Collaborative Augmented Reality

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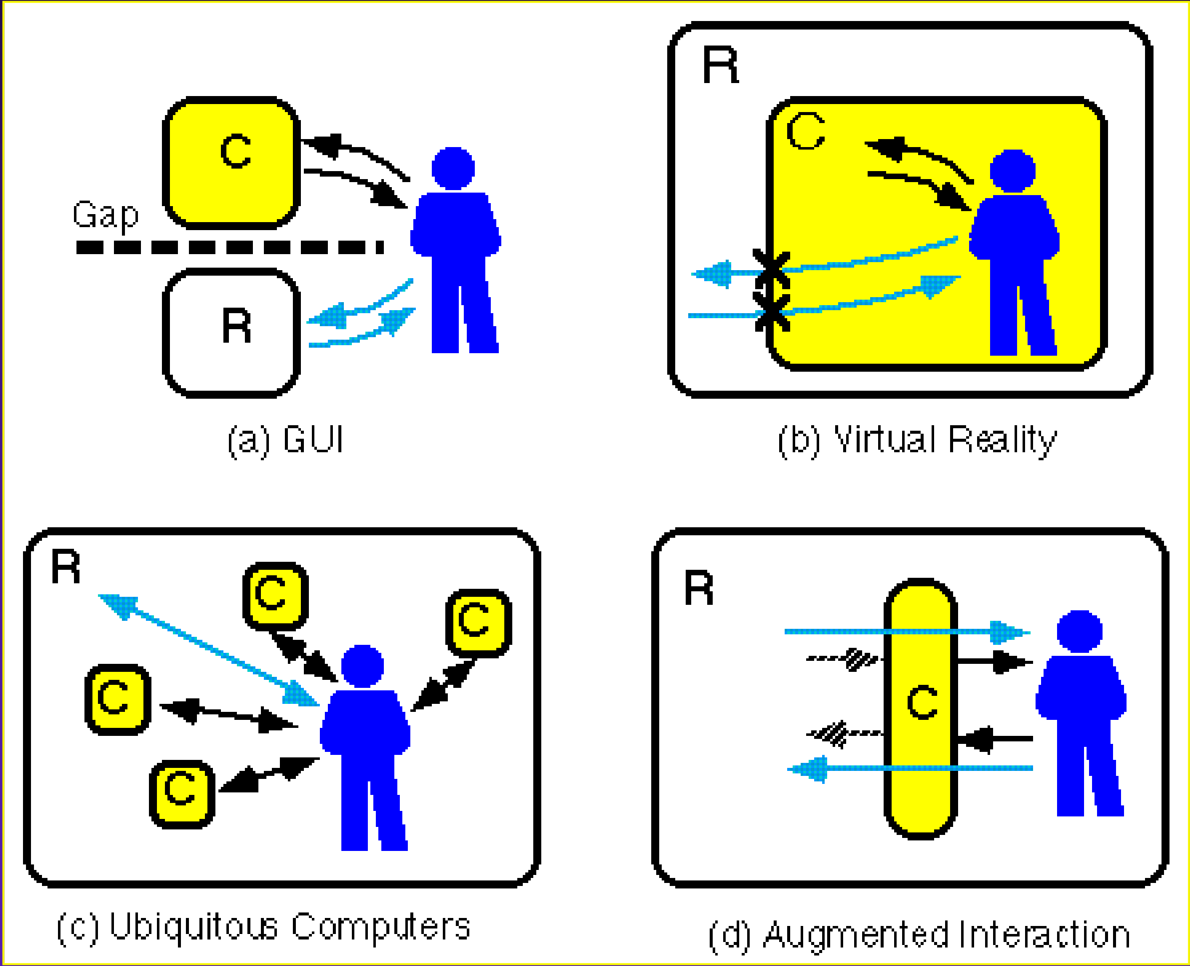
Outline

