UNIVERSITY OF CENTRAL FLORIDA

Mixed Reality

Trompe l’oëil in the 21st Century

Charles Hughes, School of Computer Science

Presentation at IRISA

June 3, 2004

Trompe l'oëil

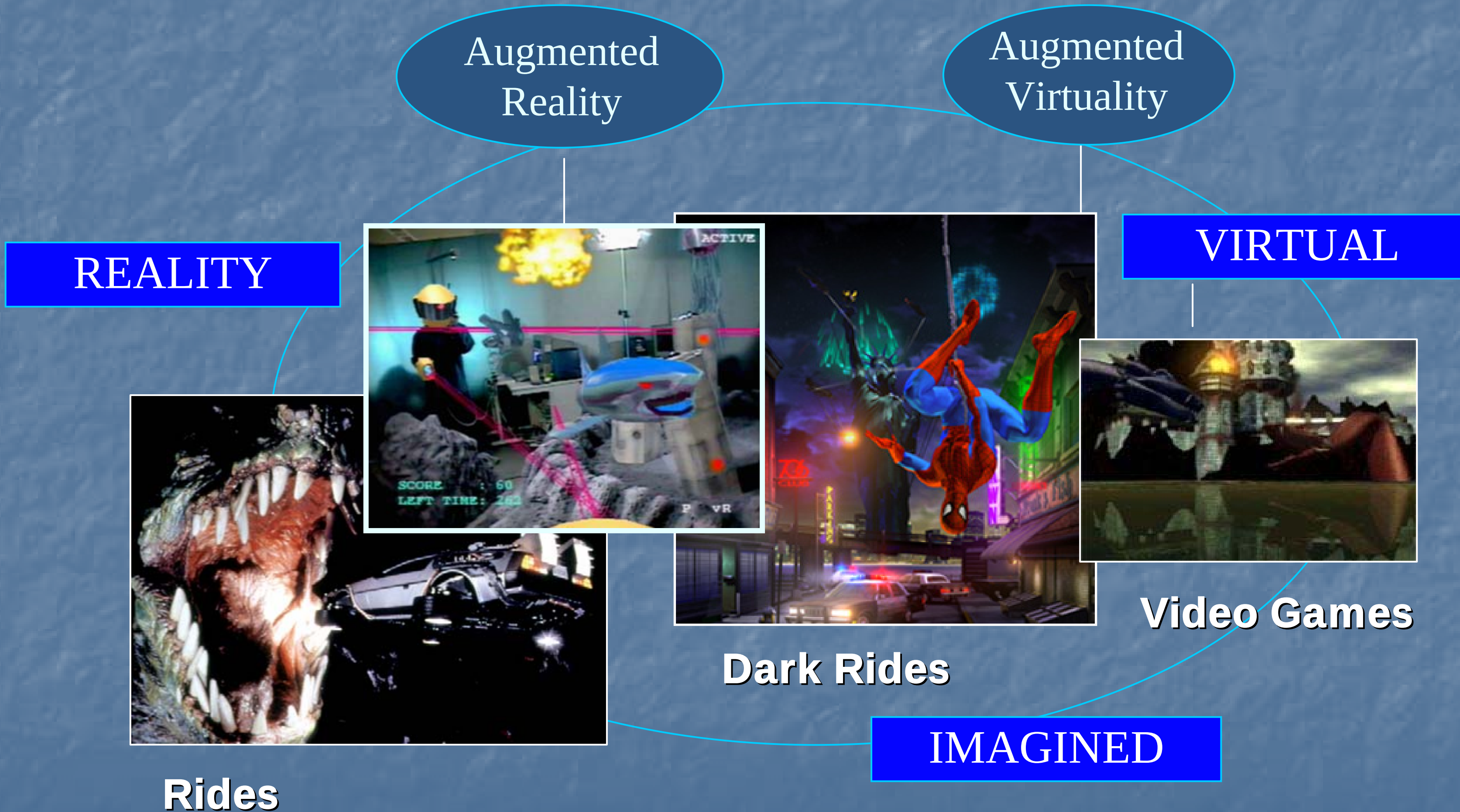
- **To deceive the viewer as to its reality.**

Mixed Reality

- Perception, deception, rendering, illusion, illumination, imagination, simulation, augmentation, mixing of realities and melting of the boundaries

Extending Mixed Reality

“Magic is behind the eyeballs”



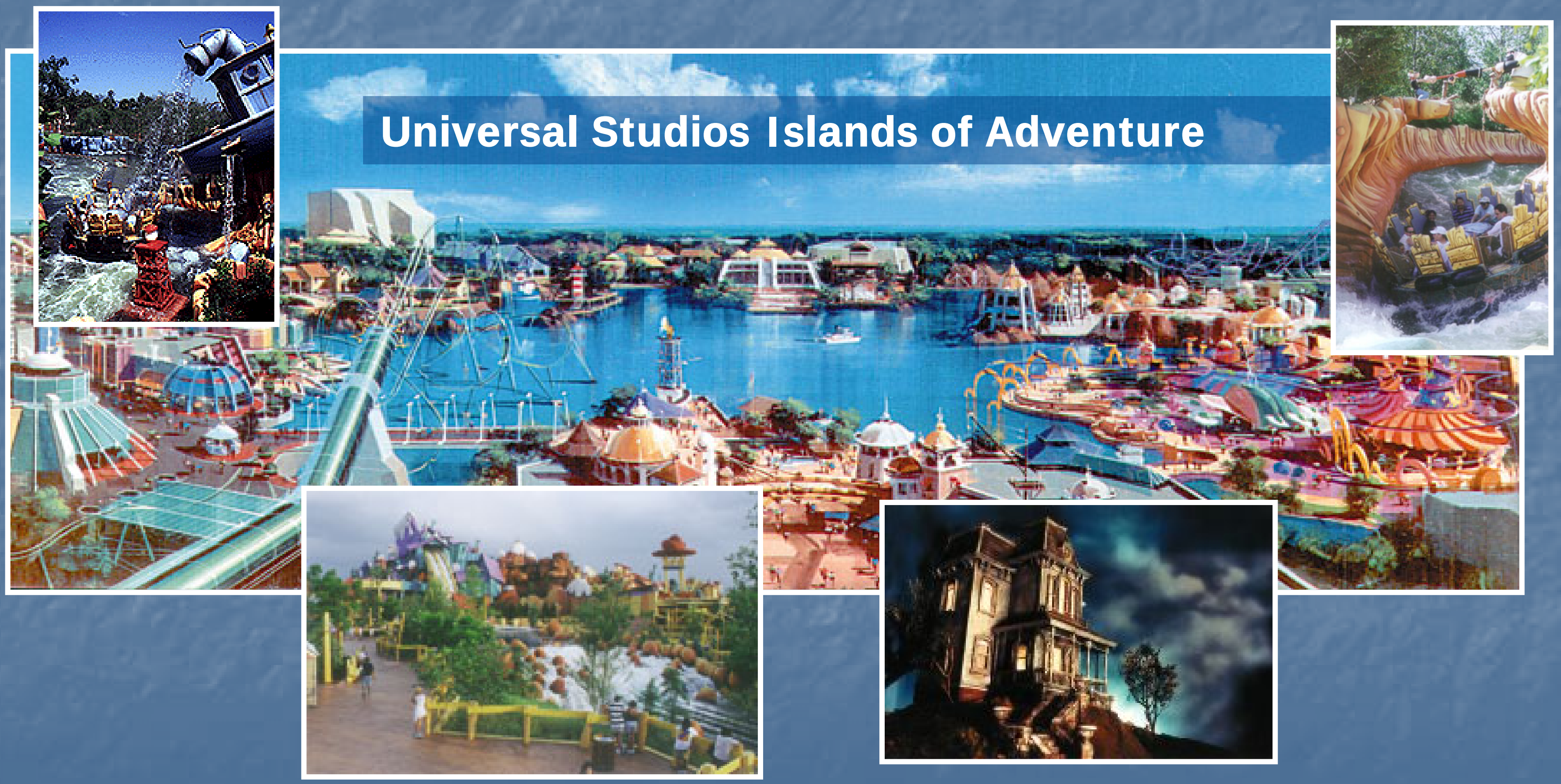
Mixed Reality Properties

- Is more about
  - Perception than Perfection
  - Receptiveness than Deception
  - Imagination than Imagery
  - Convention than Trickery
  - Recasting than Reinventing
  - Story than Arcade

Theme Parks

Chris Stapleton
Director, Media Converge Lab
Trained in Theatre
Matured in Theme Parks

Theme Park Designers Paint with the Audience's Imagination…



MR in Theme Parks

Spiderman Ride

Elements of Illusion

Line & Shape
Form & Color
Light
Shading
Perspective
Shadows
Experience Capture
Motion
Imagination
Immersion

Early Depth Techniques

- From Shading
- From Forced Perspective
- From Shadow
- From Value
- From Chroma



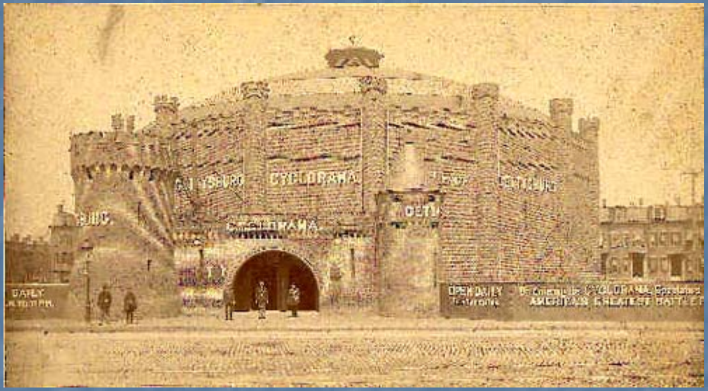


Elements of Illusion

Depth from Immersion

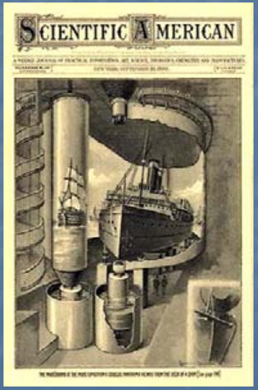
Applications of Illusion

Diorama



Cyclorama

Cinéorama



Mareorama

Applications of Illusion

Glass Matte Painting

Applications of Illusion

Chroma-Key Compositing

Mixed Reality Goals

As intuitive as
Play

As immersive as
Military Simulations

As visceral as
Theme Parks

As meaningful as
Education

As interactive as
Video Games

As compelling as
Motion Pictures

MR Experiences

Examples from our
Media Convergence Lab

Time Portal (AR)

MR @ SIGGRAPH'03

Visual+audio+SFX

Animatic

Time Portal Characteristics

- Three types of experience
  - Divers
  - Swimmers
  - Waders
- Audio
  - Ambient (environmental, mood)
  - Point source (fixed places in space)
  - Positional (attached to virtual objects)
- Special Effects
  - Force feedback
  - Shakers
  - Smoke
  - Light control

