3D Visualization and Interaction in Hybrid Augmented Virtual Environments

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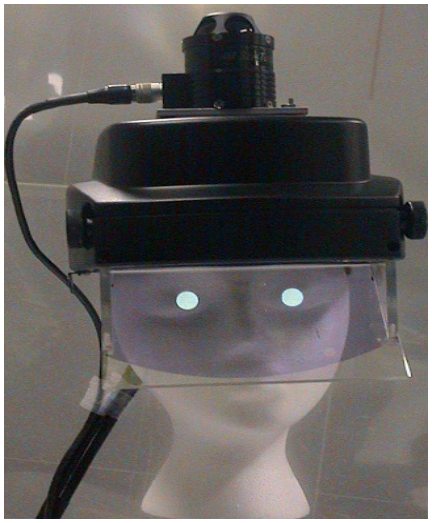
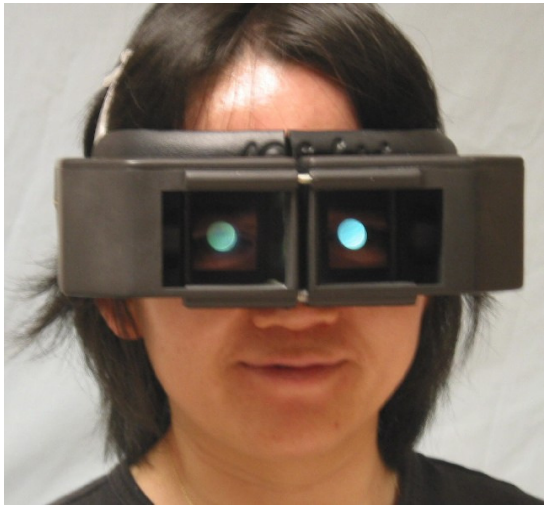
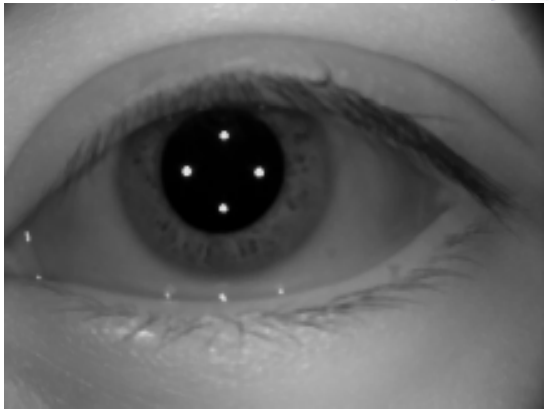
based heavily on slides by Dr. Hong Hua

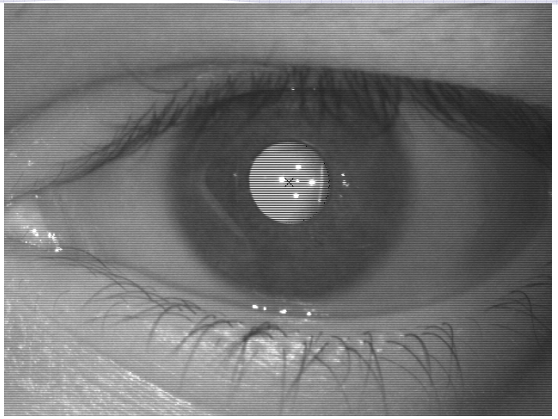
Research Projects—Stereoscopic Displays

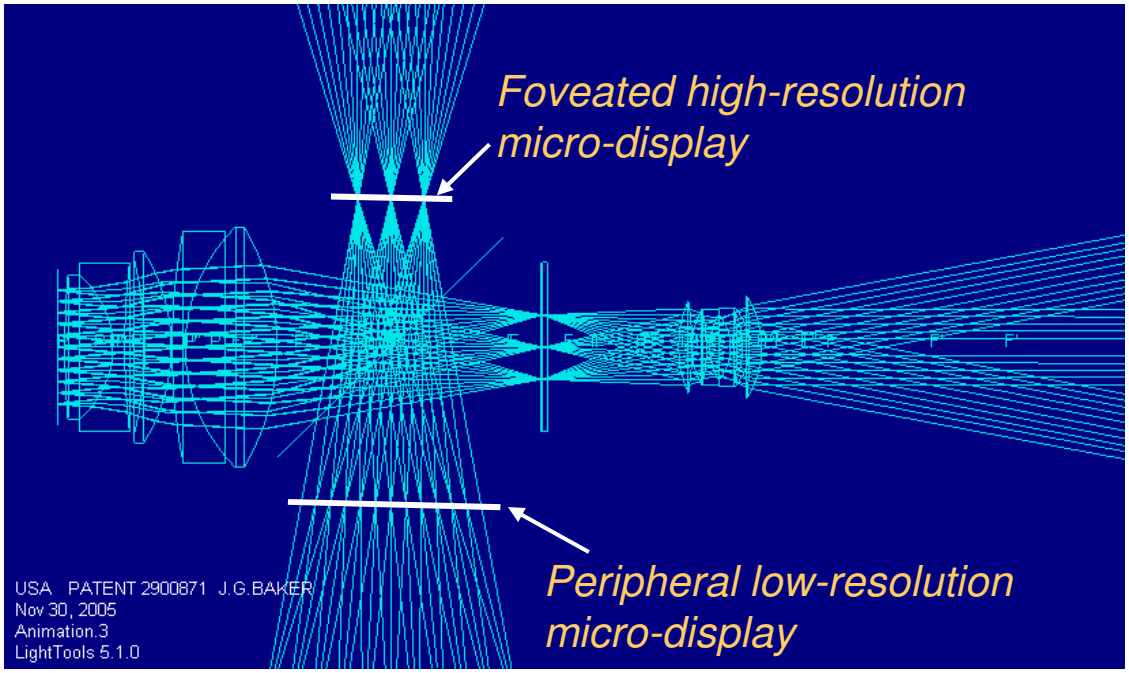




Head-mounted projection displays







Fovea Contingent head mounted displays

Objectives

- Research objective: To promote the understanding of large and very complex datasets in collaborative activities.
  - Explore the continuum of reality-virtuality
  - Explore ways of integrating heterogeneous data
  - Explore means to selective tune dataset complexity
  - Explore methods to streamline workspace, sew together

- Talk Summary:
  - What is the reality-virtuality continuum?
  - What are heterogeneous data?
  - Evolution of HMPD & SCAPE
  - Examples of augmented interfaces, applications

Virtual Reality (VR)

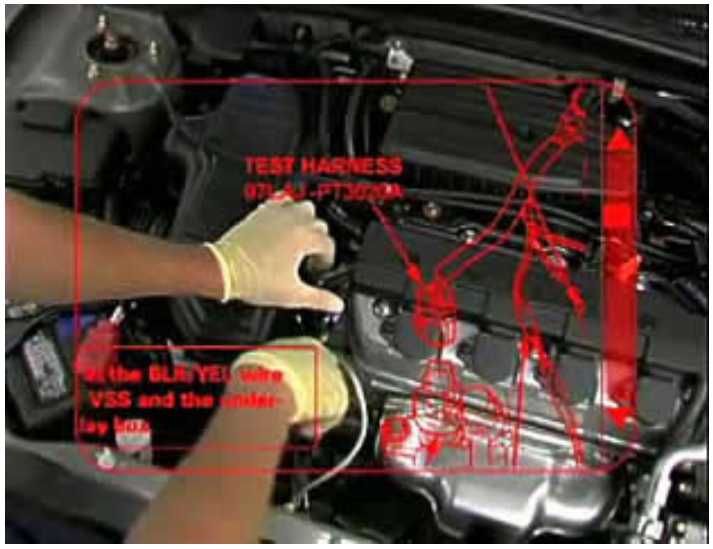
- Virtual reality creates the sense of being immersed in a computer-generated virtual world, through multiple sensorial displays (e.g. visual, auditory, tactile, smell, taste etc)
  - Imaginative: pure digital, beyond physical reality
  - Interactive: responsive to user inputs such as body motion, gesture, voice…
  - Immersive: VR aims to suspend the real world senses and emphasizes full immersion in a virtual world

NASA Ames

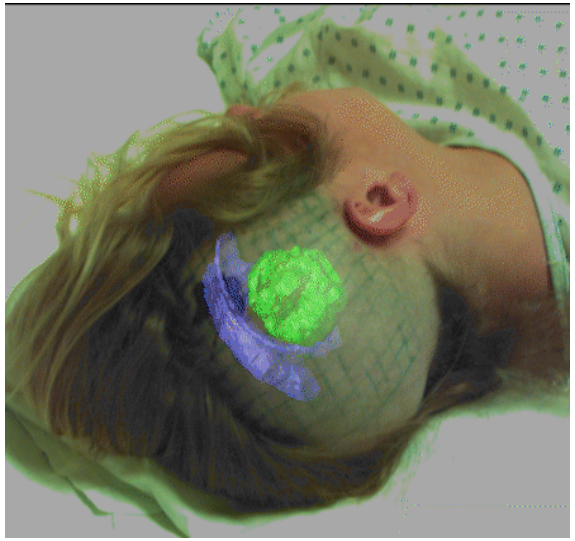
http://www.advanced.org/teleimmersion.html

Augmented Reality (AR)

- AR supplements, rather than replaces, users' perceptions of the real environment with computer-generated simulations
  - The integration of digital information into the fabric of the physical world
  - The overlaid virtual information has to be aligned with the real world senses—a process know as registration.
- It can be readily extended to other sensory forms such as sound or touch.