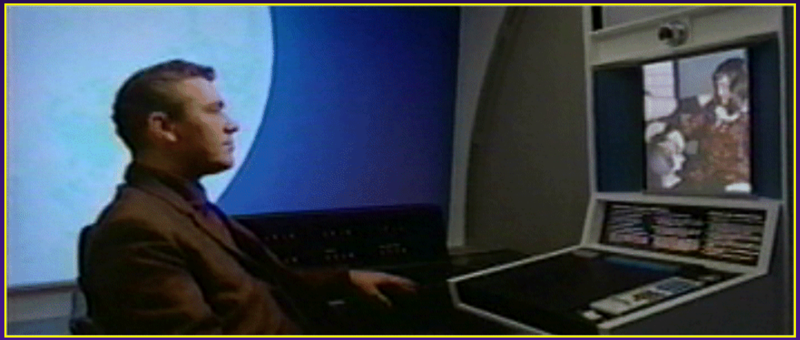
- Introduction
- Tangible AR
- Face to Face Collaboration
- Hybrid Interfaces
- Remote Collaboration
- Advertisement
- Conclusions

Invisible Interfaces

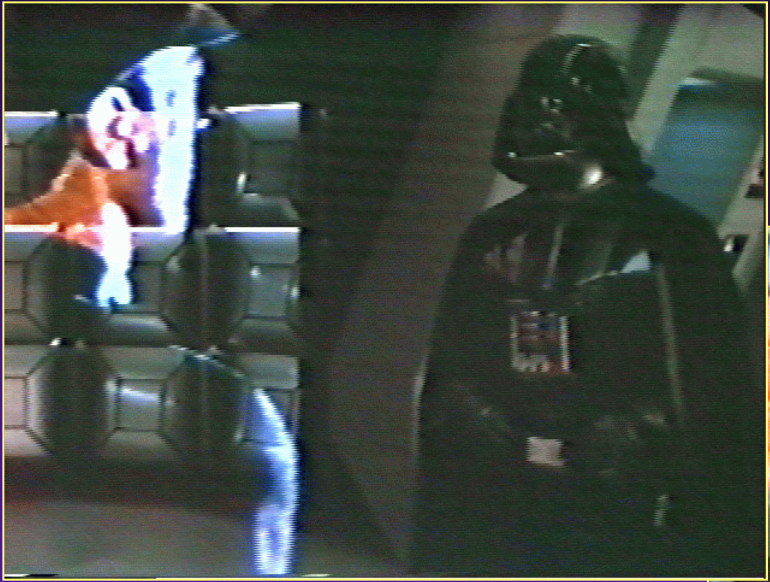


The View from 1968

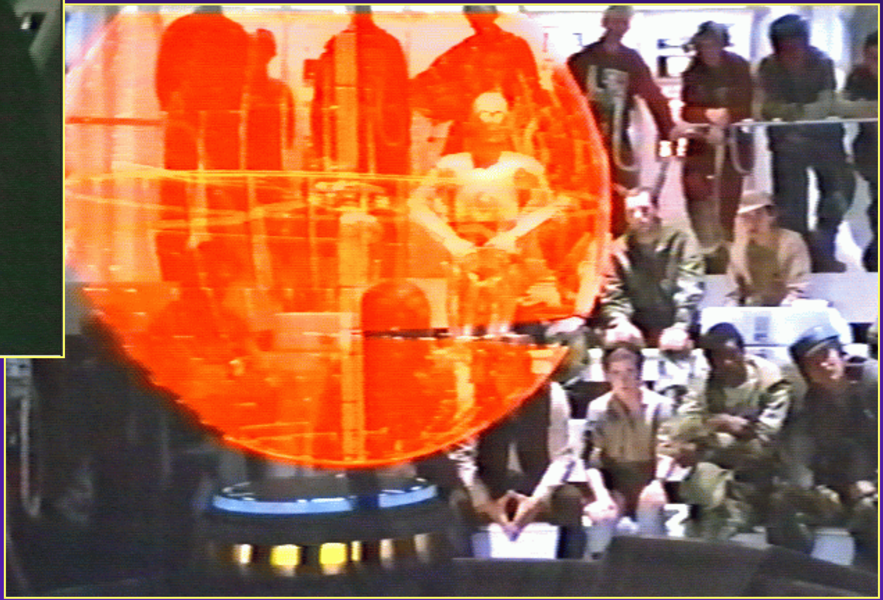
- Video Conferencing
  - lack of spatial cues
  - limited participants
  - 2D collaboration
  - separation from real world