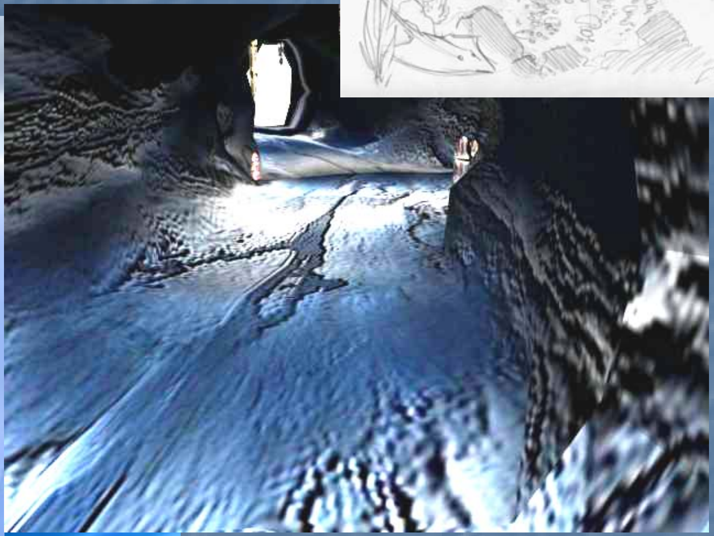
MR Interactive Trailers

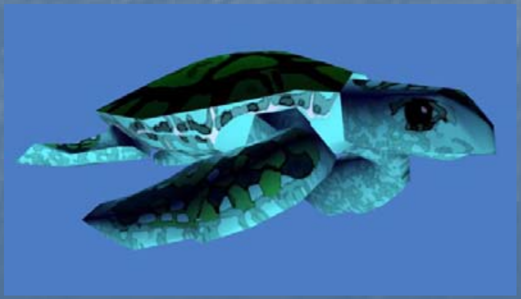
- Time Portal is really …
  - A "Stargate" interactive trailer
  - You have elements of the movie
  - But, you can participate in the action
- General concept is …
  - Movies live and die by "hype"
  - The first weekend is the most critical
  - Interactive trailers create a "buzz"
    - Consider "Blair Witch Project"

Augmented Virtuality

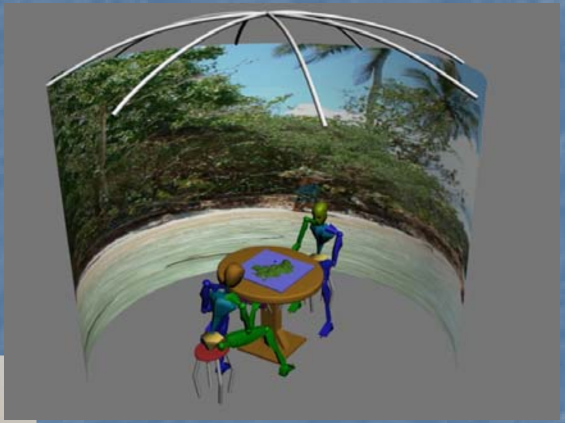
Placing Real Entities into Virtual Environments

MS Isle (AV)





Demo Dome Kiosk Portable & Collaborative



MS Isle Characteristics

- Unidirectional retro-reflective curtain
  - Light projected by each participant is cast back
  - Each has a different color
  - Each sees a blue/green/?? screen
  - Real objects (people, etc.) do not reflect light
- Effects
  - Sound, controlled light, etc.
- Navigation (shared)
  - We used a table with two handles (one per user)
- What was shared
  - An island and its underwater environs
  - The table was a God's eye view used to guide navigation
  - The first person views were on the surrounding curtain

Demo Dome Characteristics

- Relative to CAVE
  - Lightweight
  - Inexpensive
  - Can have distinct POVs
    - E.g., consider a city planner and an architect
    - Each wants specialized information
    - But both need to have a common context

MR Virtualization

- Virtual models in real settings
- Extension to scientific visualization
  - Real props
  - Collaborators
  - Multiple POV of common model(s)

MR Cartoon

MR Cartoon Characteristics

- Cartoon characters are real to kids
- Experience cartoons from the inside
- Need to avoid HMD use
- Surround the diver with
  - audio cues
  - special effect cues (rustling leaves, …)
  - composited video
- Swimmers and waders have VR window

MR MOUT (AR)