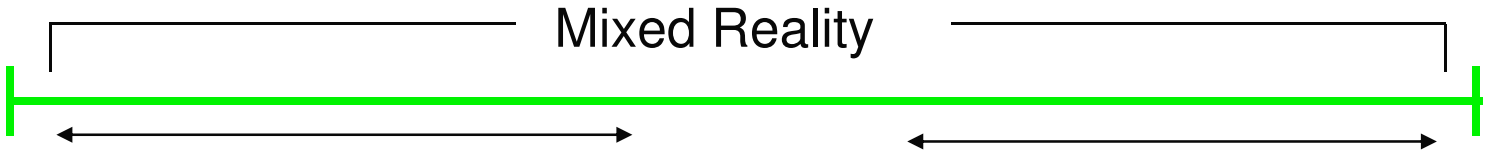
Microvision Nomad Expert System



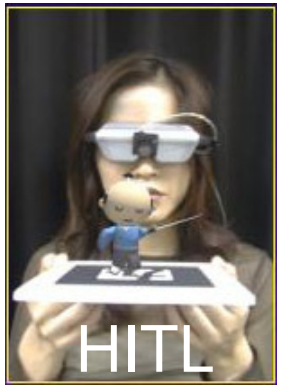
MIT AI Lab

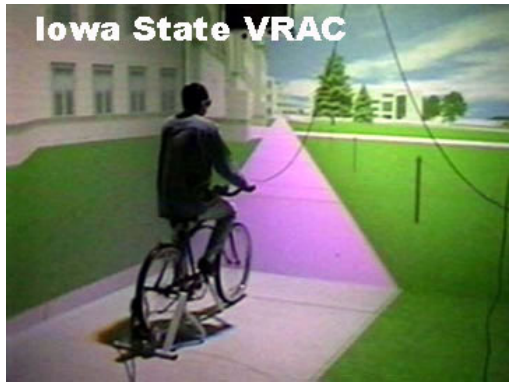
3DVIS Lab

Milgram's Reality-Virtuality (RV) Continuum



Real Environment | Augmented Reality (AR) | Augmented Virtuality (AV) | Virtual Environment





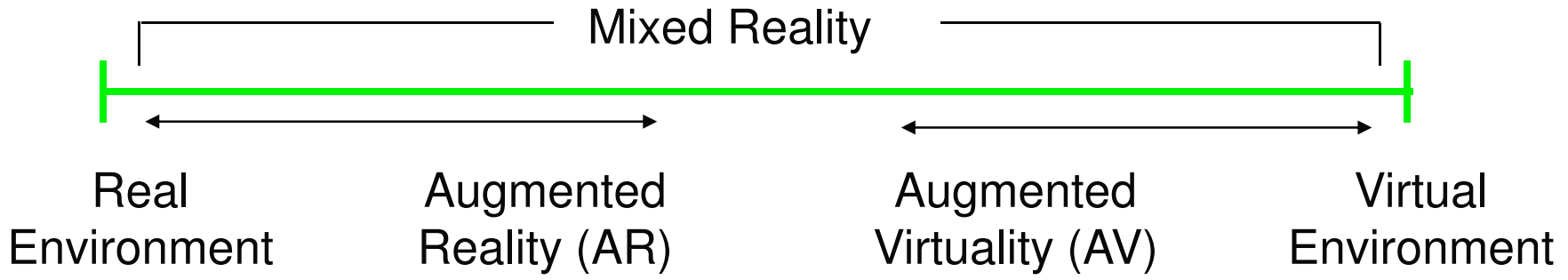
What level is appropriate for a task? Physical affordances or no?

[Milgram and Colquhoun, Mixed Reality, (Ohata ed.), 1999]
[Milgram and Kishino, IE-ICE Transactions 1994]
[Milgram, Takemura, Utsumi, Kishino. SPIE 1994]

Challenges of Traversing the RV Continuum

- Display requirements
  - VR requires a display that can create the sense of immersion and the egocentric viewpoint
  - AR requires a display with see-through capability to provide direct access to the physical world

- Visualization scale and reference requirements
  - VR requires the ability to visualize arbitrary scales
  - AR requires the overlaid virtual information be registered correctly with its physical counterparts



Dealing with Heterogeneous Complex Data

Planetary geoscientists study and correlate 2D maps of Martian topography and camera data

Immersive 3D visualization technology may be used to explore the terrain data. However, the narrow FOV prohibits the practice of correlating variety of data in a larger context.

[Images from Forsberg et al IEEE CGA 2006]

What are Heterogeneous Data Sets?

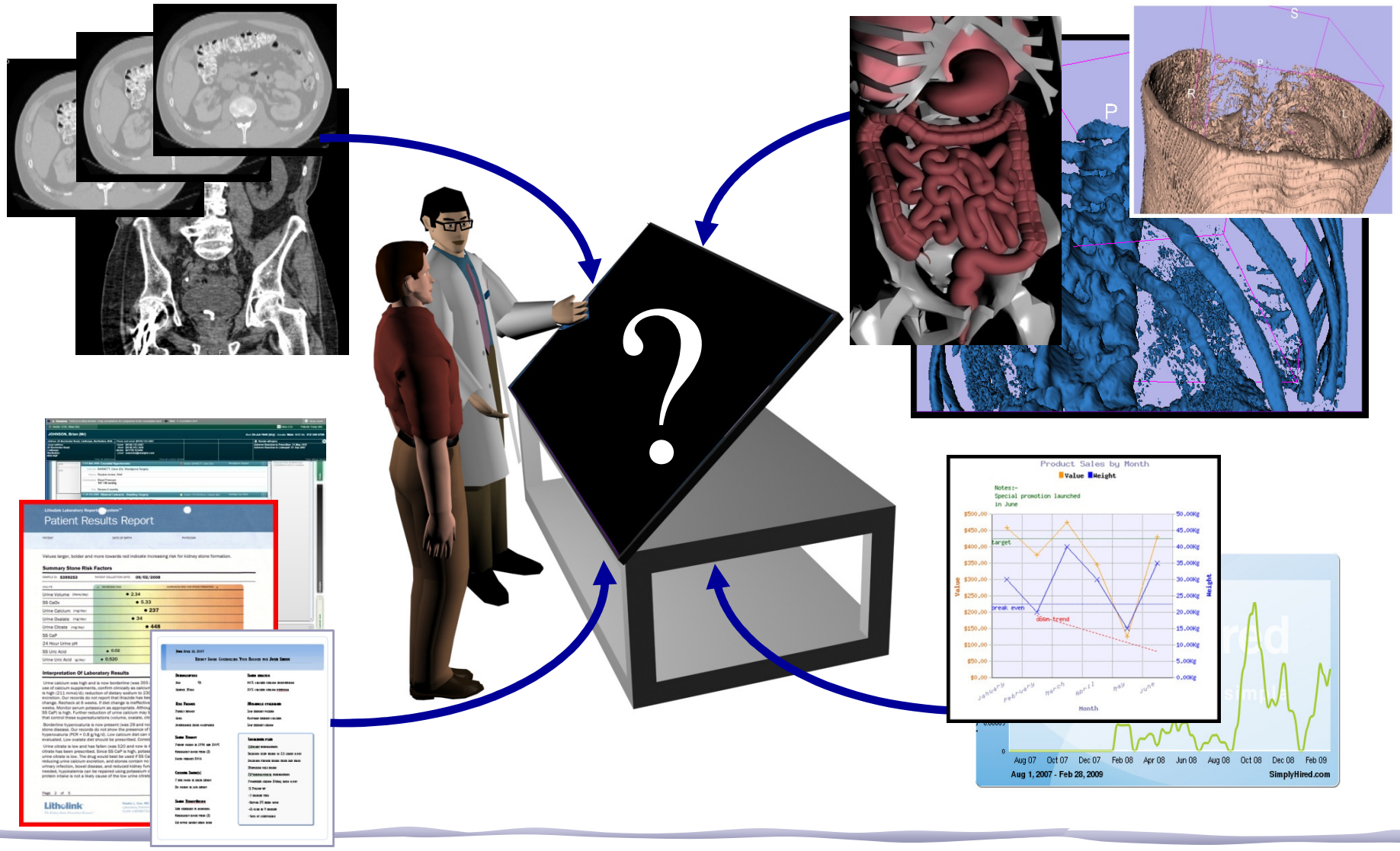
- Data sets with multiple components (contexts)
  - In contrast to Homogeneous data sets

- Mix information of differing characteristics
  - Complexity attributes (e.g. low LOD vs. high LOD)
  - Dimensionality / form factor (e.g. 2D vs. 3D)
  - Semantics (e.g. geometric vs. information tree)
  - Modality (e.g. visual vs. aural)

Challenges of Heterogeneous Data Sets

- Requirements change based on users' attention
  - Visualization (display, presentation technique)
  - Interaction (interface device, technique)
- Different levels of R-V mixing may be needed for each context
- Difficult to correlate, coordinate across contexts
- Size and diversity of data sets constantly growing
  - Increasingly prevalent in everyday applications
  - Medicine, many engineering & science disciplines

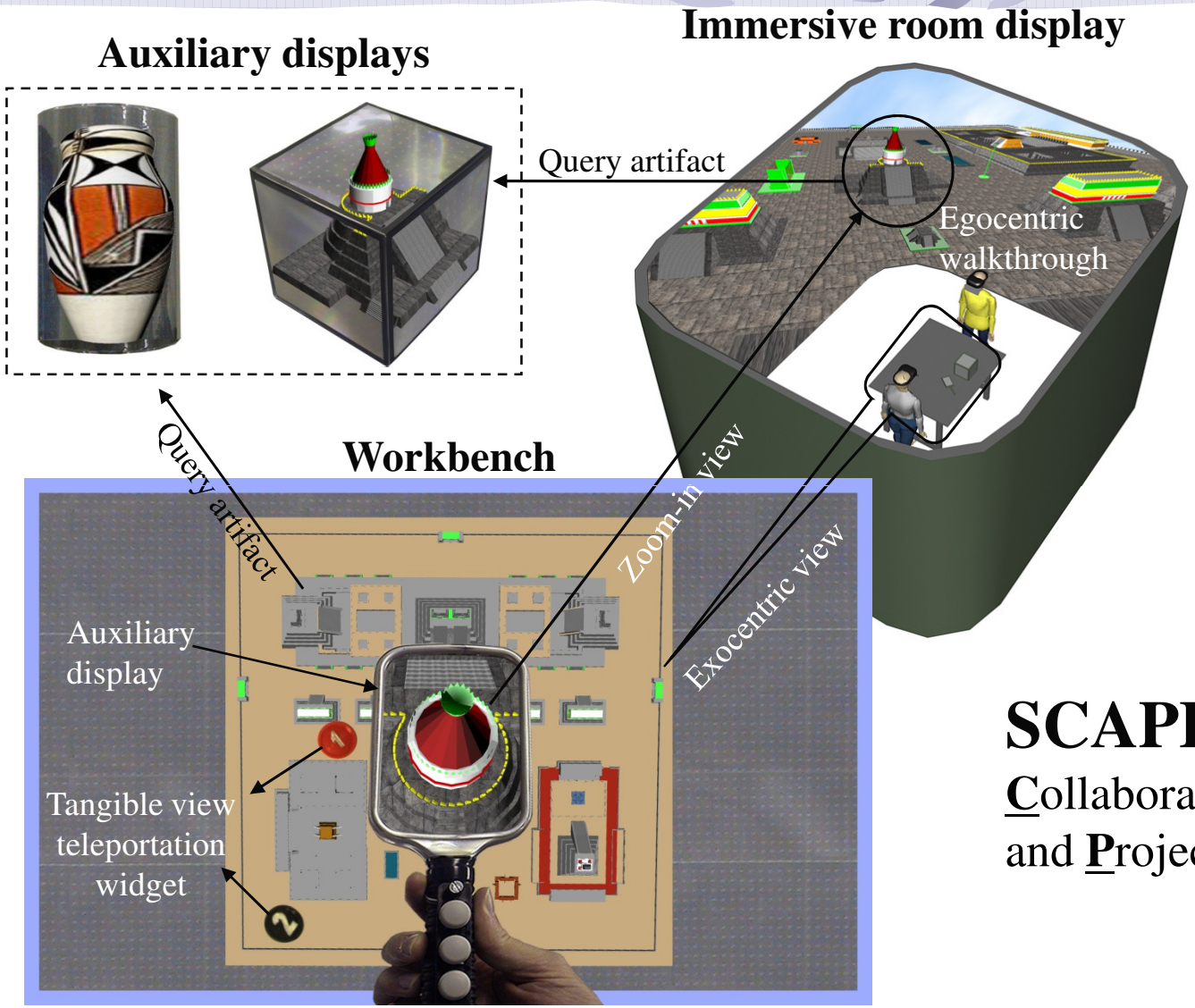
Example: Medical Visualization



Augmented Virtual Environment

- Merges the worlds of atoms and bits
- Visualization continuum
  - A visually smooth transition between the physical and virtual worlds
  - The capability of traversing arbitrary levels of immersion into the digital realm
  - The capability of exploring arbitrary presentation modalities in terms of scale, perspective, resolution, and dimensionality
- Interaction continuum
  - Unified, intuitive interaction methods in both worlds
  - Adopting direct manipulation and physics-based interaction metaphors