The View from 1979



Remote Conferencing



Face to face Conferencing

Show MR Lab Video

Video 1

Collaborative Augmented Reality

- Attributes:
  - Virtuality
  - Augmentation
  - Cooperation
  - Independence
  - Individuality

- Seamless Interaction
- Natural Communication

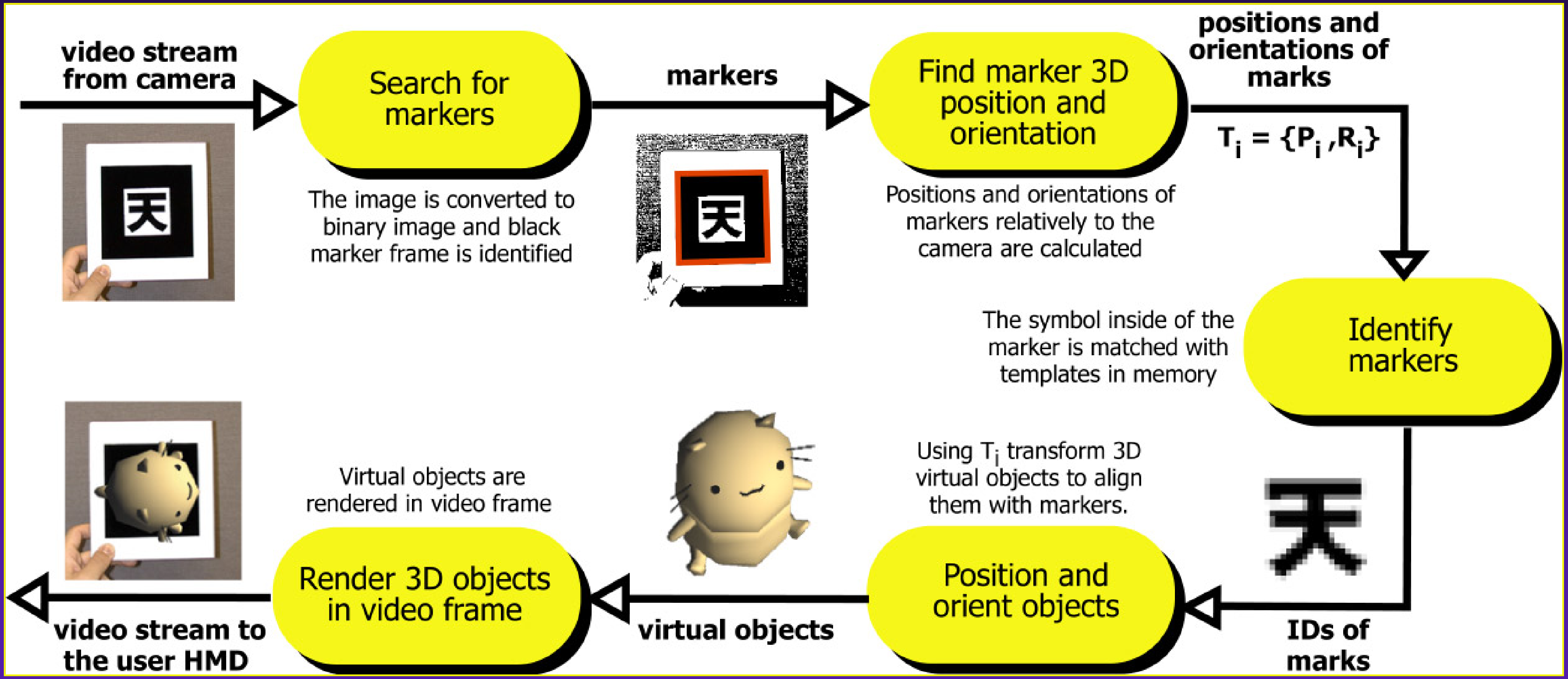
Central Claim

Augmented Reality techniques can be used to provide spatial cues that significantly enhance face-to-face and remote collaboration on three-dimensional tasks.

