- Experimentally have found log space is not necessary; thus use CIE Lab
- Can change RGB space to LMS and then to CIE Lab in a matrix multiply; inverse is also one multiply
- Can optimize mean and variance computation by ignoring transparent parts of target; also tried optimizing by skipping mean/variance computation on every other frame and/or every other pixel
Video Samples

Pegasus uncorrected

Pegasus color corrected

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Frame Rates

Figure 6: Frame times and rendered pixels as function of frame number.
Cost of Adjustments

- Found no advantage in computing mean and variance every other frame or on every other pixel (actually cost 3 fps)
- Primary cost is in shifting pixels, not in computing means and variances
- Unrolling loops brought major gain
- Current cost overhead is about 23%
- There are many improvements to be made
- Experiments continue …
Invention to Innovation

- **PUSH**: Technical Capabilities to Creative Possibilities
- **PURPOSE**: Human Impact (cognitive and Imaginative)
- **PULL**: Commercial Potential
Media Innovation Infrastructure

**IDEA**
- Limitations
- Artistic Convention
- Evaluation Analysis

**INVENTION**
- New Capabilities
- New Possibilities
- New Models

**INNOVATION**
- Product Dev Push
- Market Dev Push
- Innovation

- University
- Laboratory
- Industry

- Science & Technology
- Human Impact Cognitive & Imagine
- Business & Production Models
Media Innovation Infrastructure

- Science & Technology
- Human Impact: cognitive & imagine
- Business & Production Models

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University Laboratory Industry

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Inventing, marketing, financing, and organizing typically involve different
- People
- Places
- Priorities
- Processes

Knowledge specialization often prevents marriage of
- Problems
- Solutions
- Options
- Resources
Core Technology, Diverse Applications: “Cross-industry value transfer”

- Military Simulation & Training ($3.3 Billion/yr US)
- Destination Theme Parks ($7 Billion/yr US)
- Television Production ($70 Billion/yr US)
- Convention & Conferences ($1.1 trillion/yr worldwide)
- Location Based Entertainment
- Museums ($12 Billion/yr US)
- Arcades ($7 Billion)
- Consumer & Military Electronic Market

$ Millions: Unit Cost

# Millions: Unit Volume & increased requirements
Notable Publications:

- IEEE Computer
- Computer Graphics and Applications
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