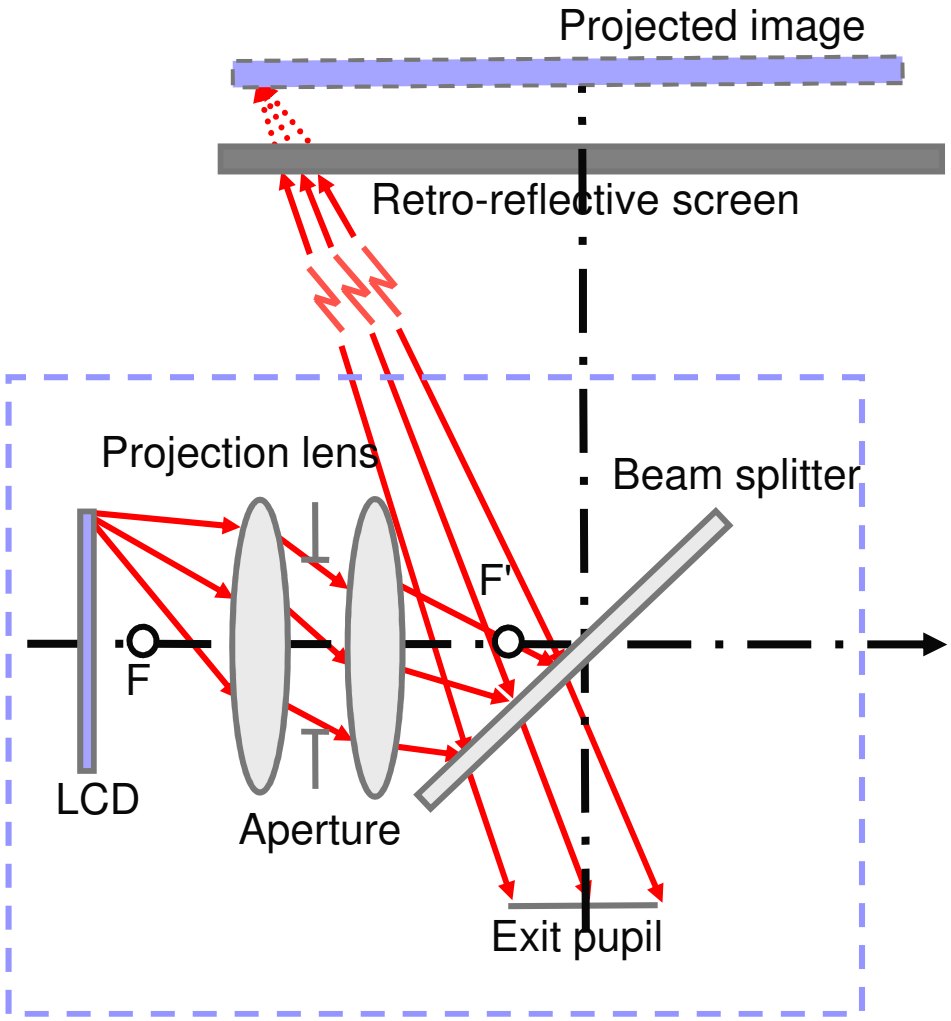
SCAPE: Multi-Scale Collaborative Infrastructure

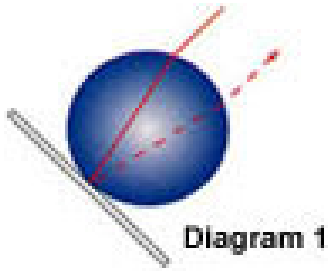


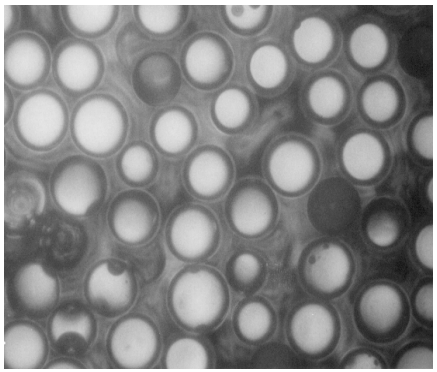
SCAPE: Stereoscopic Collaboration in Augmented and Projective Environments

[Hua et al. IEEE VR 03, IEEE CGA 04, Presence 2004]

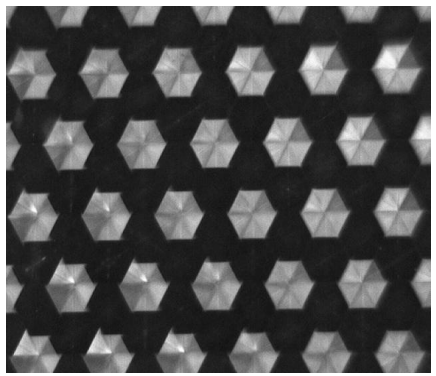
Head-Mounted Projective Display: Concept







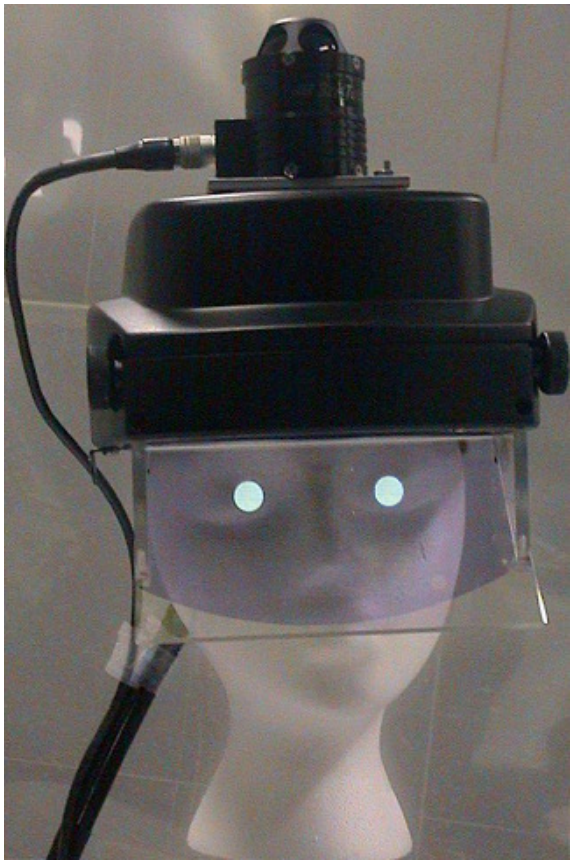
Micro-bead

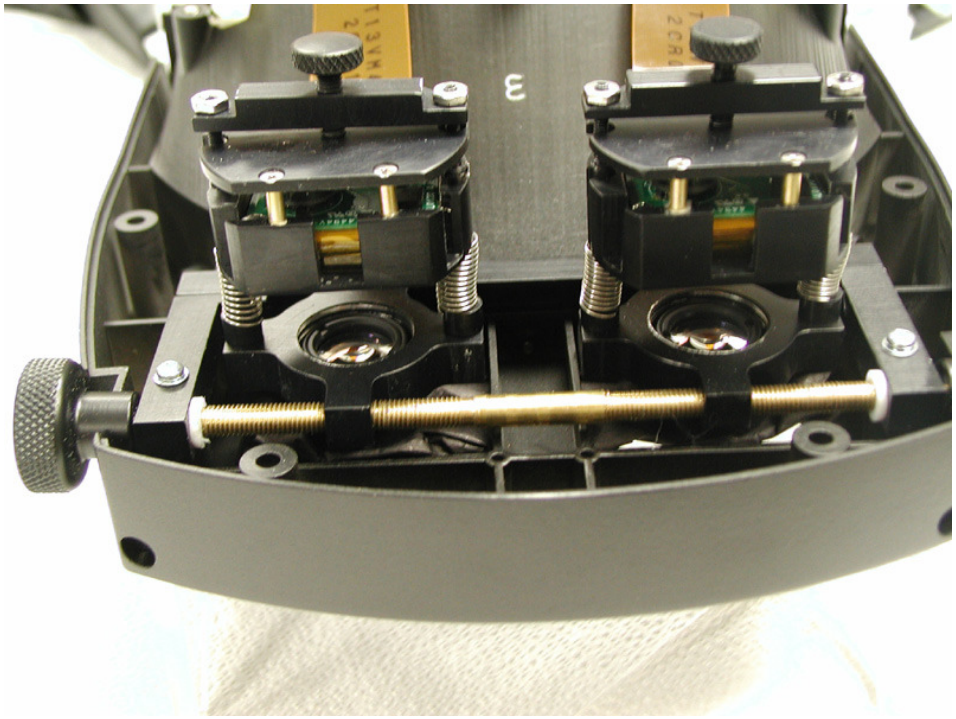


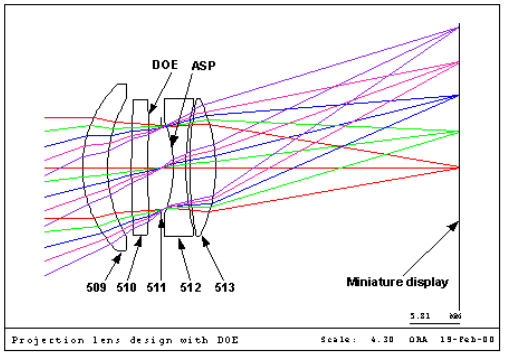
Micro-corner cube

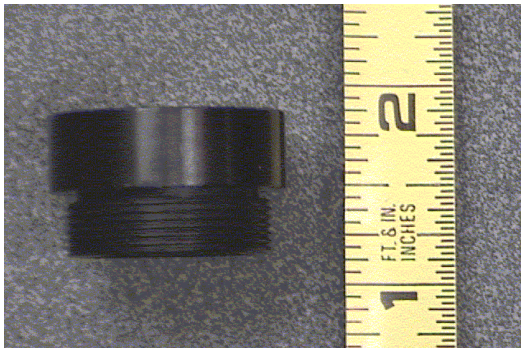
[Fisher US Patent 1996, Kijima & Ojika, IEEE VR 1997, Fergason, US Patent 1997; Hua et al AO 2000]