AR Demo

Show AR Demo

ARToolKit Tracking



ARToolKit - Computer vision based tracking libraries

Tangible AR

Tangible Interfaces (Ishii 97)

- Create digital shadows for physical objects
- Foreground
  - graspable UI
    - terraVision
- Background
  - ambient interfaces
    - pinwheels

Lessons from Tangible Interfaces

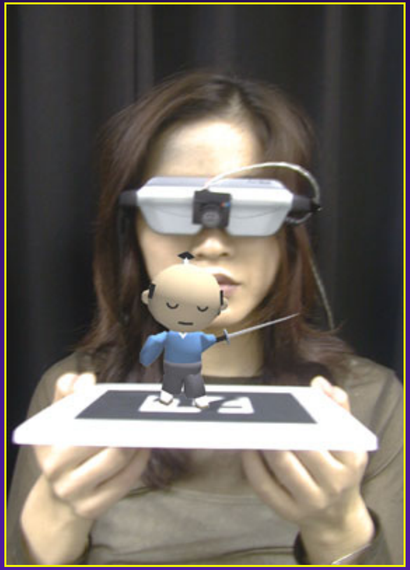
- Physical objects make us smart
  - Norman's "Things that Make Us Smart"
  - encode affordances, constraints
- Objects aid collaboration
  - establish shared meaning
- Objects increase understanding
  - serve as cognitive artifacts

Limitations

- Difficult to change object properties
  - can't tell state of digital data
- Limited display capabilities
  - pinwheels = 1D, projection screen = 2D
  - dependent on physical display surface
- Separation between object and display
  - TerraVision

Back to the Real World

- AR overcomes limitation of TUIs
  - enhance display possibilities
  - merge task/display space
  - provide public and private views



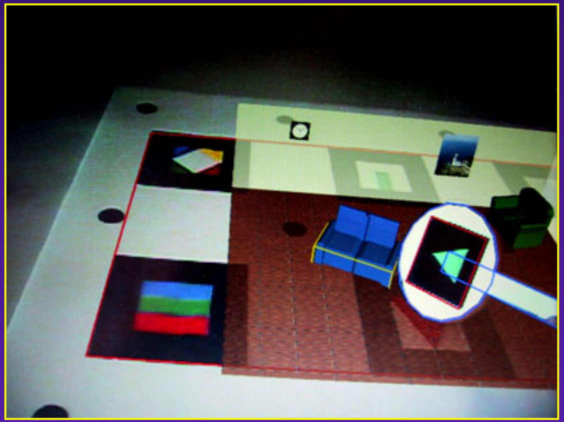
- TUI + AR = Tangible AR
  - Apply TUI methods to AR interface design

Tangible Augmented Reality

- Tangible Augmented Reality is a design concept that integrates TUI and AR.
  - Virtual objects are seamlessly coupled to physical world.
  - Physical object affordances are used for the interaction.
  - The form of objects encourages spatial manipulation.
  - Multi-handed and multi user interactions are possible.

Tangible AR Interaction Techniques

- Use of natural physical object manipulations to control virtual objects
- VOMAR Demo
  - Catalog book:
    - Turn over the page
  - Paddle operation:
    - Push, shake, incline, hit, scoop



Show VOMAR Video

Video 2

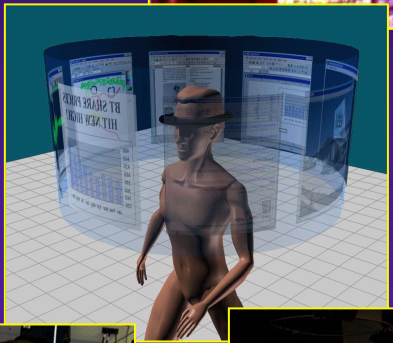
Collaborative AR Interfaces

- Face to Face Collaboration

  WebSpace, Shared Space, Table Top Demo, Interface Comparison, AR Interface Comparison