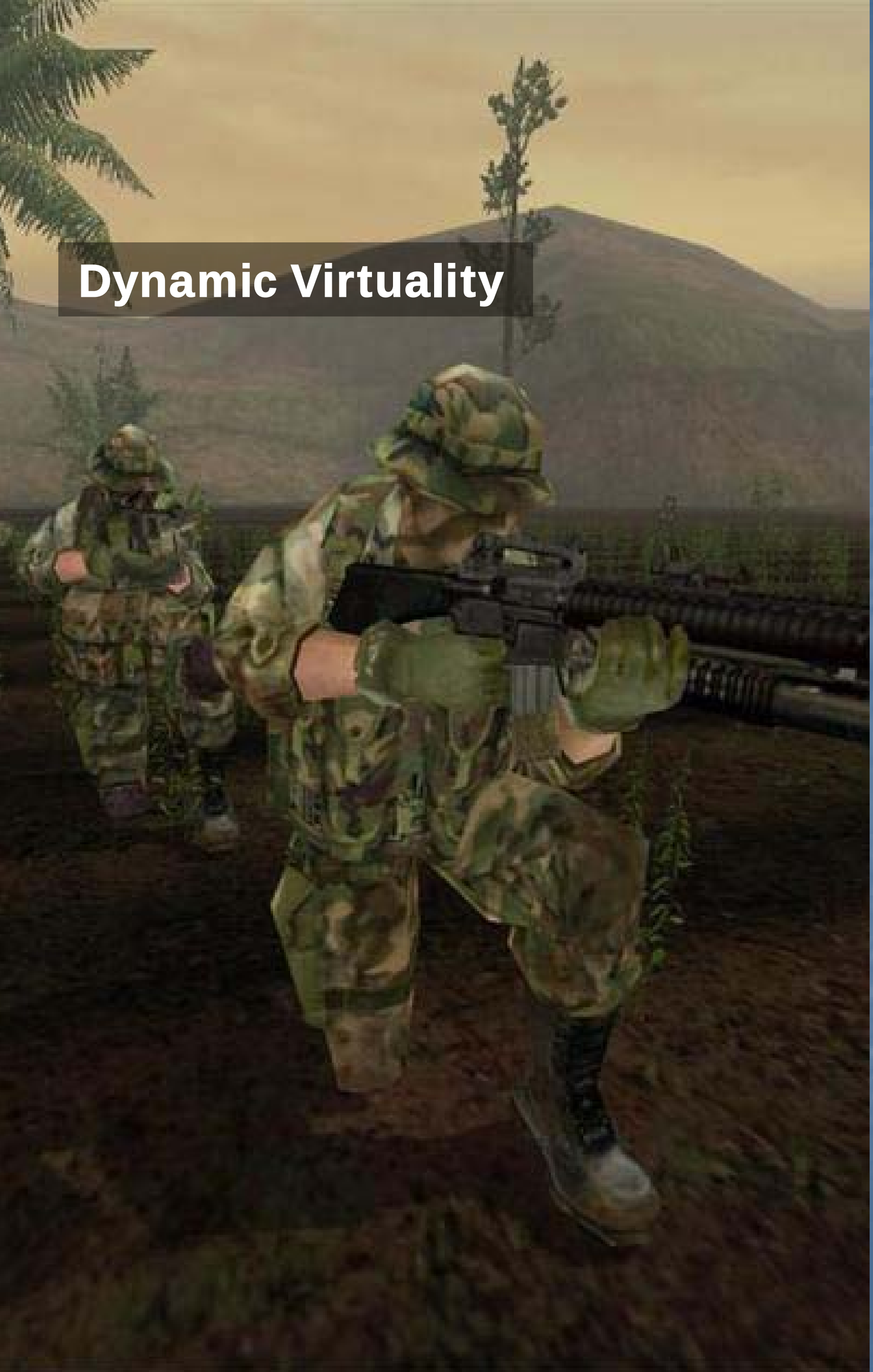

MIXED REALITY:
Melting the Boundaries
Between Virtual and Real Simulation

Mixed Reality in Military Operations in Urban Terrain

MOUT

Richly Layered, Multi-modal, 3D, Compelling Mixed Reality

Dynamic Virtuality

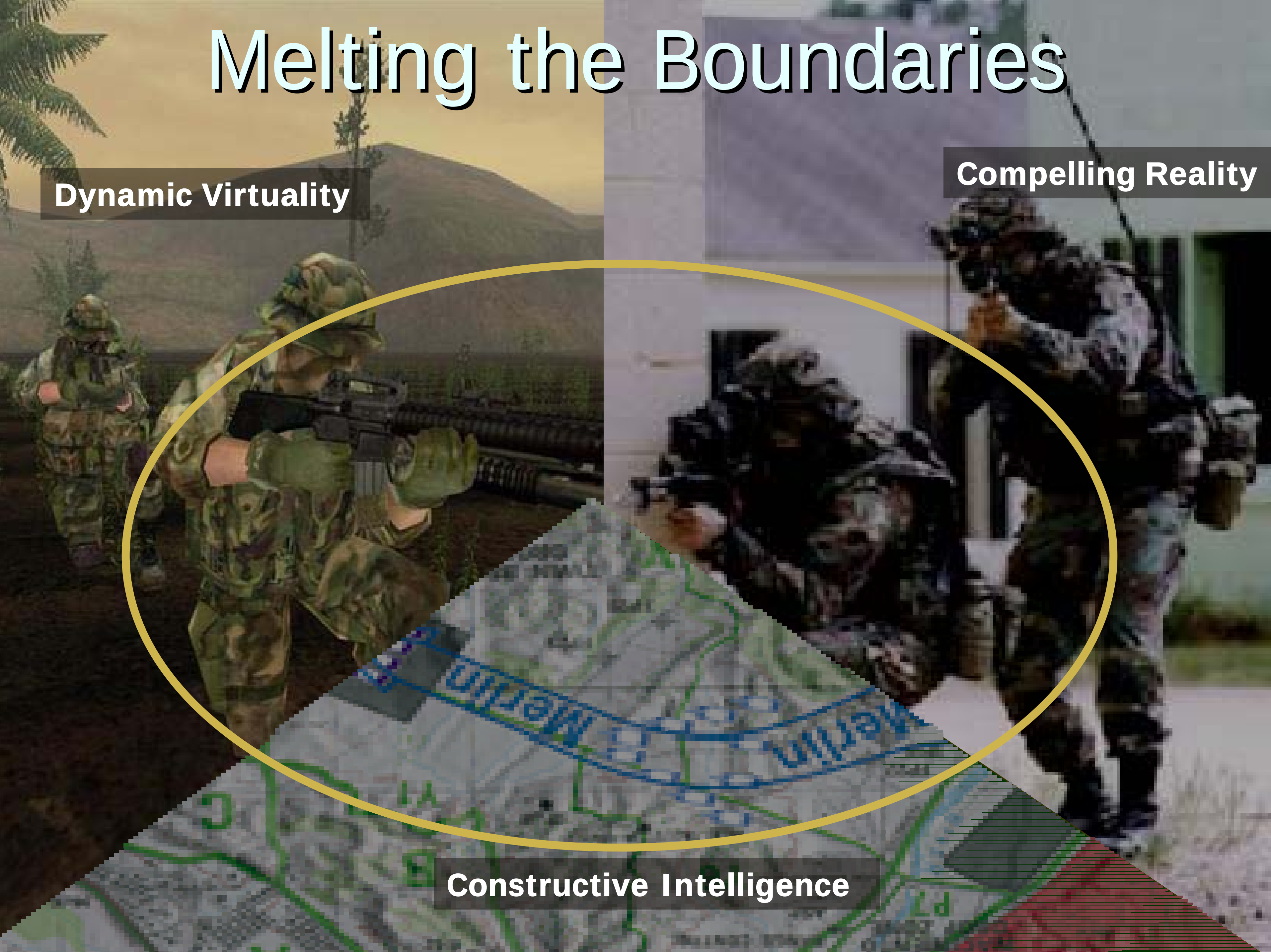


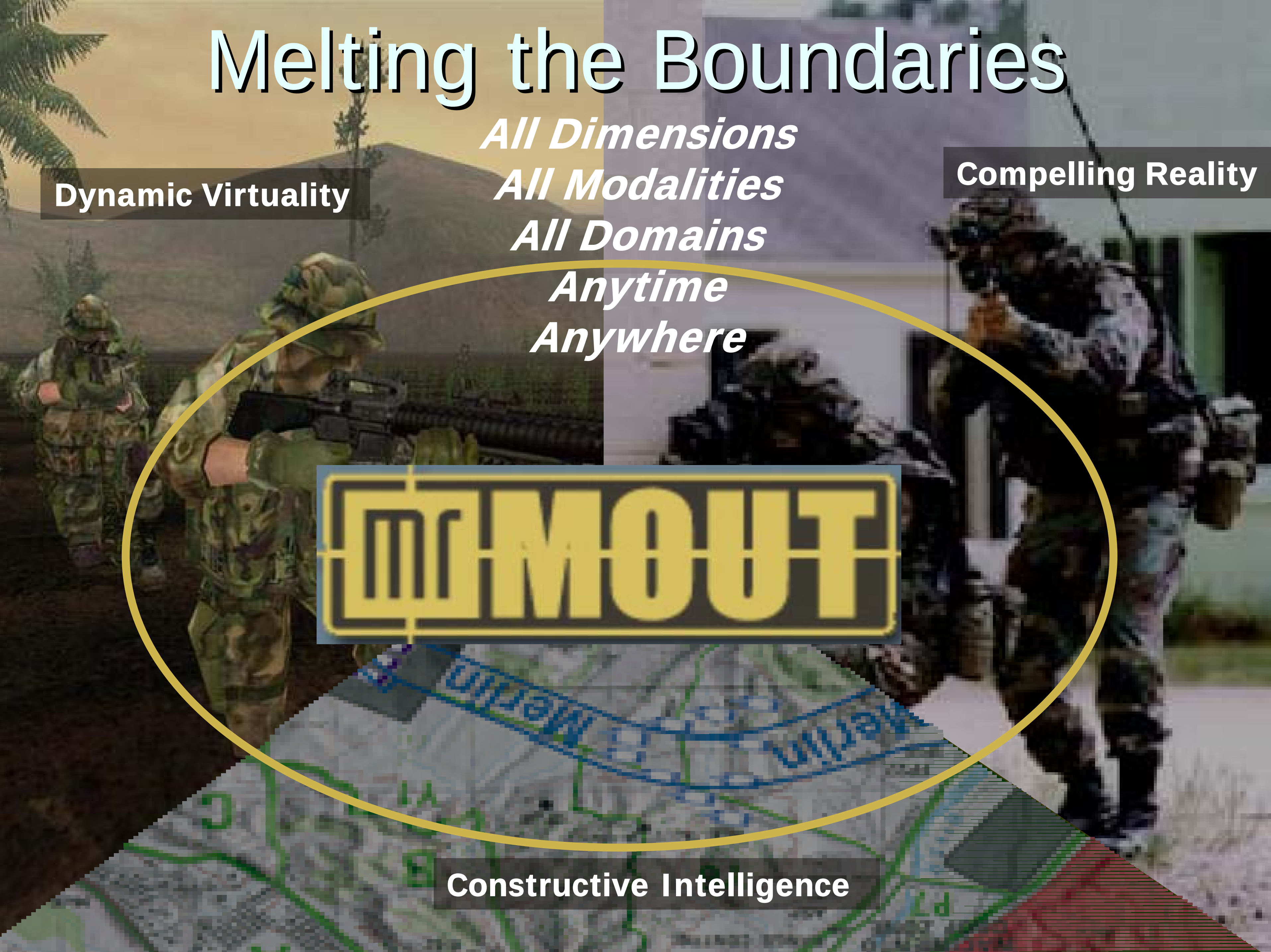

Dynamic Virtuality

Compelling Reality

Dynamic Virtuality
Compelling Reality
Constructive Intelligence

Melting the Boundaries





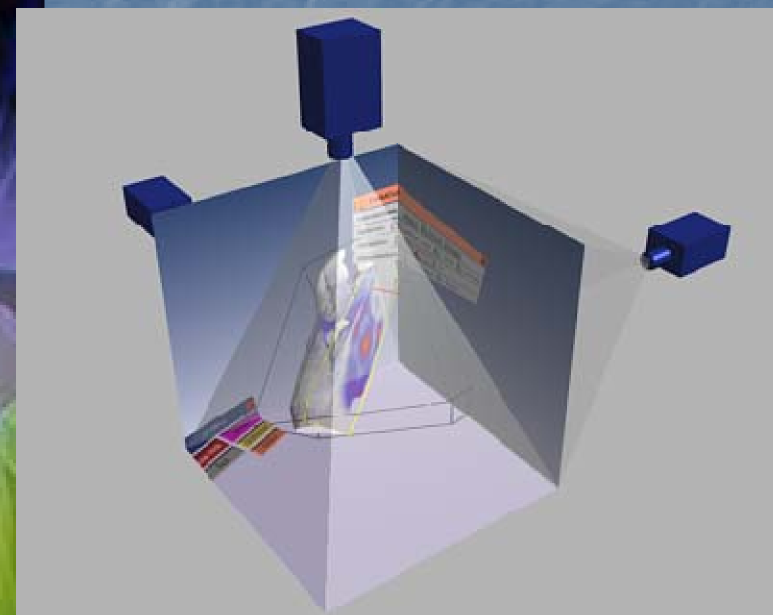
Melting the Boundaries
All Dimensions
All Modalities
All Domains
Anytime
Anywhere
Dynamic Virtuality
Compelling Reality
MR MOUT
Constructive Intelligence