1st-Generation HMPD Prototype — 2001





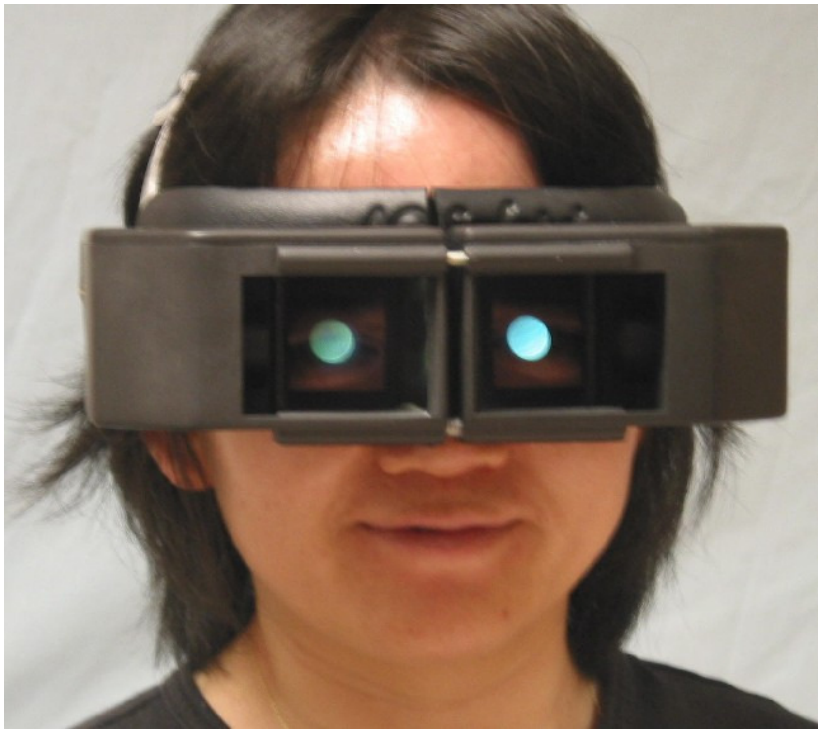




- Optical see-through;
- FOV:52.4° diagonal;
- Display: 640x480 VGA;
- Pixel subtend: 4 arc min/pixel;
- Helmet about 750 grams.

[Hua, Rolland et al. IEEE VR 2001, AO'03, US Patent 2004]

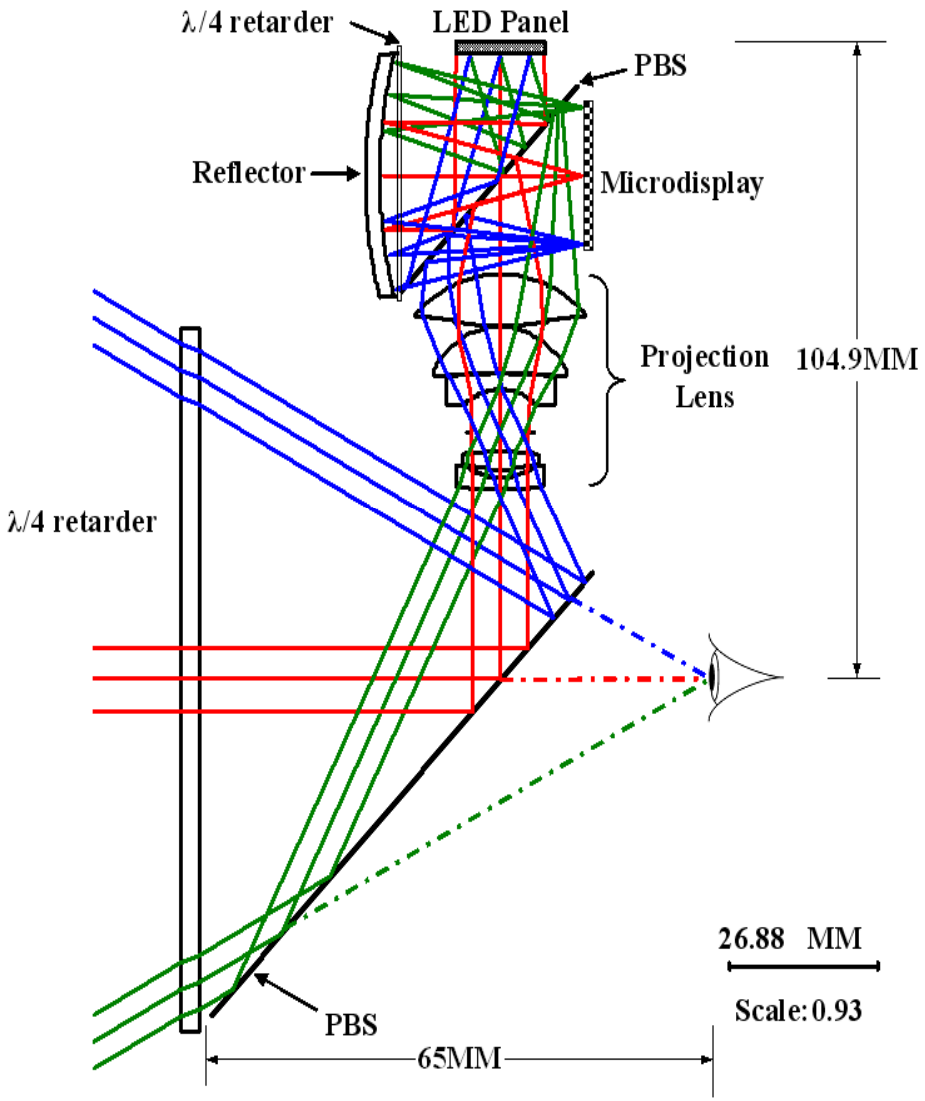
2nd-Generation HMPD Prototype — 2005

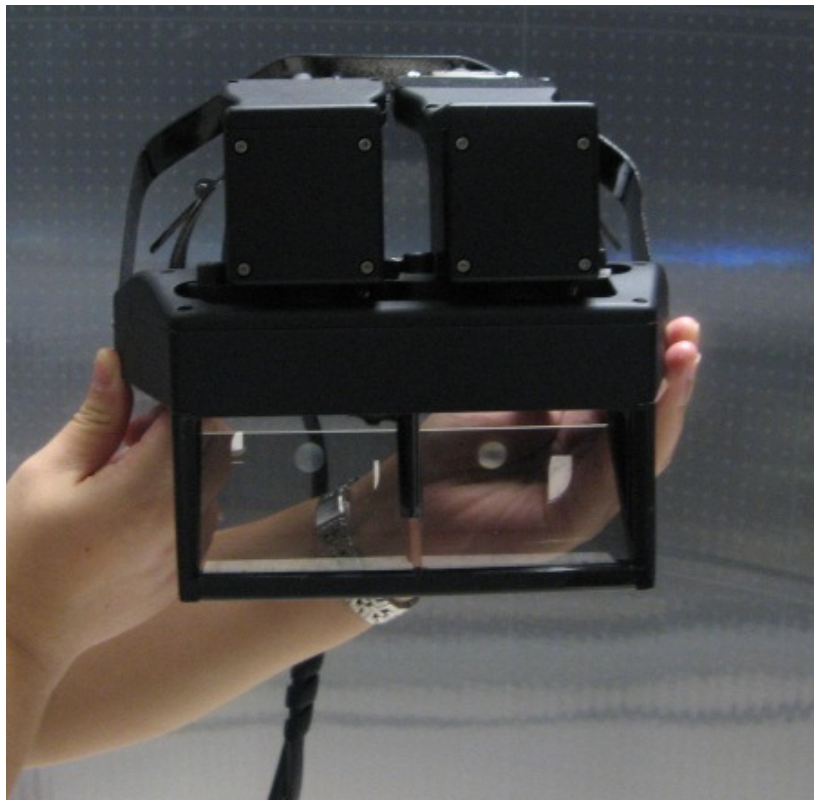


- Polarized scheme with significantly improved luminous transfer efficiency;
- Optical see-through, side mounted;
- FOV:52° diagonal;
- Display: 640x480 VGA;
- Pixel subtend: 4 arc min/pixel;
- Helmet about 450 grams.

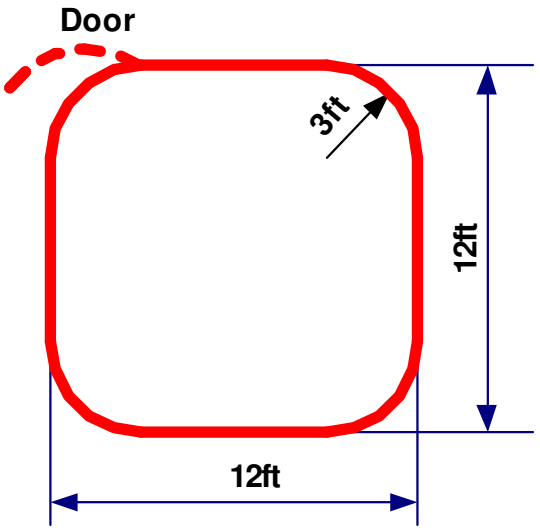
[Hua and Gao, ISMAR 2005, AO 2006]