- Remote Collaboration

  SharedView, RTAS, Wearable Info Space, WearCom, AR Conferencing, BlockParty

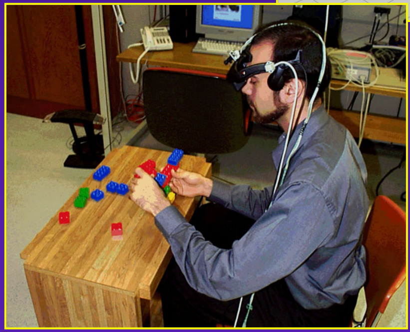


- Transitional Interfaces

  MagicBook

- Hybrid Interfaces

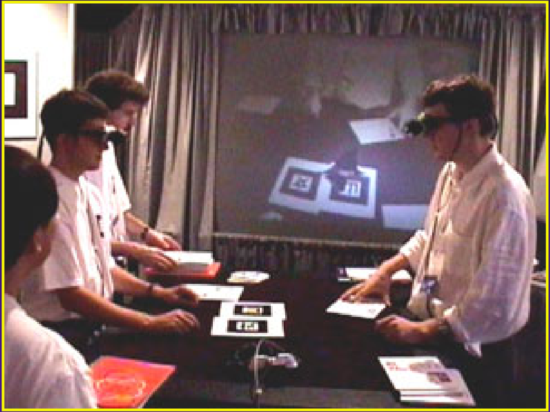
  AR PRISM, GI2VIS



Face to Face Collaboration

Table Top Demo

- Goal
  - create compelling collaborative AR interface usable by novices
- Exhibit content
  - matching card game
  - face to face collaboration
  - physical interaction



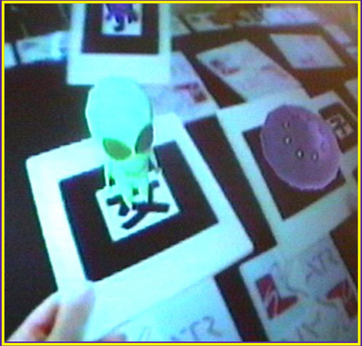


Table Top Demo

Video 3

Results

- 2,500 - 3,000 users
- Observations
  - no problems with the interface
    - only needed basic instructions
  - physical objects easy to manipulate
  - spontaneous collaboration
- Subject survey (157 people)
  - Users felt they could easily play with other people and interact with objects
- Improvements
  - reduce lag, improve image quality, better HMD

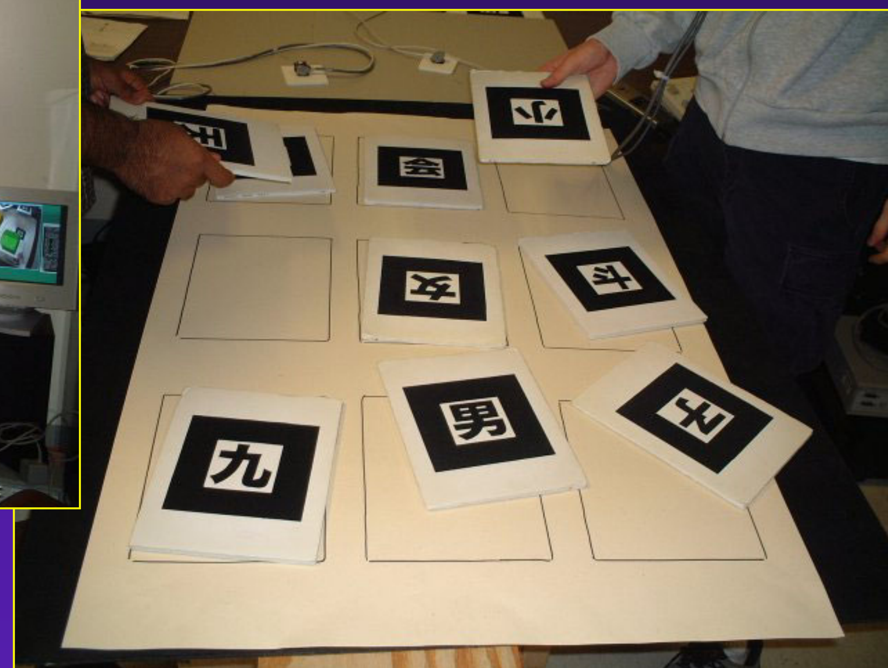
Interface Comparison

- Compare two person collaboration in:
  - Face to Face, AR, Projection Display
- Task
  - Urban design logic puzzle
    - Arrange 9 building to satisfy 10 rules in 7 minutes
- Subjects
  - Within subjects study (counter-balanced)
  - Pilot – 8 pairs grade school children
  - Full – 12+2 pairs of college students