Common Limitations

CAVES, Flats, Overlays

Milgram’s Continuum

Immersion beyond the projection screen

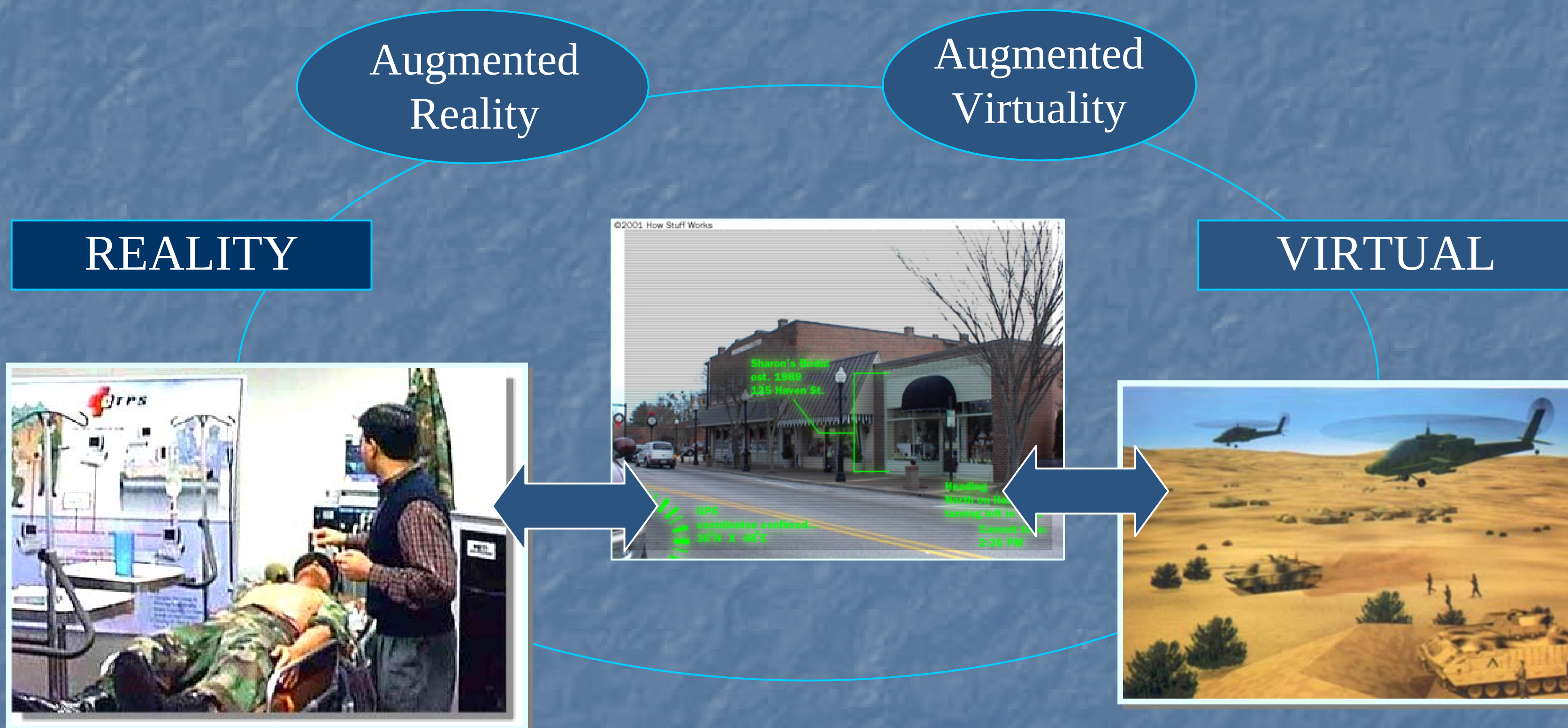


CAVE

Not confined to exist in a preset environment

Beyond 3D Spatialized HUD Overlays

Milgram's Reality-Virtuality Continuum

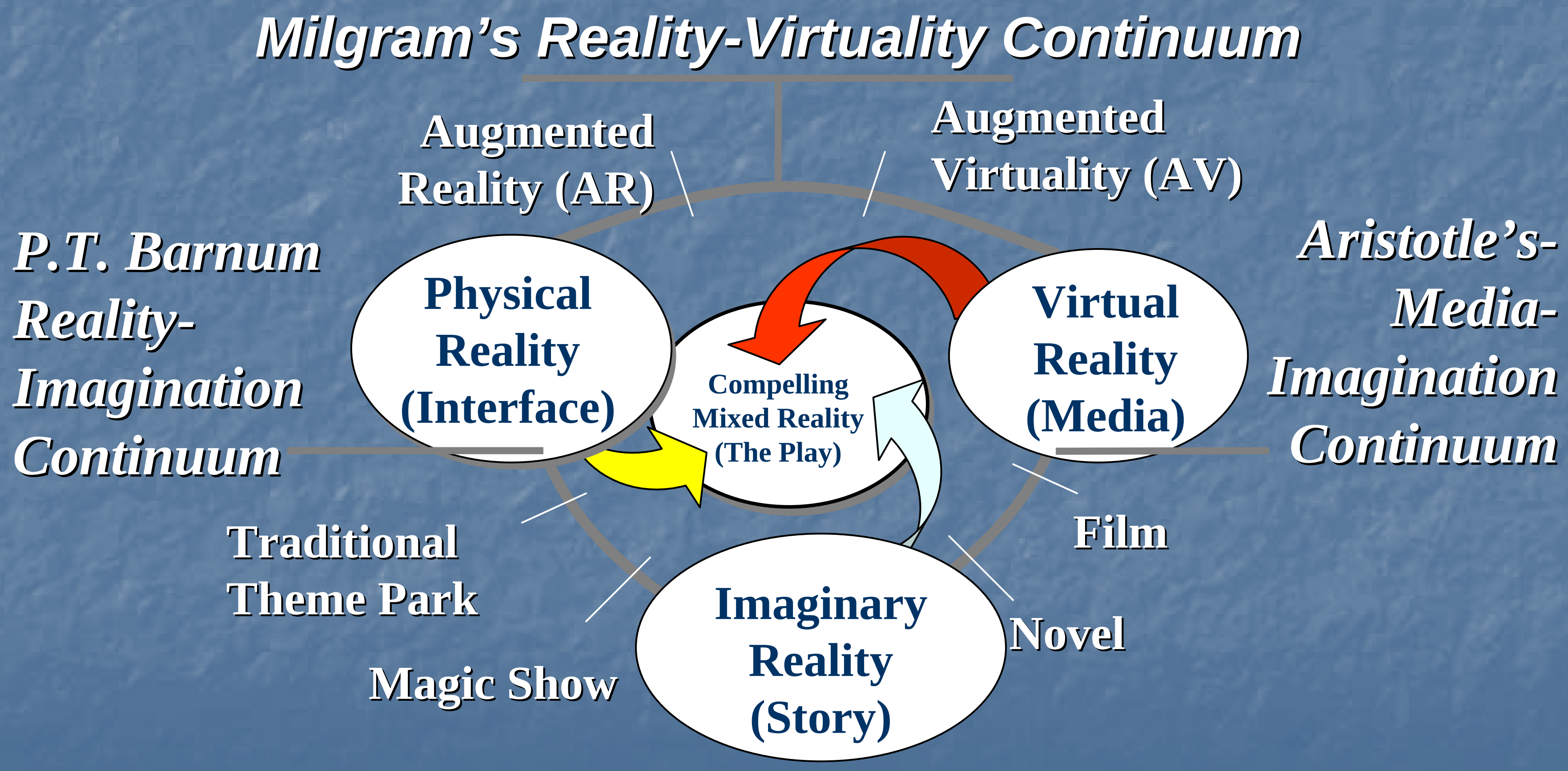


Hybrid Simulation

Live Simulation

Virtual Simulation

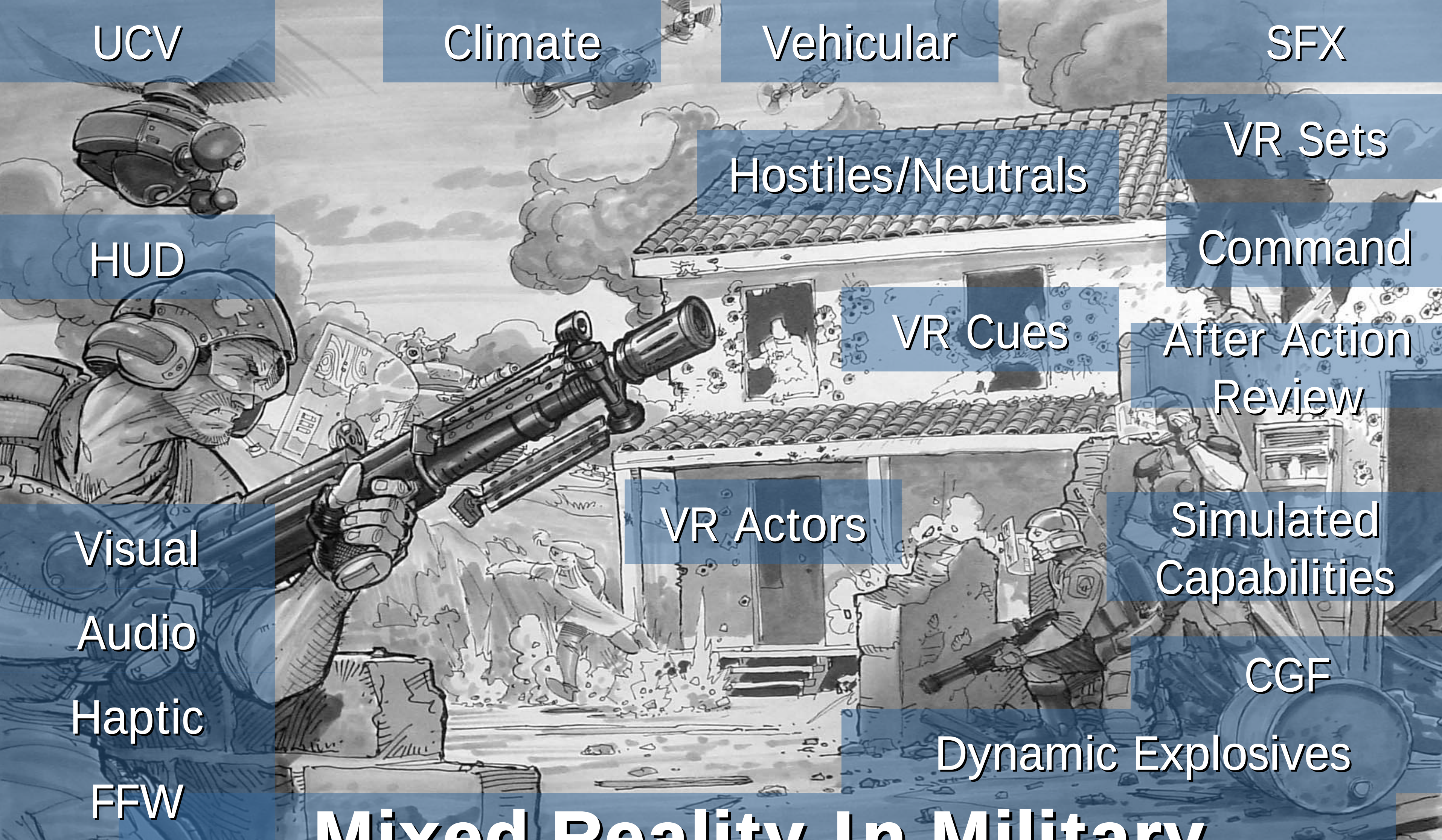
Mixed Fantasy Continuum (adding imagination)



Producing an Experience

Concept Story + Artistic Rendering
Animatic (one POV, rough work)
VR (many POVs, interaction points)
Refined Models and Primitive Animations
Mixed Reality Experience

Eileen Smith
Matt O'Connor, Scott Malo, Darin Hughes,
Nick Beato, Scott Vogelpohl,
Shane Taber, Theo Quarles, Peter Stepniewicz



Mixed Reality In Military Operations in Urban Terrain

MR MINI-MOUT

Asset Planning

Virtual Set From MOUT 3.0

Virtual Urban Surroundings

Extend world, provide imposters and occlusion models

Under 20000 triangles
Multiple textures

Animatic

Merging Realities

MR SEA at Science Center

- New experience at a science center
- Extend existing Dino Digs exhibit
- See (real) dinosaurs and bones
- Water (virtual) fills the hall; you are underwater in prehistoric times
- You can navigate to find bones
- Your vehicle vacuums up bones, extracts DNA and recreates reptiles
- If you are not good at finding bones, a giant tortoise comes and leads you
- At end of experience, water recedes and you see real bones again

MR SEA at ISMAR

- Redoes experience but with Demo Dome; two players
- Navigation and observation is a shared experience
- You can shine (virtual) light on bone, as it passes through DNA analyzer; light is cast on other player with shadow of bone

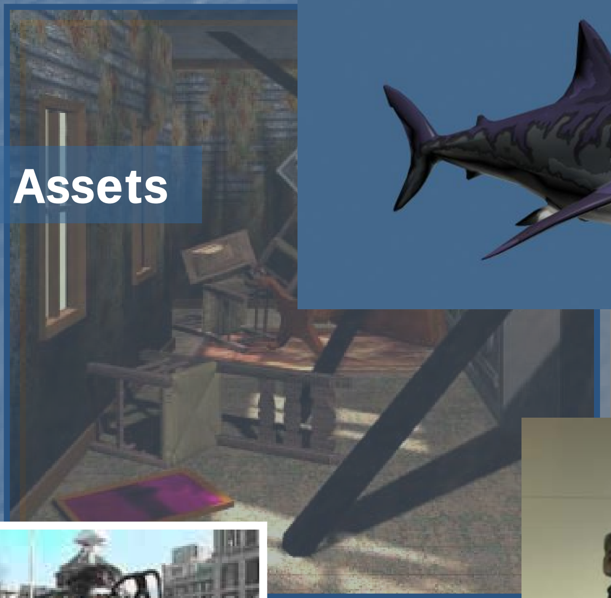
Under the Hood

Technologies
Engines
(story, graphics, audio, SFX)
Science

Technologies

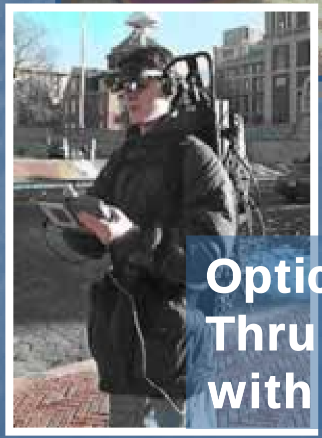
HMD
Tracking
Light Acquisition
Audio
Special Effects
Soon (3d scanner, depth camera)

Tools of the Trade



Virtual Assets

Video See-Thru Display with Tracker



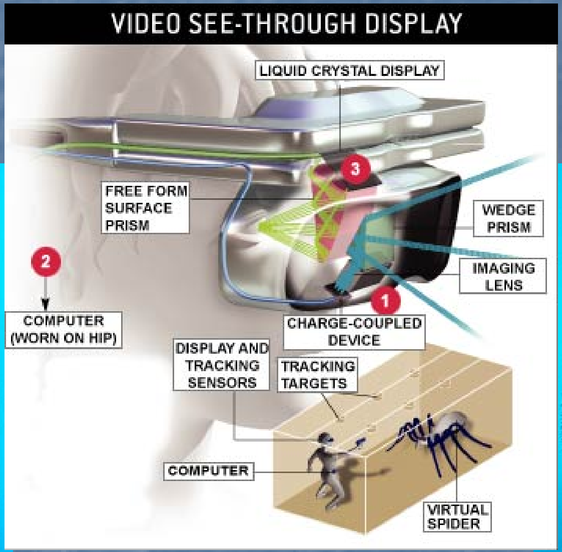
Optical See-Thru Display with GPS

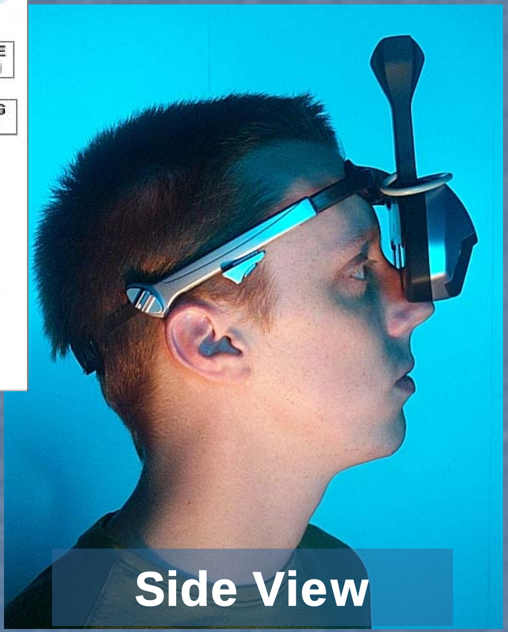
Desktop and

Embedded Projection Display

Canon Coastar HMD
(Video See-Thru)

Front View





Side View

Tracking

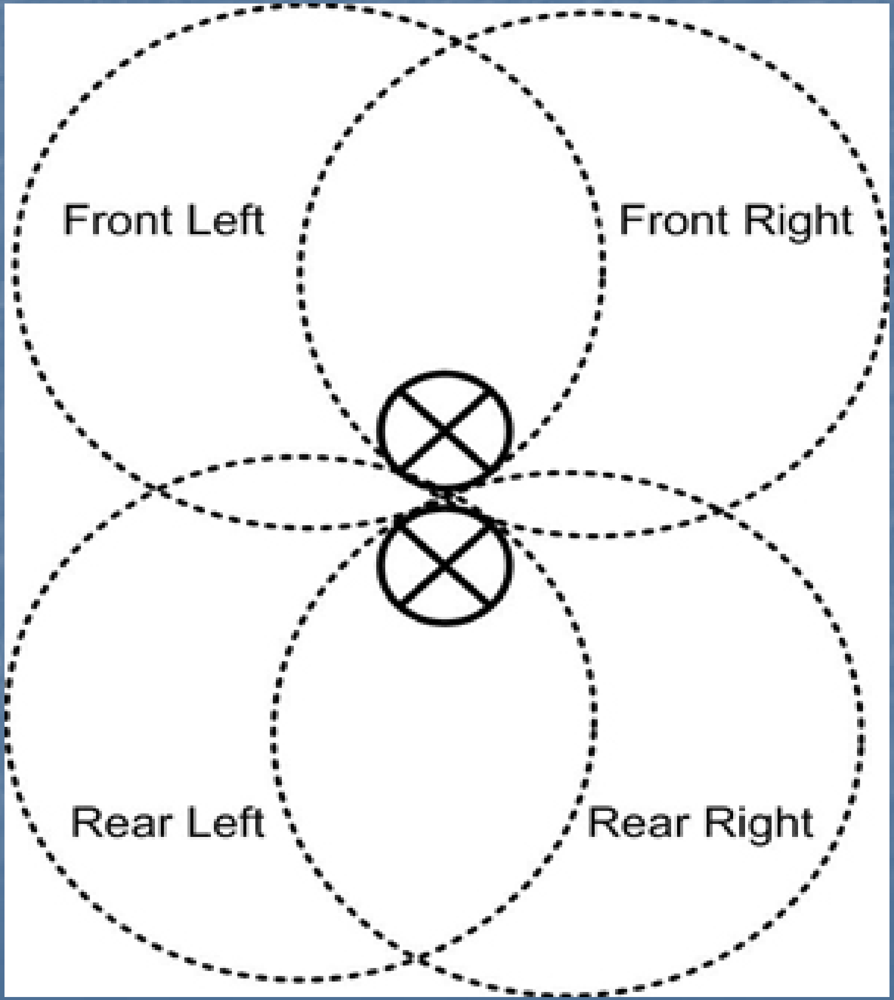
- Acoustical
- Magnetic
- Optical
- Vision
  - Marker-based
  - Shape-based