3rd-Generation HMPD Prototype — 2008



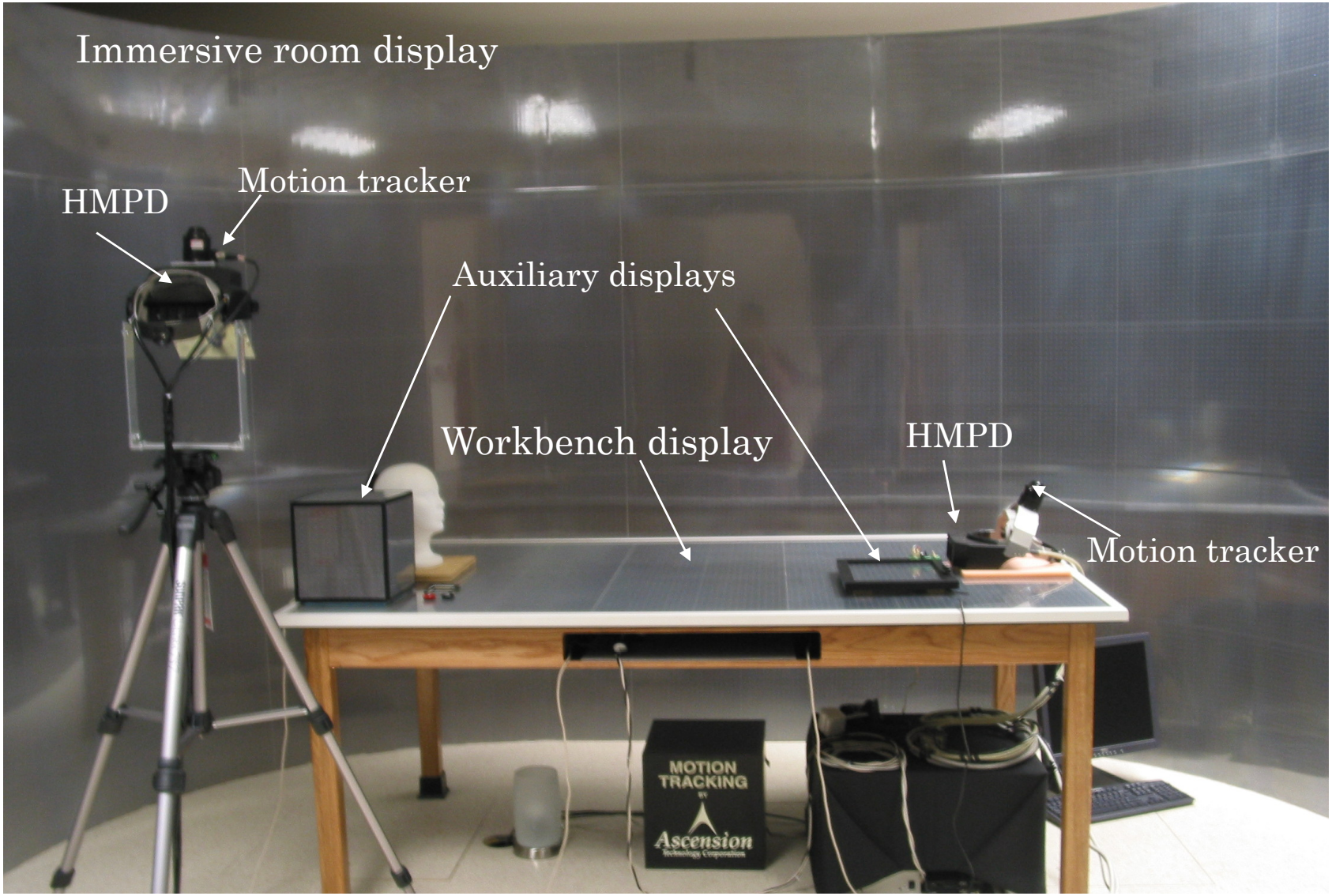


SCAPE Implementation



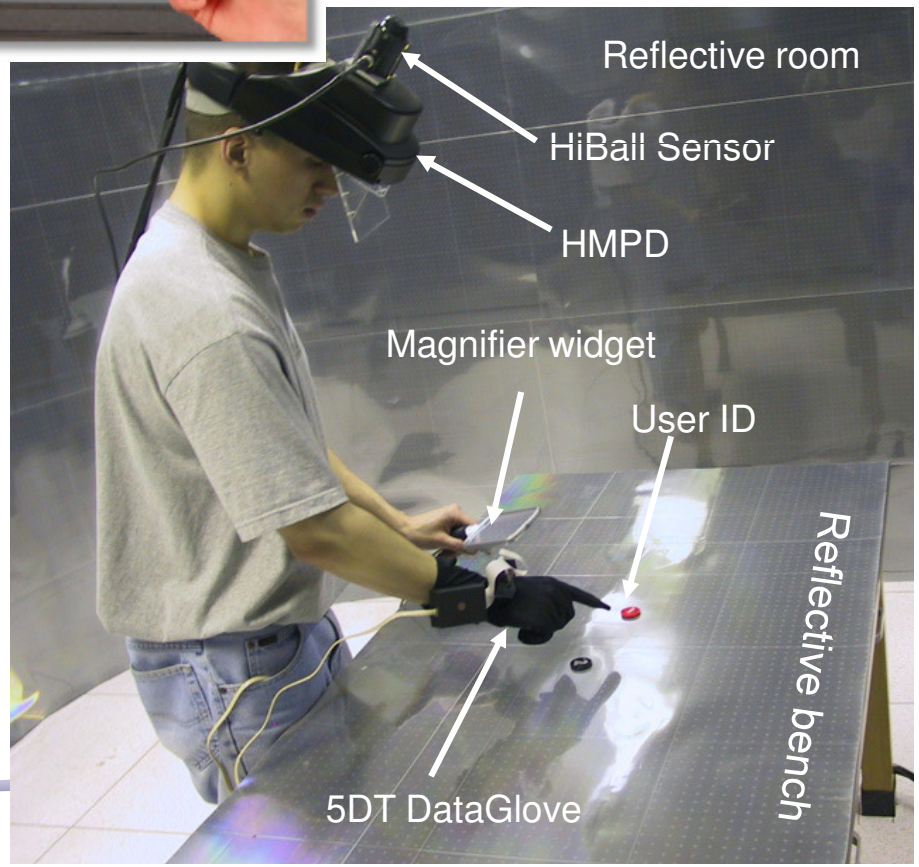
[Hua et al. IEEE VR 2003, Presence 2004, CGA2004]

SCAPE Implementation



Core SCAPE Interfaces

- Hiball tracker
  - Optical technology
  - Head tracking
- FOB tracker
  - Magnetic technology
  - Widget tracking
- Tracking cameras
  - Vision-based algorithms
  - Fiducial marker tracking
  - Hand & finger tracking

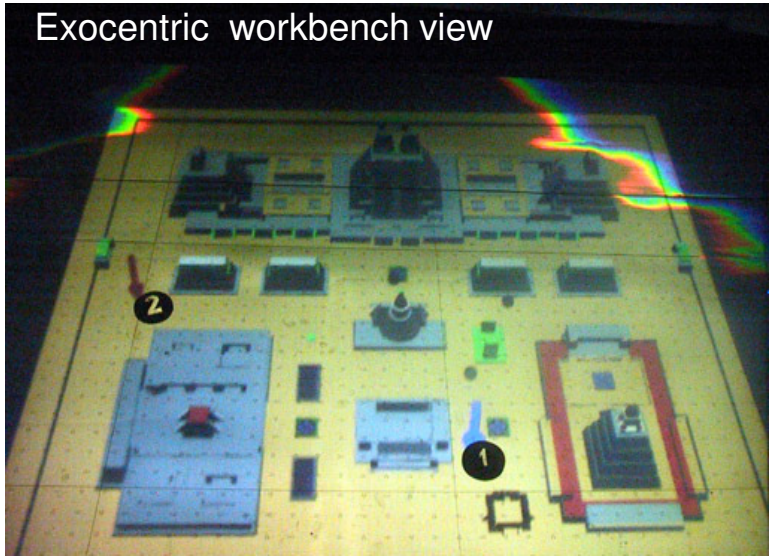


SCAPE: Primary Displays

- Dual scale and dual perspective visualization
- "World-in-Miniature" (WIM)

  [Stoakley, Conway, & Pausch, 95]

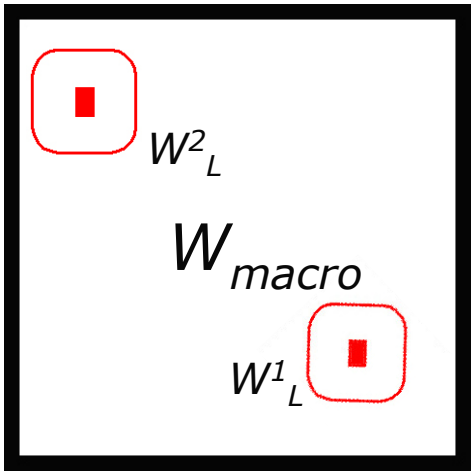
  - Macro-scene: High detail
  - Micro-scene: Low detail
- Hybrid of virtual and augmented reality paradigms

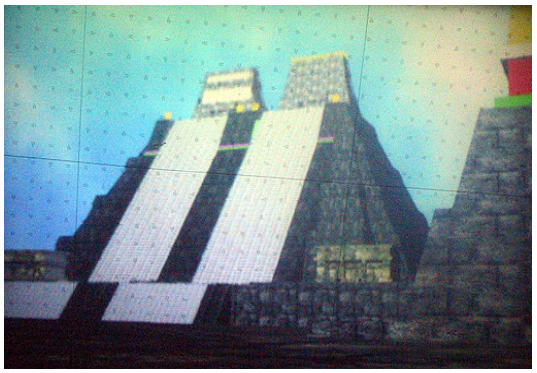


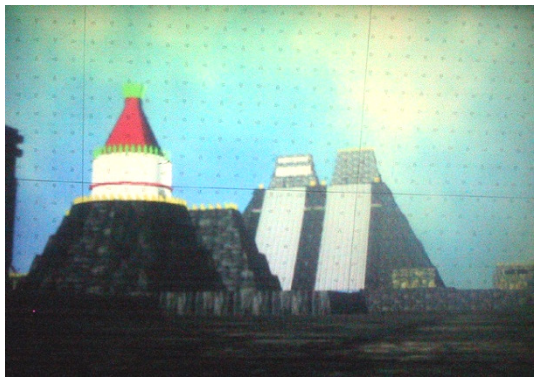
Navigation Via ID Markers

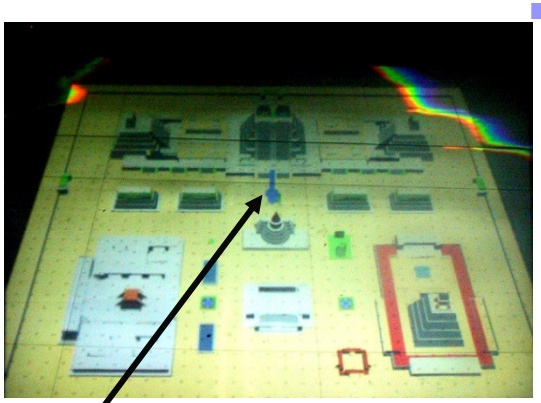
- Each user is assigned with an ID Marker
- A vision system recognizes chekers and tracks their location
- Each user controls his/her own anchor in the immersive walk-through by manipulating his/her ID