Face to Face Condition

Moving Model Buildings

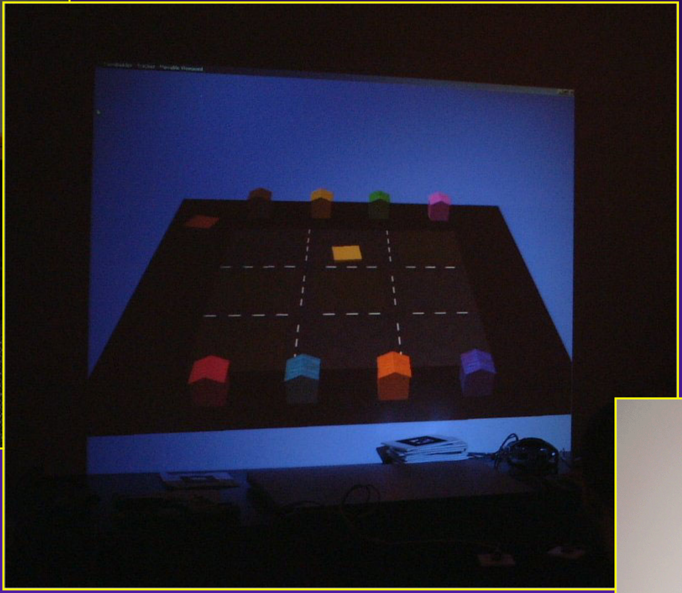
AR Condition



Cards with AR Models

SVGA AR Display (800x600)
Video see-through AR

Projection Condition



Tracked Input Devices

Measured Results

- Performance
  - AR collaboration slower than FtF + Projection
- Communication
  - Pointing/Picking gesture behaviors same in AR as FtF
  - Deictic speech patterns same in AR as FtF
    - Both significantly different than Projection condition
- Subjective
  - FtF easier to work together and understand
  - FtF easier to see non-verbal cues
    - Subjects felt no difference between AR and Proj.
  - Interaction in AR easier than Proj. and same as FtF

Interview Comments

"AR's biggest limit was lack of peripheral vision. The interaction was natural, it was just difficult to see. In the projection condition you could see everything but the interaction was tough"

- Face to Face
  - Subjects focused on task space
    - gestures easy to see, gaze difficult
- Projection display
  - Interaction difficult (8/14)
    - not mouse-like, invasion of space
- AR display – "working solo together"
  - Lack of peripheral cues = "tunnel vision" (10/14 pairs)

AR Pad

- Handheld AR Display
  - LCD screen
  - SpaceOrb
  - Camera
  - Peripheral awareness