Capturing Real Light

Lady Bug Acquires Dynamic Lighting

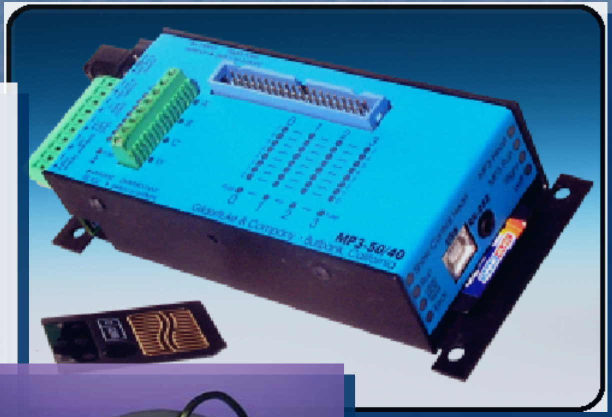
Audio Capture

- 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



Special Effects


- Colorkinetics SmartJack3 (USB to DMX)
- Colorkinetics JuiceBox2 / iColor MR Lights
- Gilderfluke MP3-50/40
- 4 Channel Dimmer Packs
- Pneumatic / Smoke System
- Sound Transducers (”Bass Shakers”)



Bringing it Together

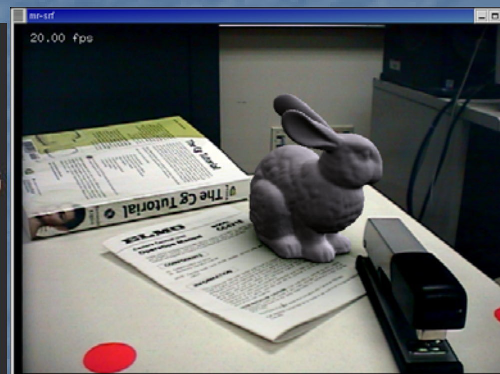
Engines

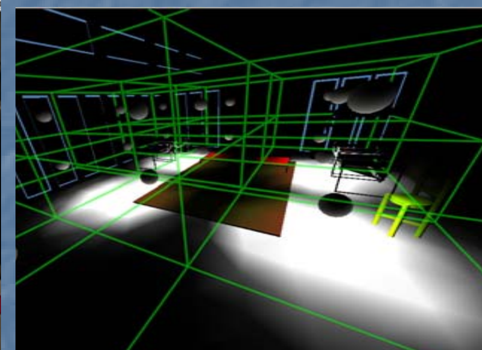
Software Infrastructure

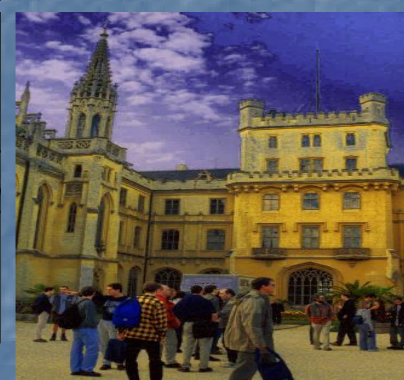
The Engines

- Story
  - XML-based agent scripting
  - soon drag and drop (Hollywood backlot)
- Graphics
  - OSG, Cal3D
  - scene analysis
- Audio
  - ambient, point, dynamic
- SFX / DMX
  - smoke, lights, many other actuators
- Simple, efficient communication protocol

Contributing Science







Illumination and Shadows

Sumanta Pattanaik
Erik Reinhard
Matt O'Connor (former UG, now IST)
Jaakko Kontinnen (UG senior)
Ruifeng Xu (PhD student)
Ahmet Akyuz (PhD student)
Mark Colbert (PhD student)
Jaroslov & Pascal (IRISA)

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

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

Current Method

$$
\begin{aligned}
s_L &= 1 - s + s\,\frac{\sigma_{L,\text{example}}}{\sigma_{L,\text{target}}} \\
s_a &= 1 - s + s\,\frac{\sigma_{a,\text{example}}}{\sigma_{a,\text{target}}} \\
s_b &= 1 - s + s\,\frac{\sigma_{b,\text{example}}}{\sigma_{b,\text{target}}}
\end{aligned}
$$

$$
\begin{aligned}
d_L &= d\left(\bar{L}_{\text{example}} - \bar{L}_{\text{target}}\right) \\
d_a &= d\left(\bar{a}_{\text{example}} - \bar{a}_{\text{target}}\right) \\
d_b &= d\left(\bar{b}_{\text{example}} - \bar{b}_{\text{target}}\right)
\end{aligned}
$$

$$
\begin{aligned}
L_{\text{target}} &= s_L\left(L_{\text{target}} - \bar{L}_{\text{target}}\right) + \bar{L}_{\text{target}} + d_L \\
a_{\text{target}} &= s_a\left(a_{\text{target}} - \bar{a}_{\text{target}}\right) + \bar{a}_{\text{target}} + d_a \\
b_{\text{target}} &= s_b\left(b_{\text{target}} - \bar{b}_{\text{target}}\right) + \bar{b}_{\text{target}} + d_b
\end{aligned}
$$

The Parameter d and s

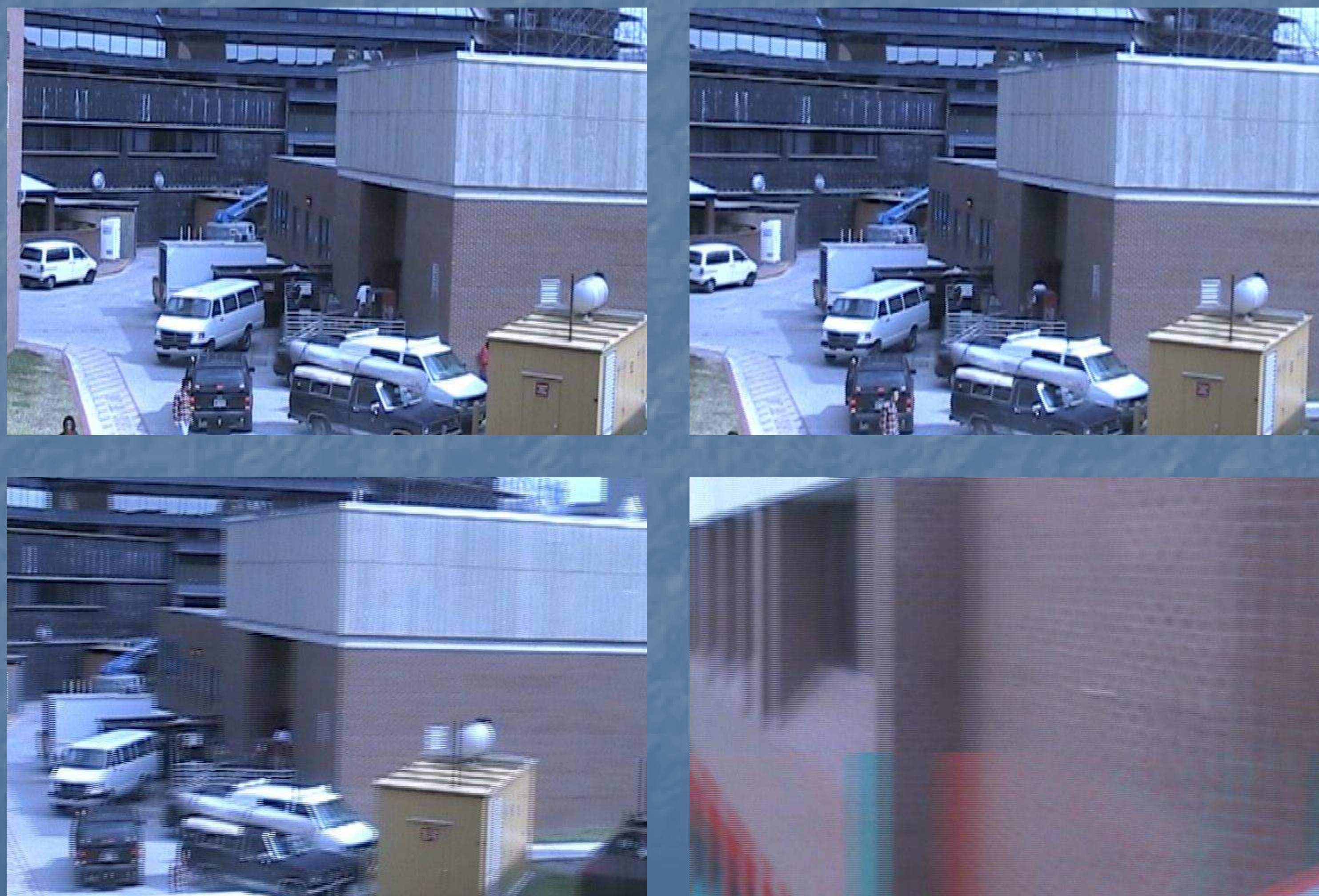
- User selected control and degree of shift toward source's variance and mean, respectively
- In current experiments we use s= 0.4 and d = 0; set and forget