Symmetrical Collaboration

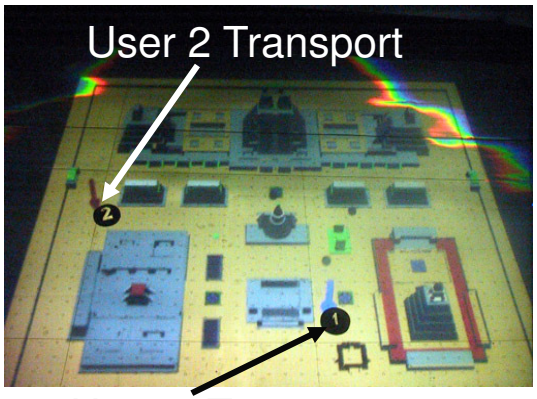






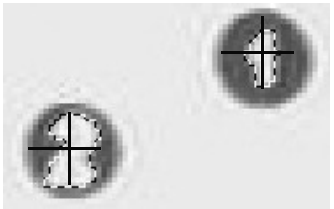


Start Position



Raw image

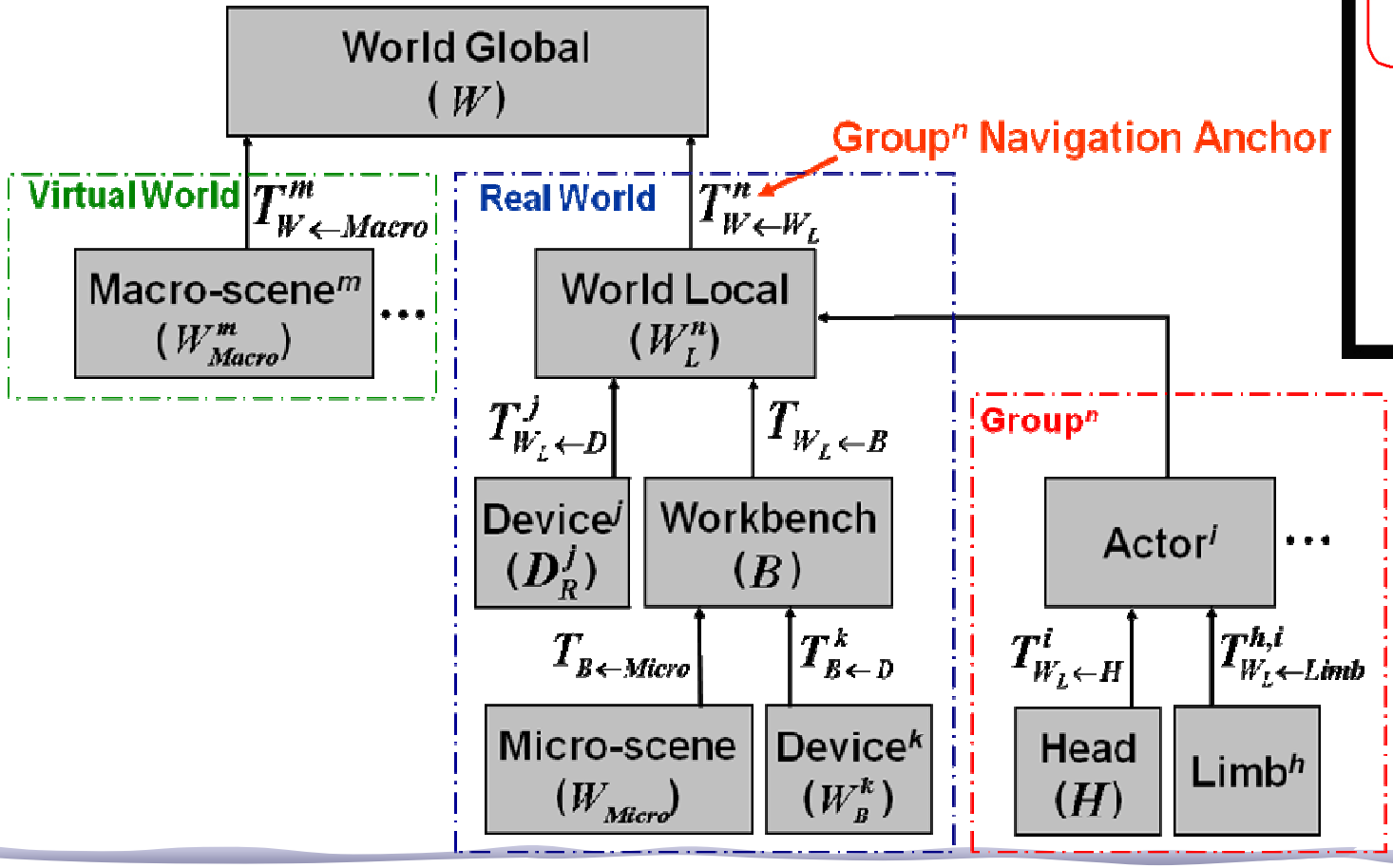
Tracking image

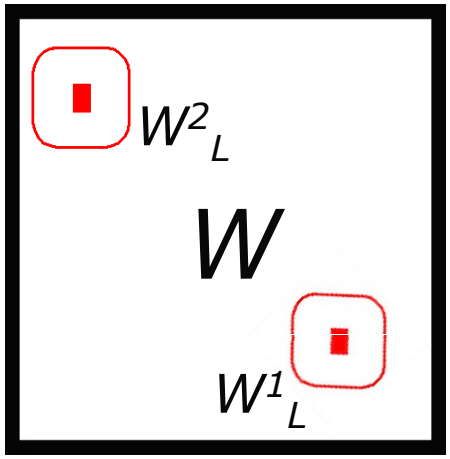


Tracking User IDs

A Transformation Hierarchy

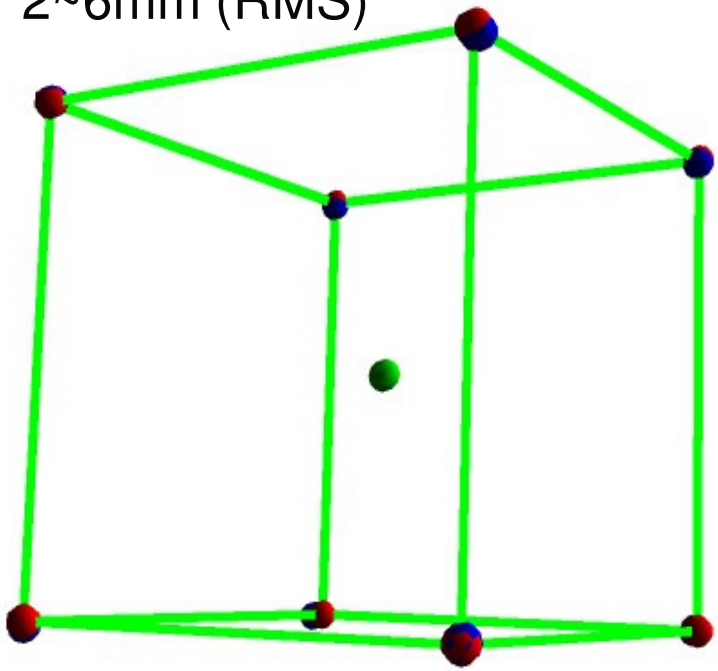
- Coordinates, allows registration of real & virtual worlds
- Must know transformation between real and virtual worlds!
- Requires multi-step calibration process

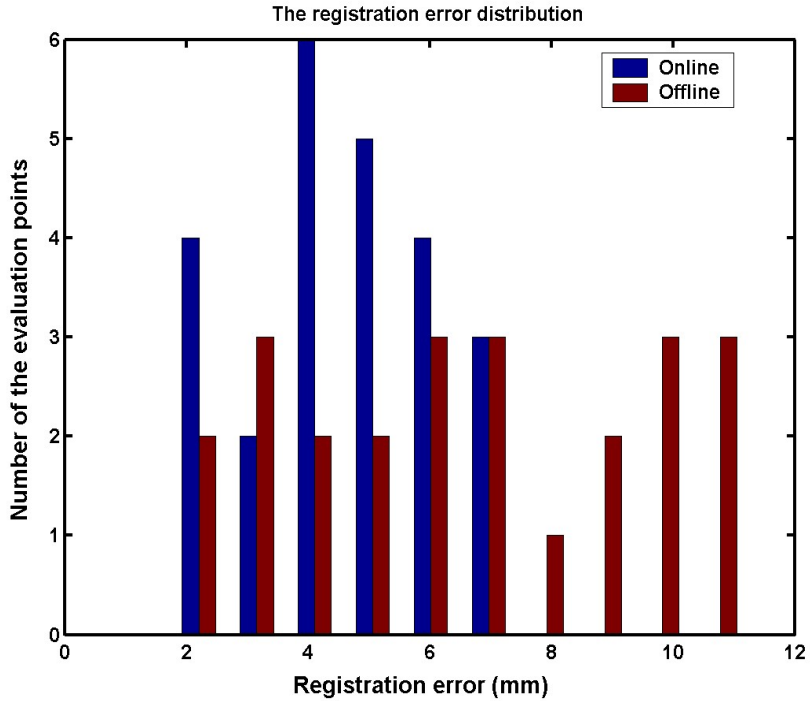




Calibration & Registration in SCAPE

- Two-step calibration methods
  - Off-line calibration to estimate intrinsic & extrinsic unknown transformations
    - Manual correspondence matching (MCM): 6~15mm (RMS)
    - Automatic correspondence matching (ACM): 2.5~11mm (RMS)
  - On-line refinement to compensate user-dependent transformations: 2~6mm (RMS)