Support for Collaboration

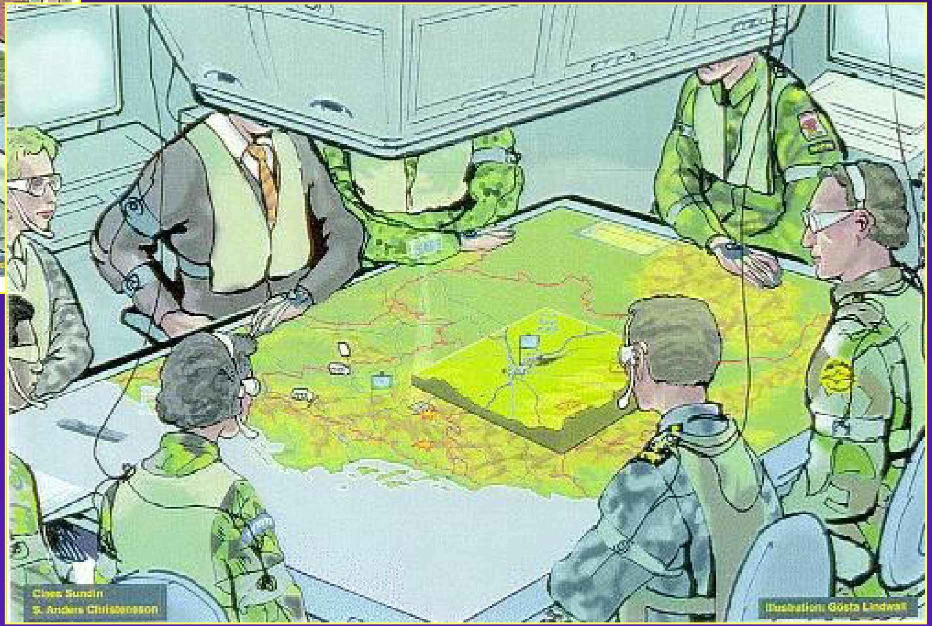
Virtual Viewpoint Visualization

AR Pad Video

Video 4

Hybrid Interfaces

The Data Center of the Future



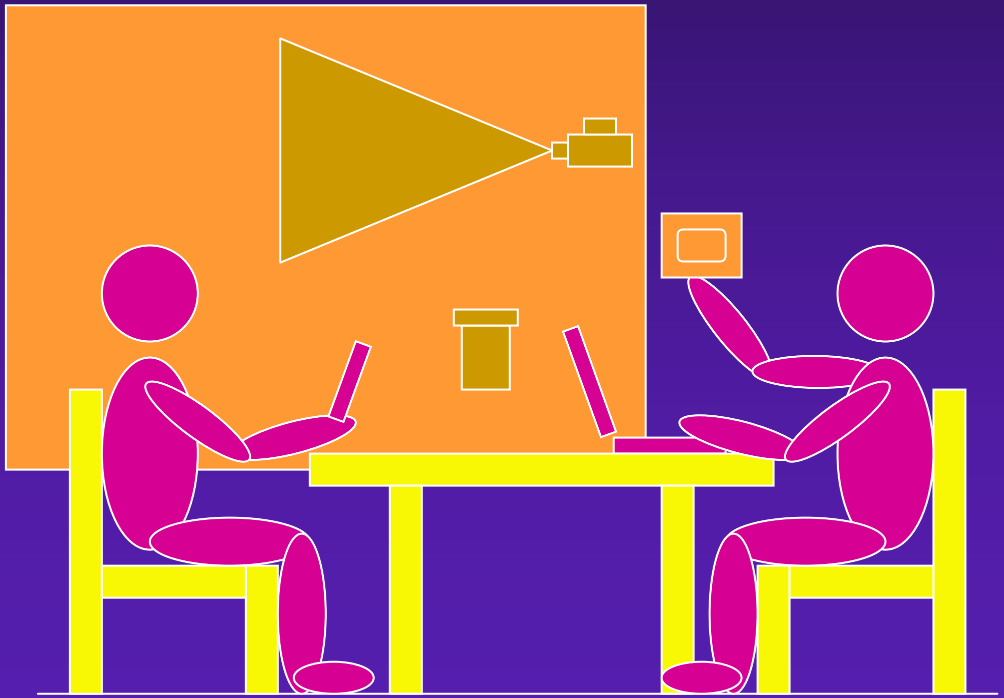
Combine AR with other tools

- Use the most appropriate tools for any given task
  - Manipulate 2D text or images on a Tablet PC or PDA
  - Manipulate 3D objects in 3D space
- Use the most appropriate displays
  - size, resolution, stereopsis
  - privacy vs sharing