Video Samples

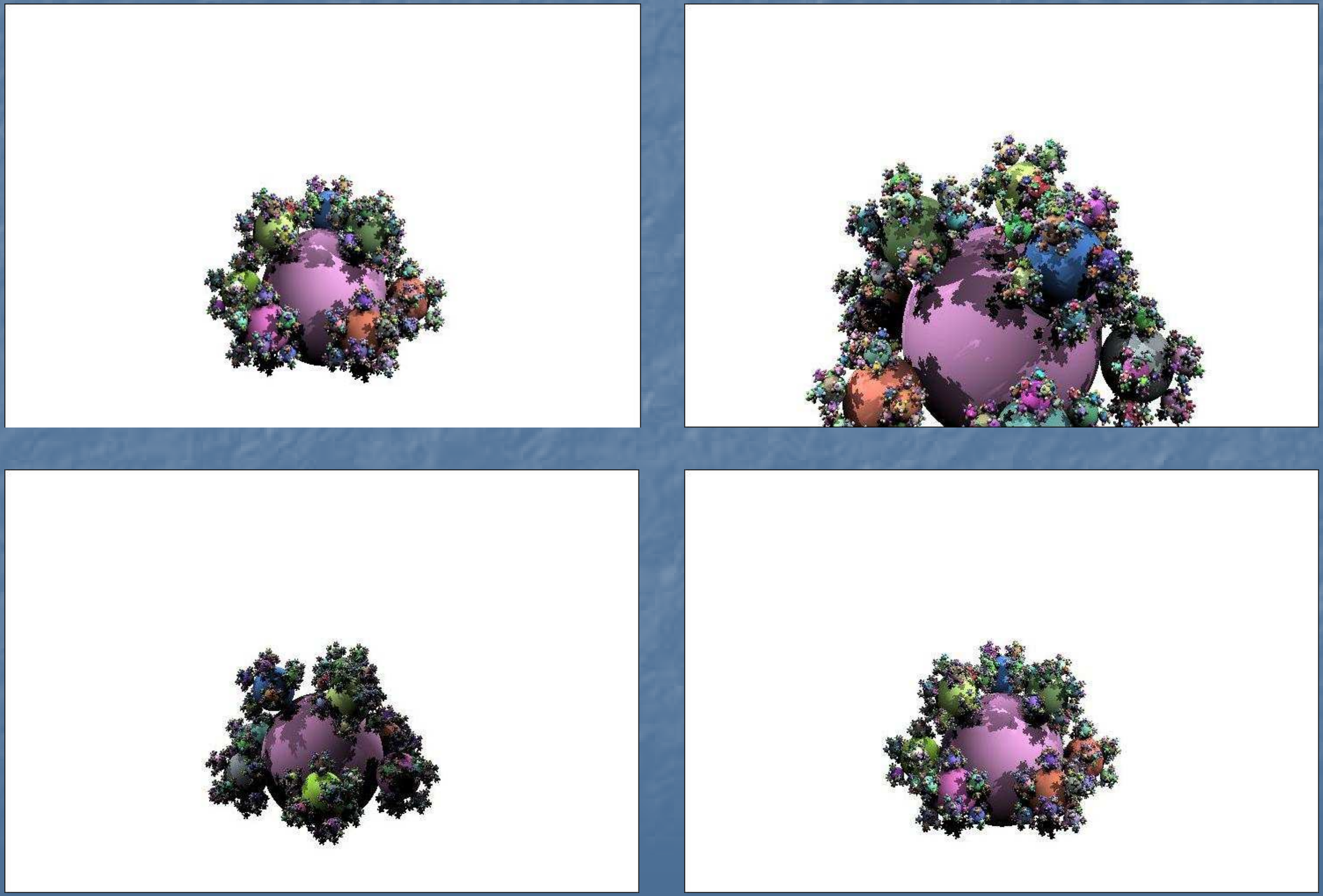
- Logo Uncorrected

- Logo Corrected
  - d=0; s=0.4

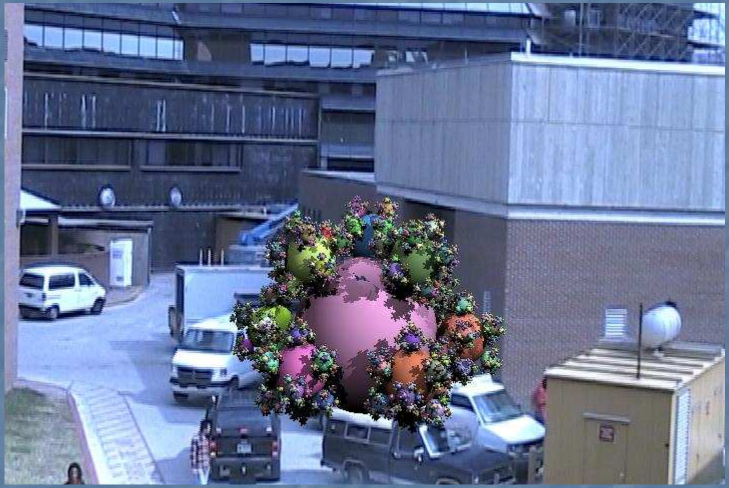
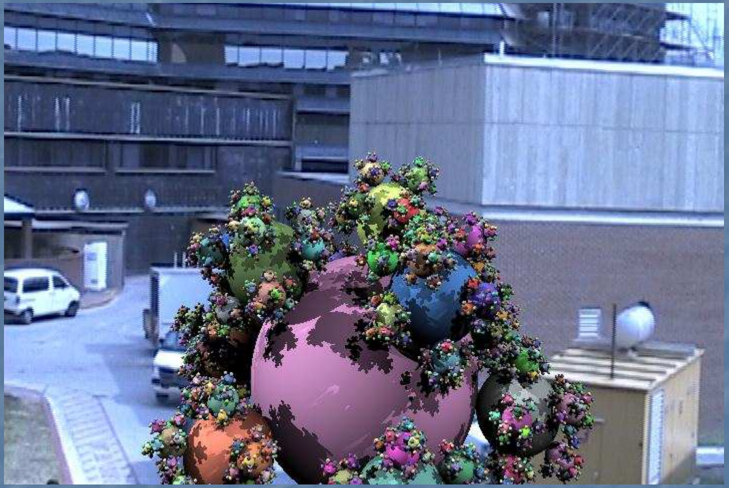
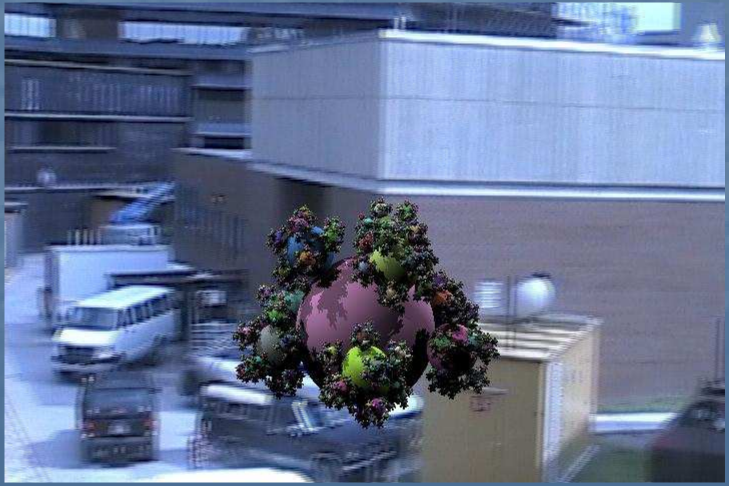
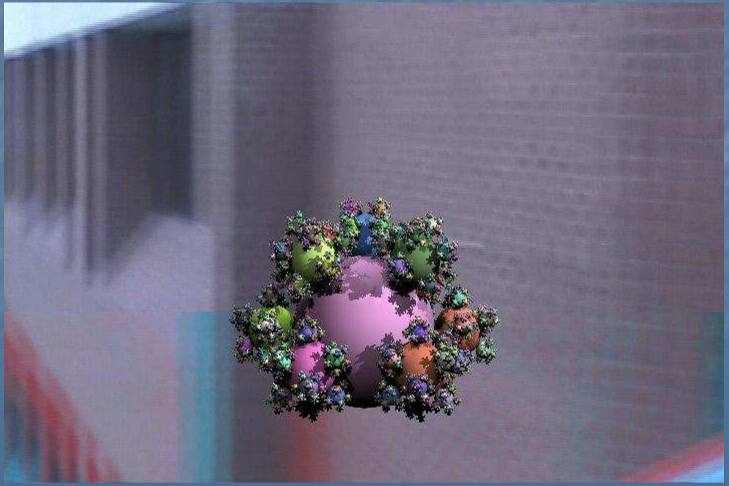
Frames in Video Sequence