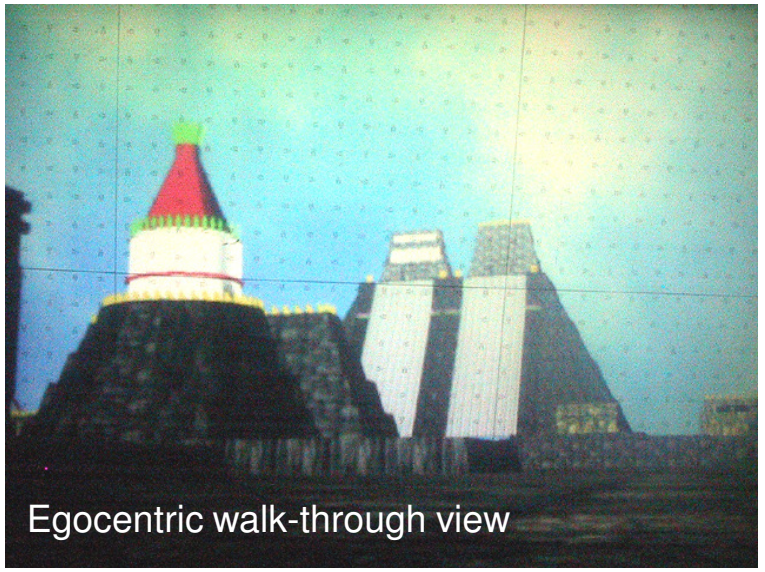


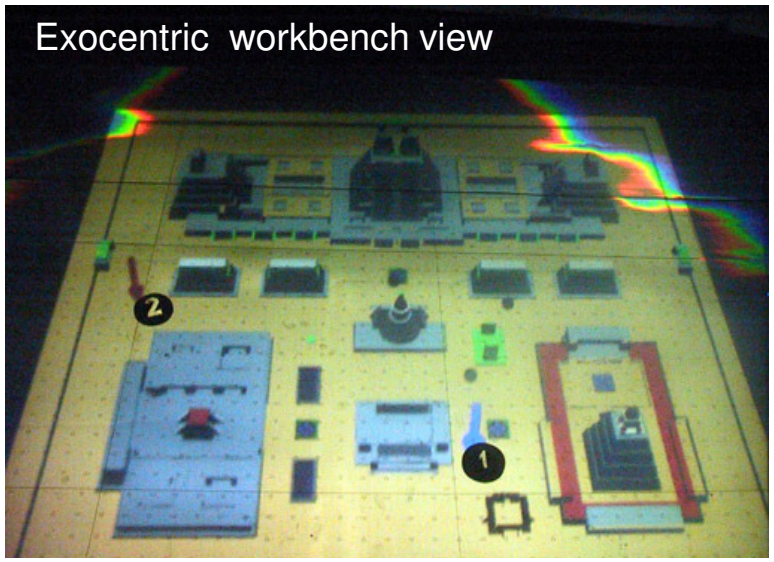


[Hua et al. SIGGRAPH 01, IEEE-VR2002, ISMAR 2002, IEEE-VR2003]

Primary Displays: Issues

- Fixed scale, detail, & perspective
  - Macro-scene: High detail
  - Micro-scene: Low detail
  - Lack of continuity
- Desire for adaptive visualization techniques
- Desire for tangible interaction techniques





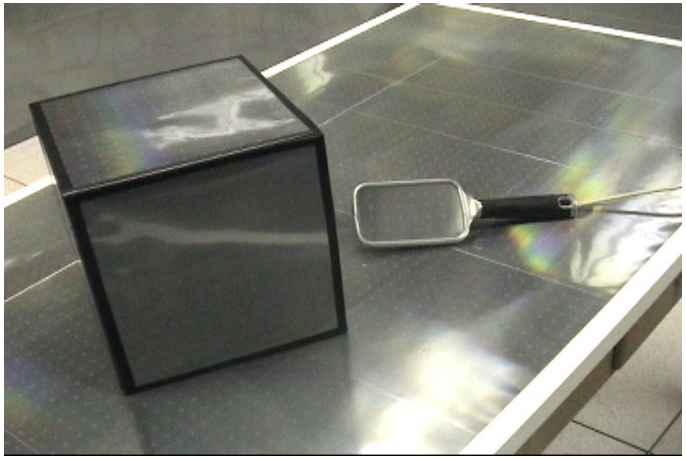
Augmented Interfaces: Tangible Magic Lens

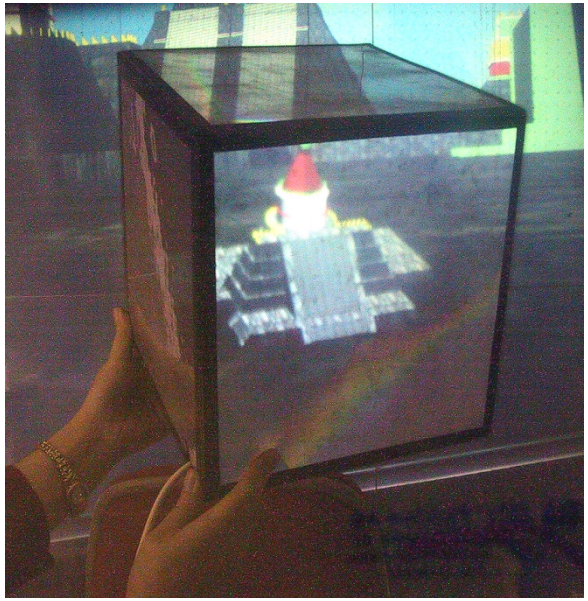
- Auxiliary displays which supplement primary displays
  - Physical objects (props) coated with retro-reflective material
  - Tracked by a 6 DOF tracker sensor or camera with fiducials
- Arbitrary shapes & sizes, e.g. flat panel, cube, cylinder

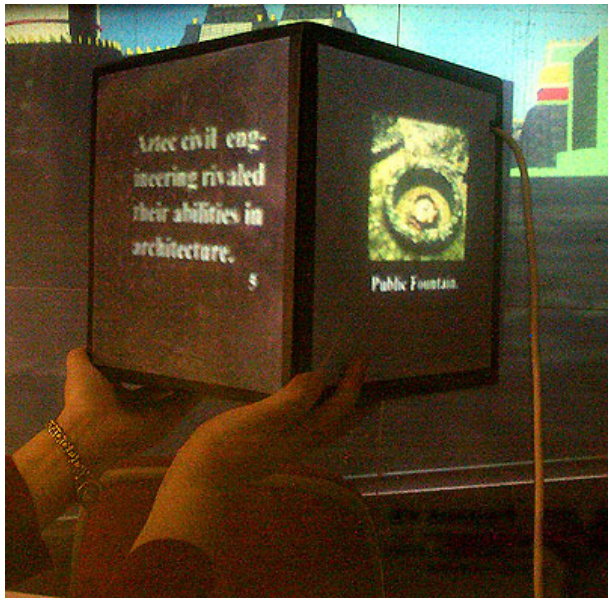
[Brown and Hua, UIST03; IEEE CGA 06]

The Co-Cube Display / Interface

- Construction
  - A 9” cube coated with retro-reflective film
  - Tracked with FOB
- Three-mode interface
  - Object selection
  - Object inspection
  - Augmented book







[Hua et al. VR03, Brown et al. UIST03]

Application: Medical Education

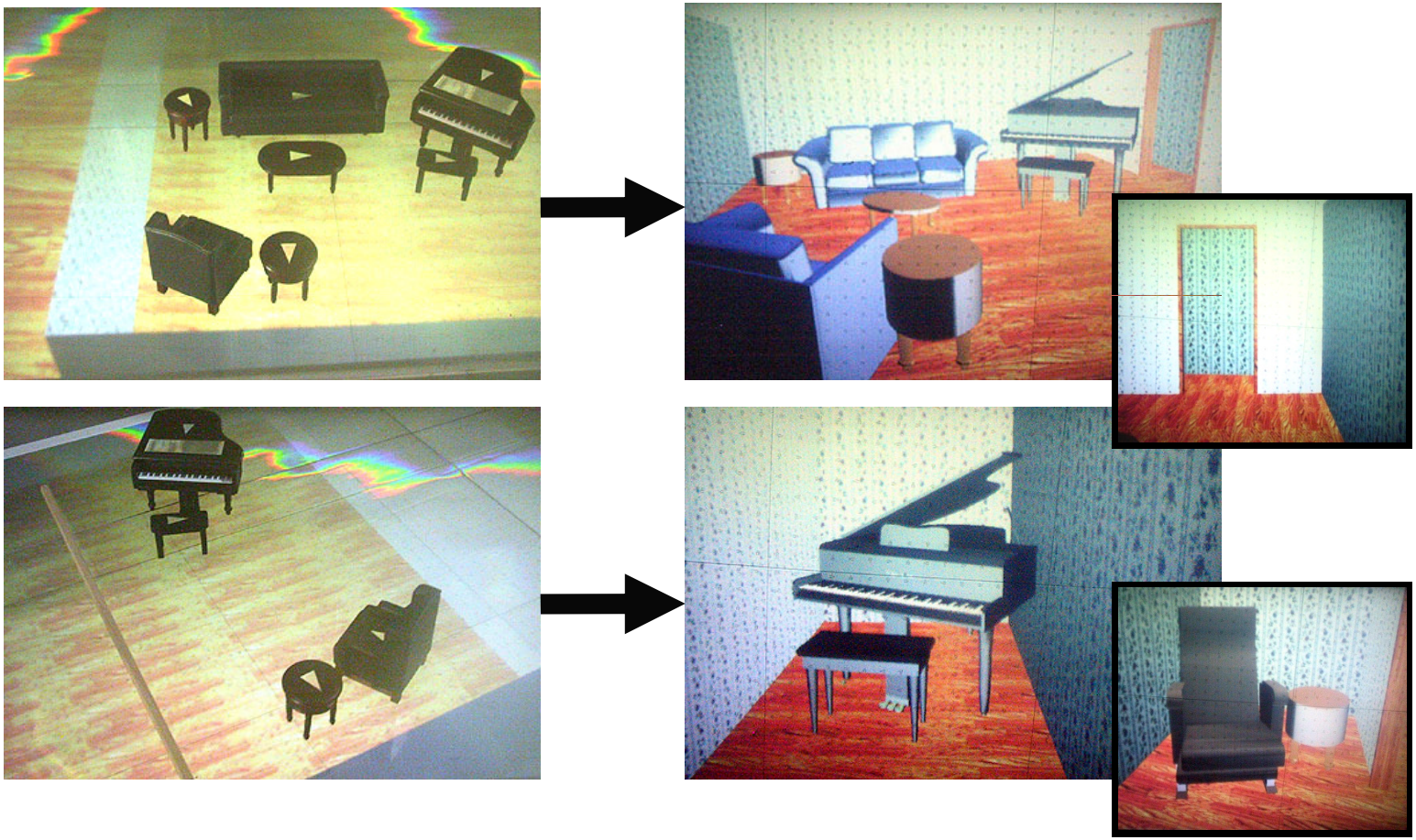
Application: Interior Design

- Workbench display components
  - Virtual, scaled floor plan
  - Real furniture miniatures
  - Camera-based tracking
- Room display components
  - Virtual life-size room(s)
  - Virtual life-size furniture
- Cute demo, but demonstrates some important capabilities:
  - Augmentation of virtual with real (augmented virtuality)
  - Arbitrary objects can be interfaces (choose meaningful objects!)

Application: Interior Design

Augmented workbench view

Virtual life-sized view

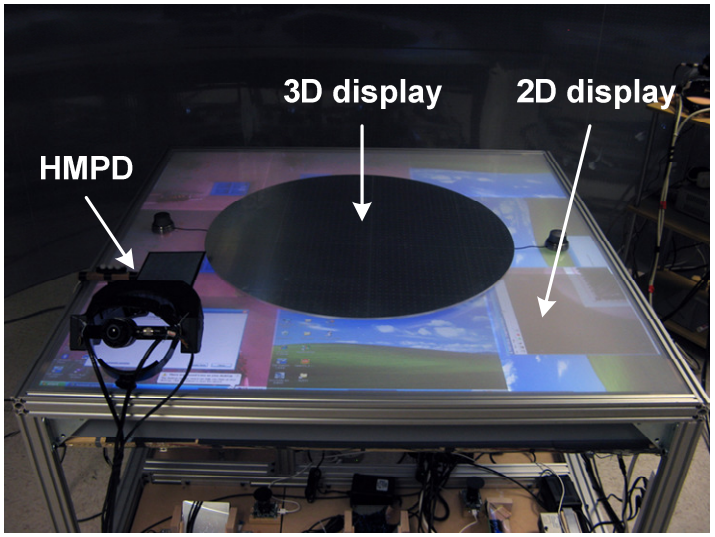


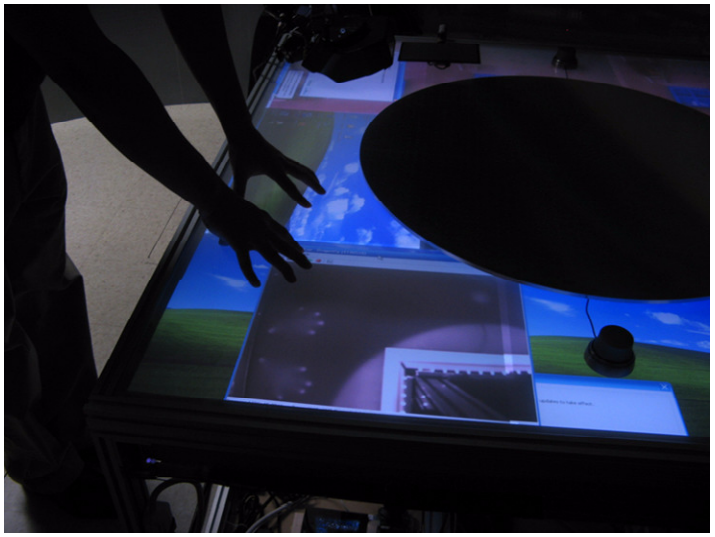
Movie: Tangible Augmented Interaction

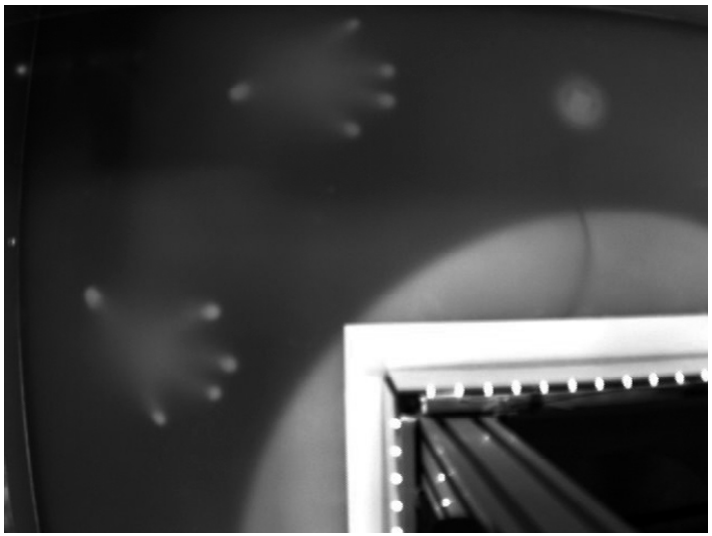
Toward a *Hybrid* Augmented Virtual Environment

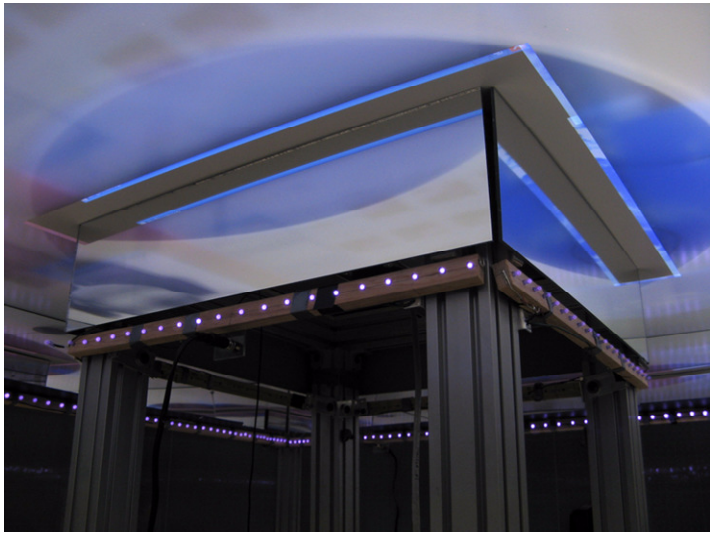
- Hybrid display environments
  - Integrate multiple display technologies into same workspace to accommodate diff data types
  - Each display technology provides some advantages
  - SCAPE: HMPD display technology can be used to augment other types of displays
  - Hybrid workbench
  - Hi-res 2D view surface + 3D stereoscopy capabilities
  - 8 mini-projectors concentric to 3D display platter
  - 2D display provides 3.8 Megapixel view area
  - Integrated multi-touch on 2D surface

Hybrid Workbench Implementation (2008)



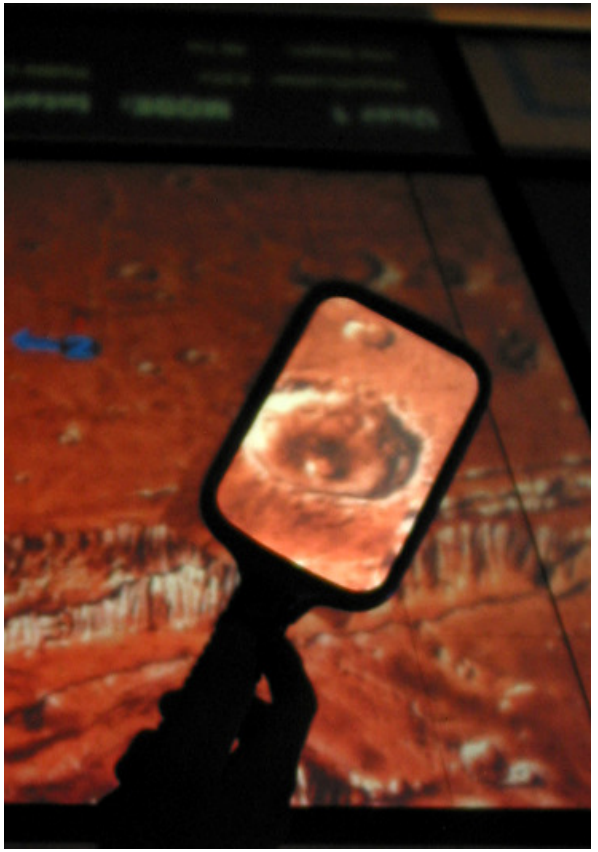






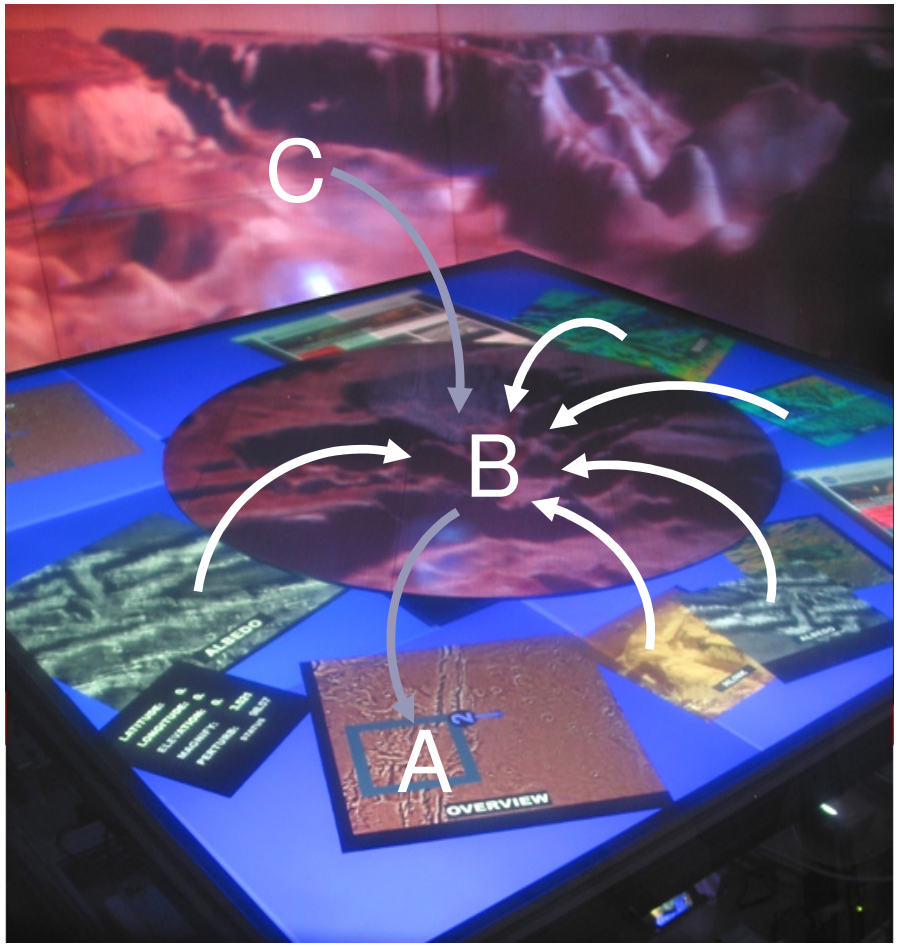
Hybrid Workbench with Magic Lenses (2008)

- Use in conjunction with other displays, interfaces
- Application: A Mars mission planning tool



View Hierarchies & Mixing on Hybrid Displays

- Coordinate data of different types (recall challenges of heterogeneous data sets)
- Link data together into hierarchies of correlated information
- Take advantage of each display tech based on data requirements (3D complexity, text display, etc)
- Each display represents position on R-V Continuum (e.g. wall = VR; workbench = AV; Magic Lens = AR)
- Combination of displays can be used to suit mixing needs of hetero data



Movie: Mult-touch Enabled Hybrid Interaction

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