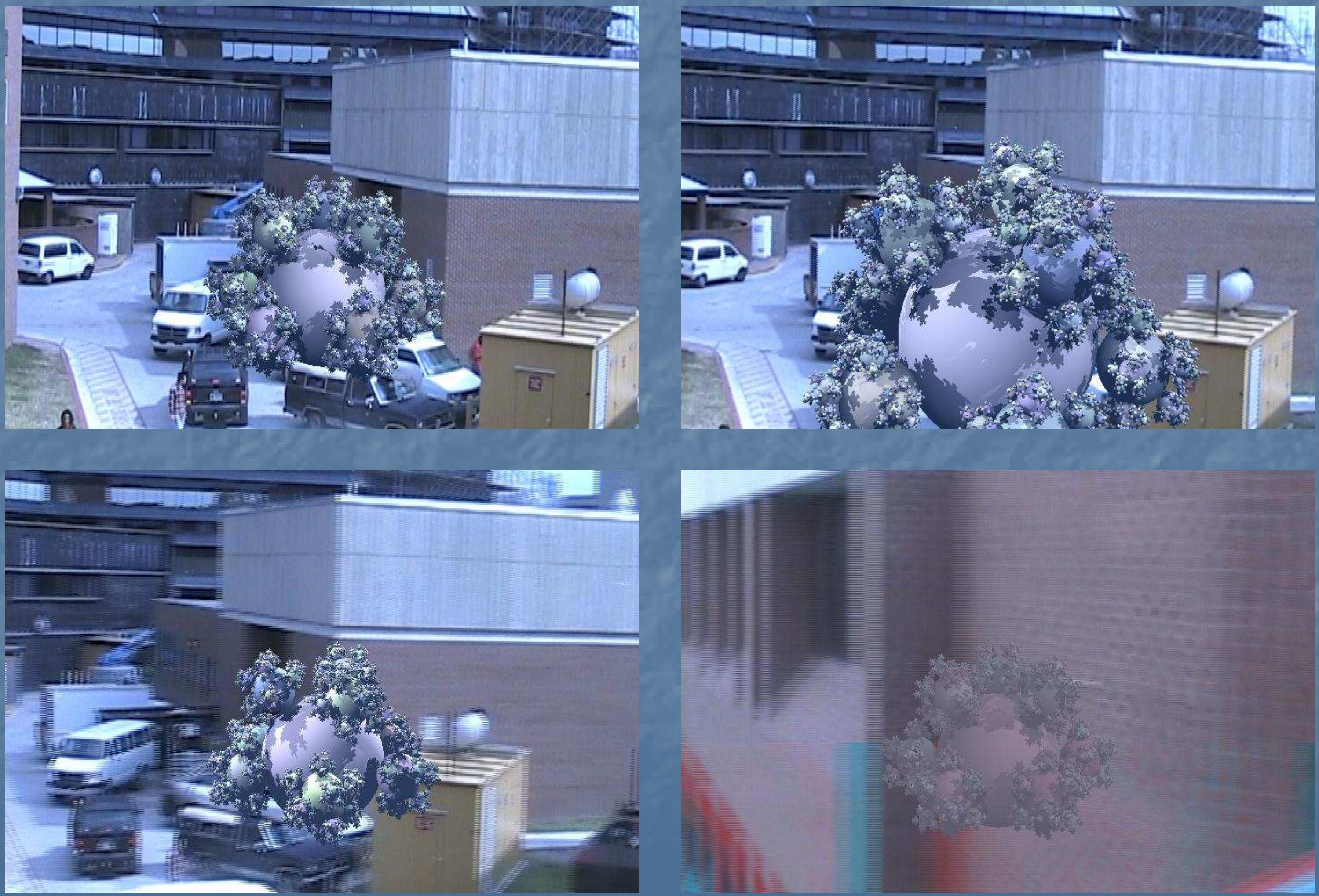
Frames in Animation



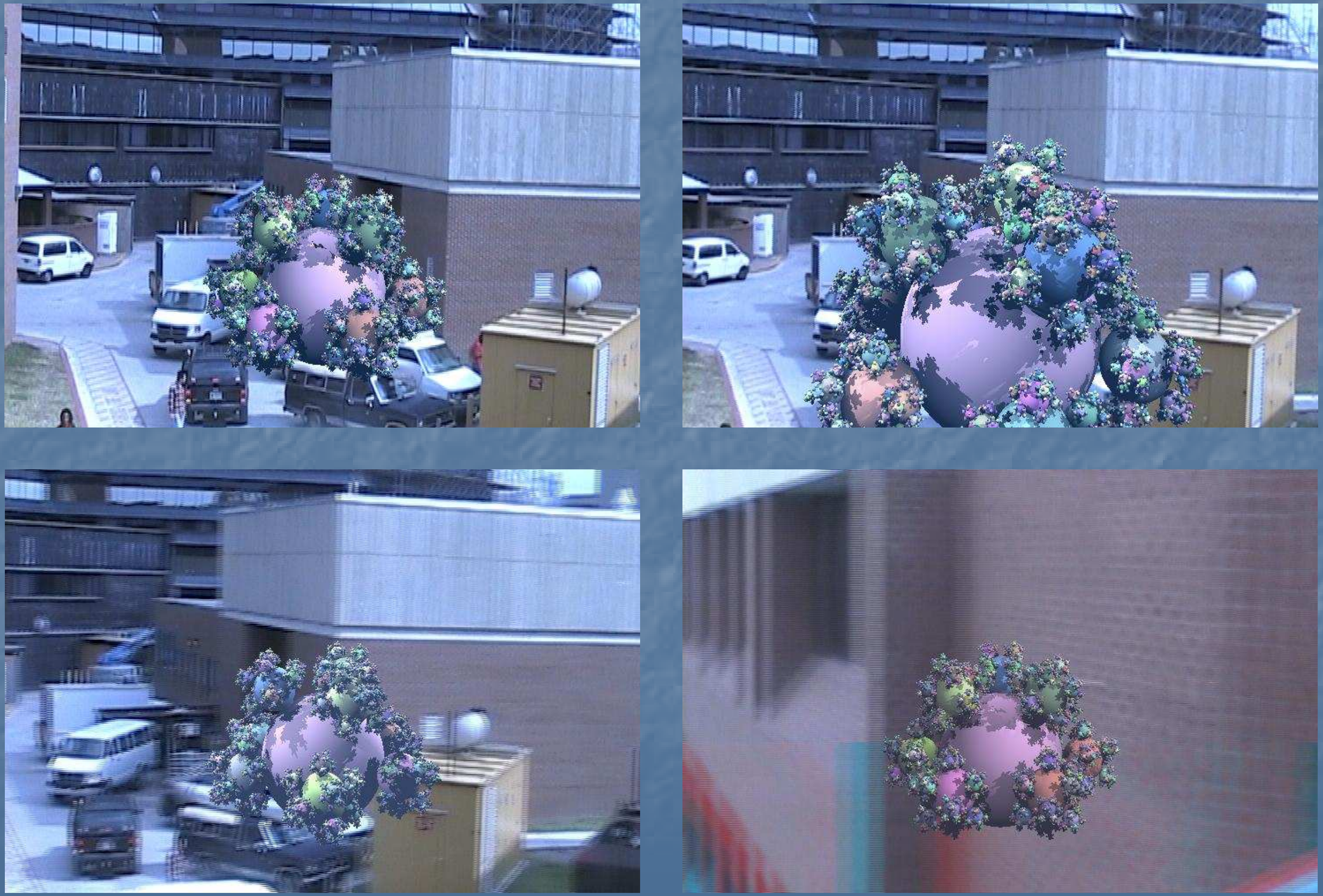
No Color Adjustments

Full Color Adjustments



Partial (s=.4) Adjustments



Frame Rates

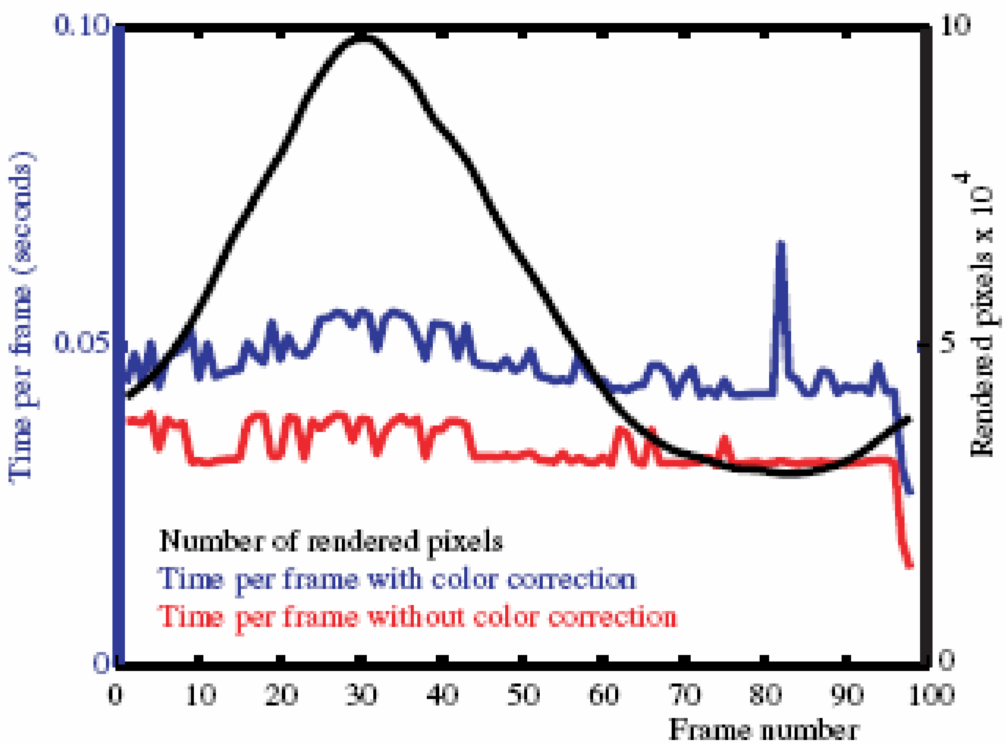


Figure 6: *Frame times and rendered pixels as function of frame-number.*

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 ...

Shadows & Fire

Sumanta Pattanaik

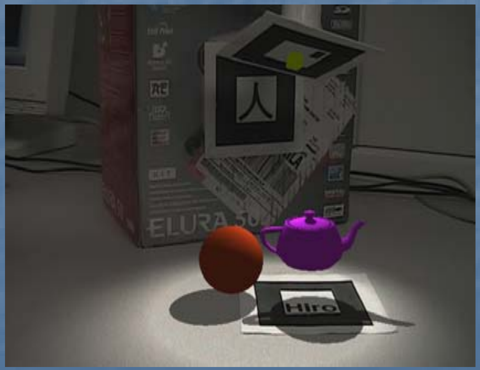
Markers used but techniques are independent of tracking method

Virtual Light Process

(a) Original

(b) Partially Darkened

(c) V to R Shadows

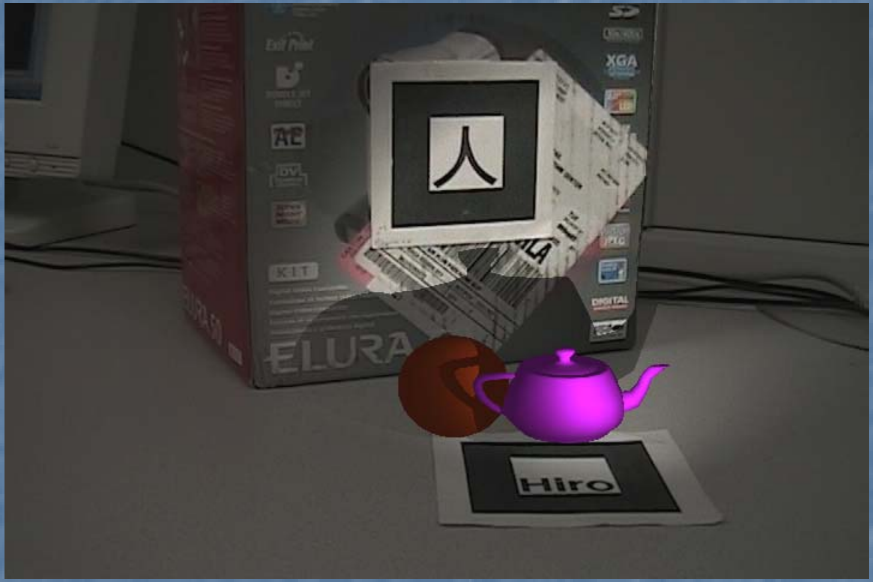


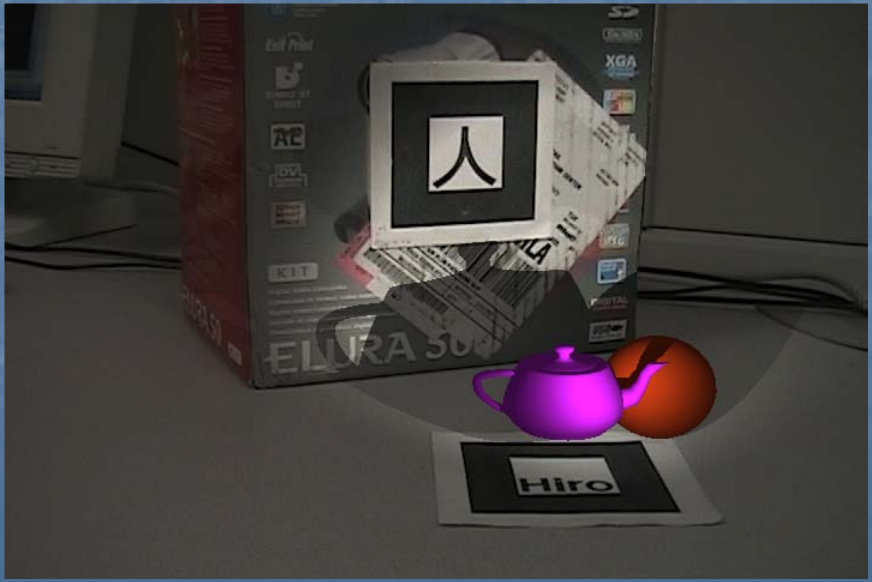
(f) Final

(e) Unlit V Objects

(d) Added V Light

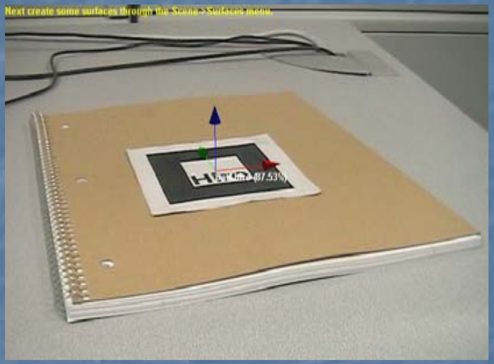
Dynamic Shadow Volumes



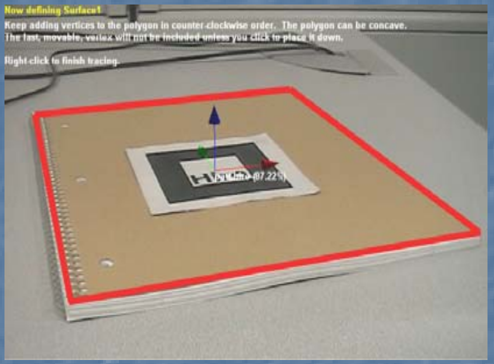


Phantoms and Fire

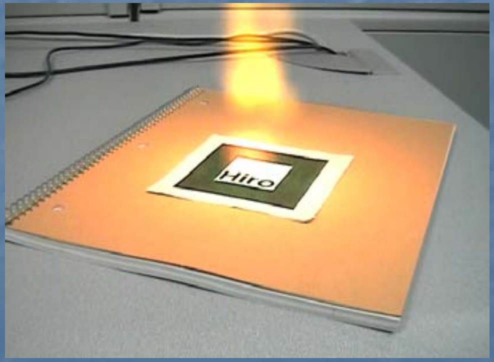
(a) Notebook



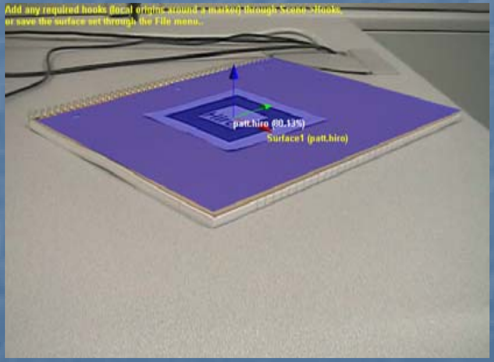
(b) Marker Placed



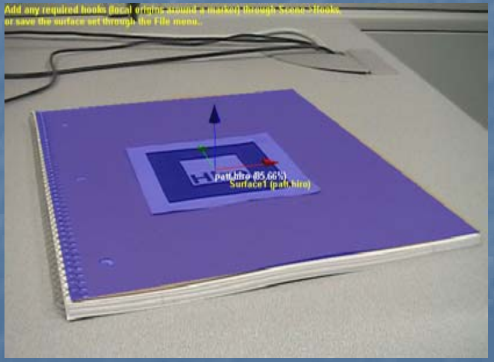
(c) Surface Polygon



(f) Lit by V Fire



(e) Different Angle



(d) 3D Phantom

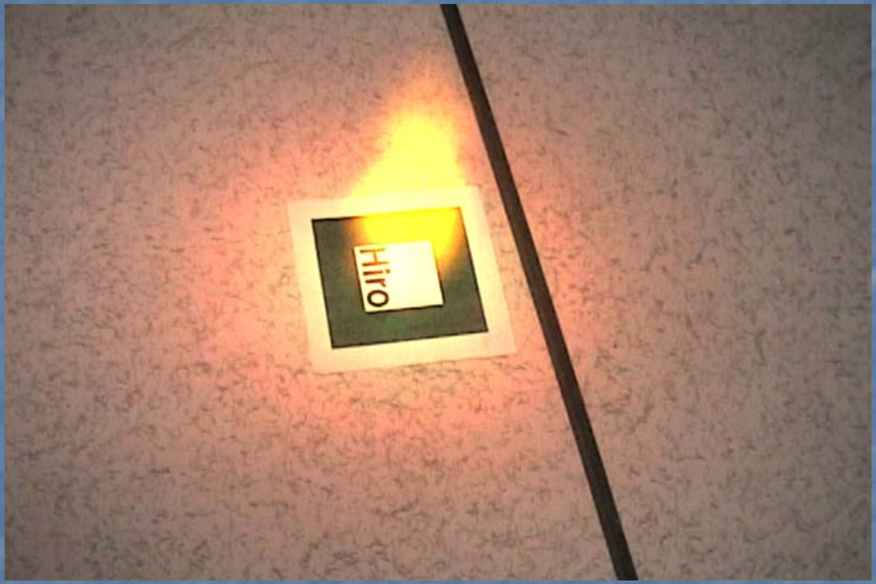
Illumination by Virtual Fire

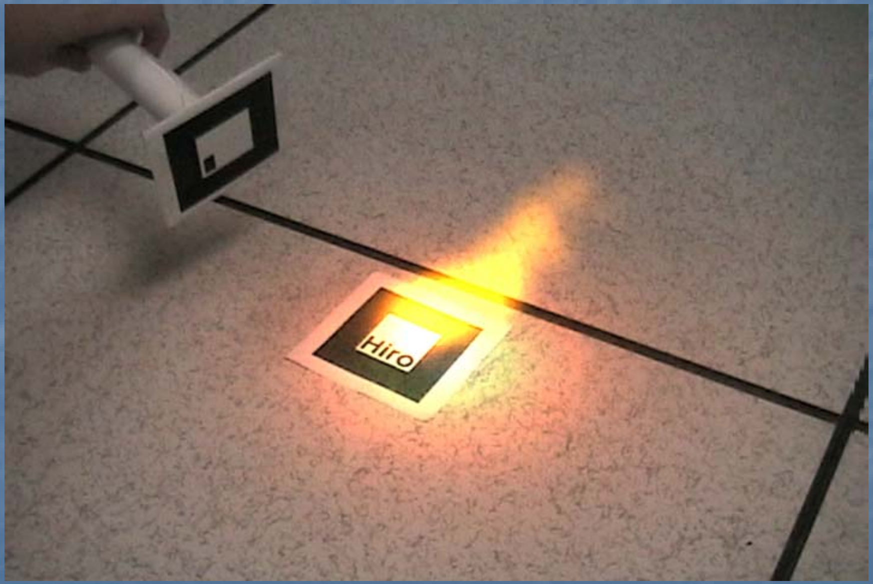
(a) Original

(b) Illuminated

(c) Composed

Effects of Virtual Fan





Other Research Projects

Flicker in Fire (Adabala)

Lighting Animated Objects

Flicker in Fire

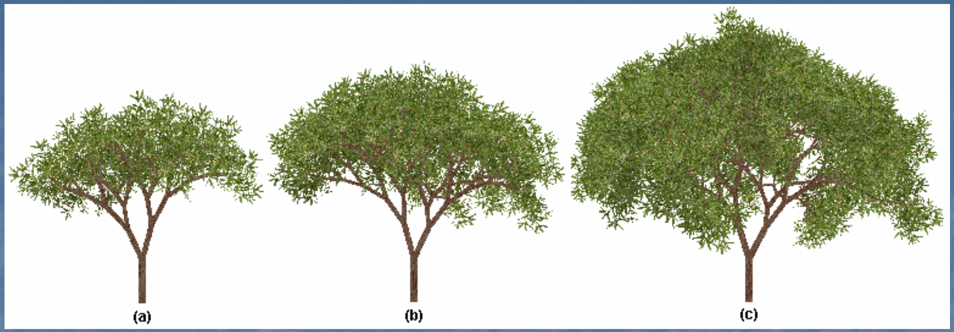
- Combine
  - Thermodynamics
  - Chemical reaction
  - GPU speed-up
- Get
  - Fire spread
  - Flicker
  - Flame brushes
  - Interactive time

Dynamic Lighting

- Combine
  - Precomputed radiance
  - Animation sequence
  - Compression
  - GPU speed-up
- Get
  - Rendering with
    - Dynamic light
    - Dynamic motion
  - Interactive time

Yet Other Projects

- Continuation of forest work (Paulius, Kadi, Julien)
- Dynamic shared state maintenance in distributed interactive VEs (Kadi, Jean-Eudes)
- Adding emotion to characters (Wu, Fabrice)
- Linkage with semi-automated forces (Garfield)
- Depth perception in MR (Paulius, Hassan Foroosh, Eric Marchand)
- MR audio
- New audio tools for production and delivery
- Audio expectation
- L systems & training sets (Kadi, Julien)
- Media asset management (with EA)



Virtual Forest

J. Michael Moshell
Paulius Micikevicius

Research Underlying Trees

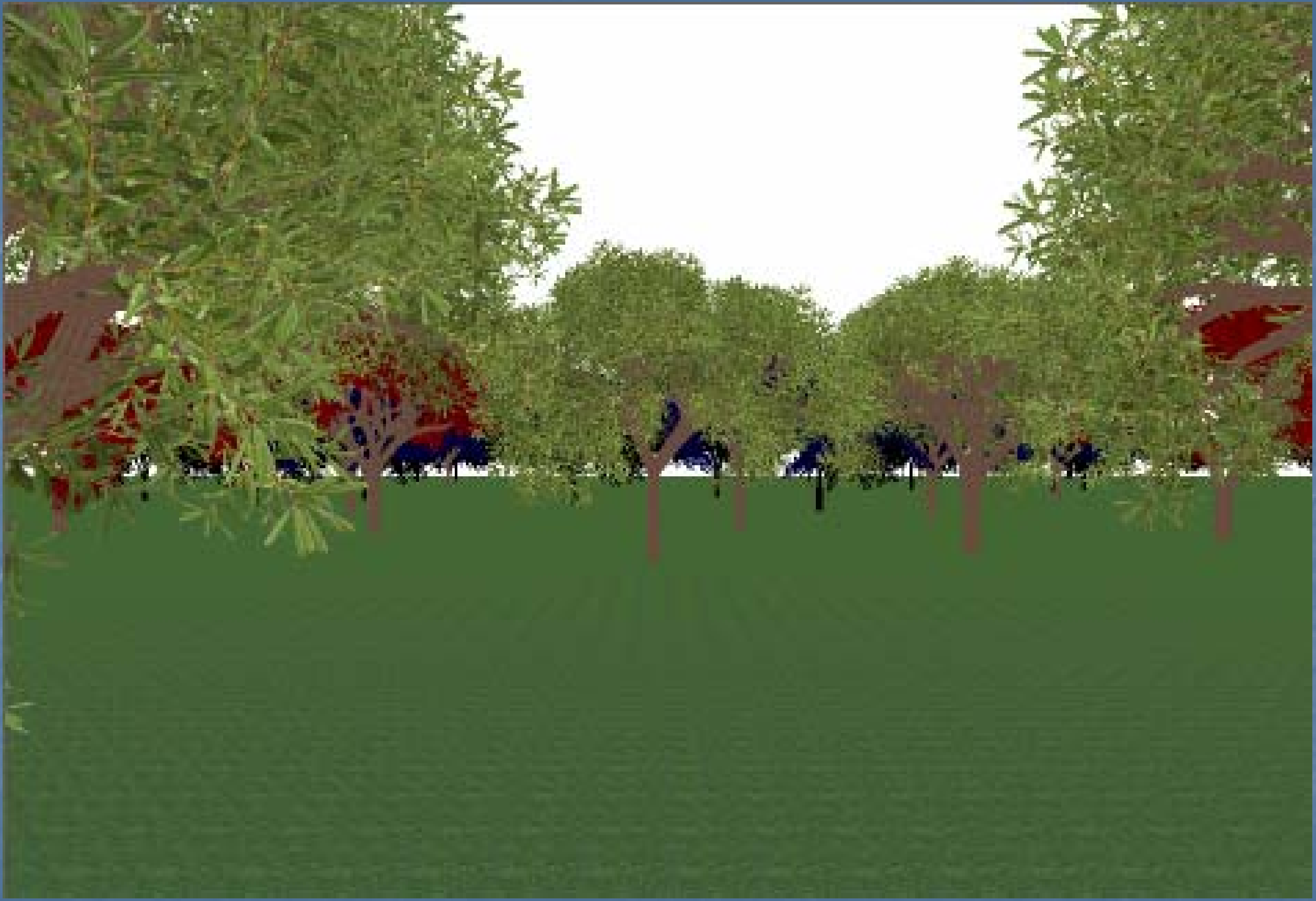
- Large scenes of vegetation
  - forests, fields, *etc.*
  - thousands to millions of <u>unique</u> trees
- Biologically accurate models
  - trees
  - forest (context for trees)
- Realistic rendering; Interactive frame rates
- Interaction with vegetation
  - accelerating the growth rate; changing fire rate; drought
  - fluttering in winds; breaking branches, trees
- Applications
  - informal science education
  - urban planning
  - search and rescue training

Challenges

- Computationally intensive
  - "growing" the forest
    - L-System for biological correctness and variations
    - plant interaction
    - fires, droughts, *etc.*
  - rendering the forest
    - each tree is unique and has complex geometry
    - a large number of trees can overwhelm current graphics hardware

Our Research

- Increasing the frame rate
  - LOD models for the trees
  - framework for selecting LOD at run-time
    - no pre-computation step
  - Parallelization
- Determining emphases
  - Perception as a basis to emphasize what matters (Valerie Sims, Psychology)



Visual Cues Showing Various LODs (red / blue / black)

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- Sumanta Pattanaik – sumant@cs.ucf.edu
- Erik Reinhard – reinhard@cs.ucf.edu
- Mike Moshell – j.m.moshell@cs.ucf.edu

Our Laboratories

- IST Media Convergence Laboratory – http://mcl.ucf.edu
- CS Graphics Laboratory – http://www.cs.ucf.edu/graphics/
- Joint use Simulation Training Center

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Other Faculty Collaborators (partial list)

- Paulius Micikevicius – post-doc, now faculty in Georgia
- Hassan Foroosh – CS, vision-based registration
- Valerie Sims – psychologist, human factors

Student Collaborators (partial list)

- Ruifeng Xu – PhD student, lighting on animated objects
- James Burnett – PhD student, dynamic range
- Felix Hamza-Lup – PhD student, distr. infrastructure
- Jaakko Kontinnen – undergraduate, shadow / fire
- Peter Stepniewicz – at CMU ETC, gadgets

Staff Collaborators

- Eileen Smith – user experiences
- Matt O’Connor – chief software developer at MCL
- Darin Hughes – 3d audio researcher / producer
- Scott Malo – chief modeler and content producer
- Shane Taber, Theo Quarles – modelers

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