Augmented Conferencing

- ***EMMIE*** **[Butz99]**

  Conferencing assisted by multiple computing devices



Beyond the Desktop Metaphor

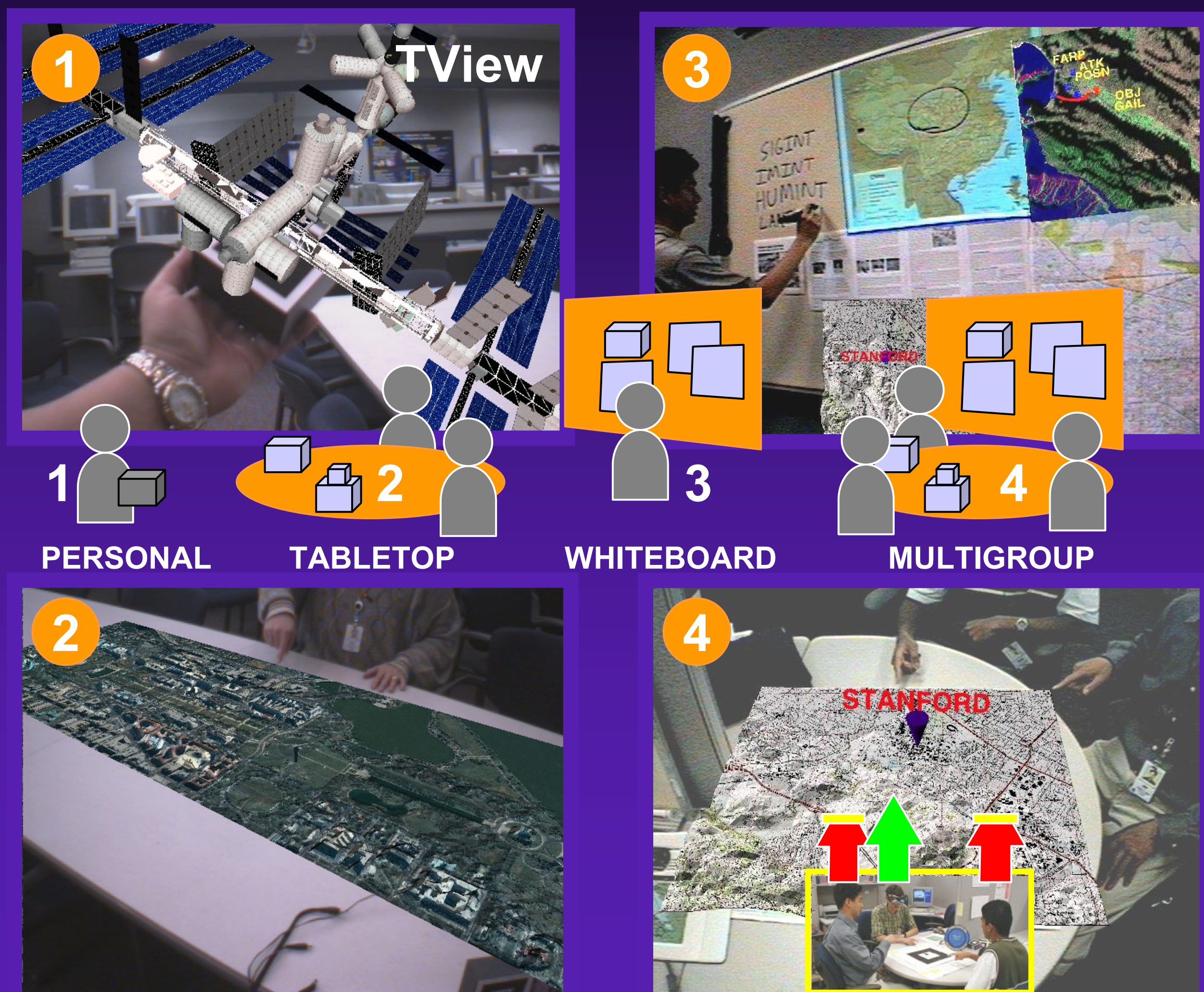
- Managing 3D space and multiple 2D/3D Displays
- Drag and drop between dimensionalities
- Multiple users --> privacy management
- Using interaction devices provided by participating computers
  - keyboards
  - 2D mice
  - pens
  - displays

MagicMeeting Video

Video 5

Holger Regenbrecht
Daimler-Chrysler, Ulm

Multi-scale Collaboration



Remote Collaboration

AR Conferencing

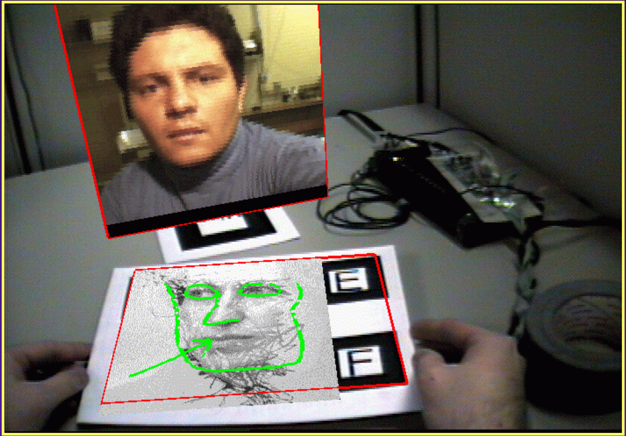
- Moves conferencing from the desktop to the workspace

AR Conferencing Video

Video 6

Pilot Study

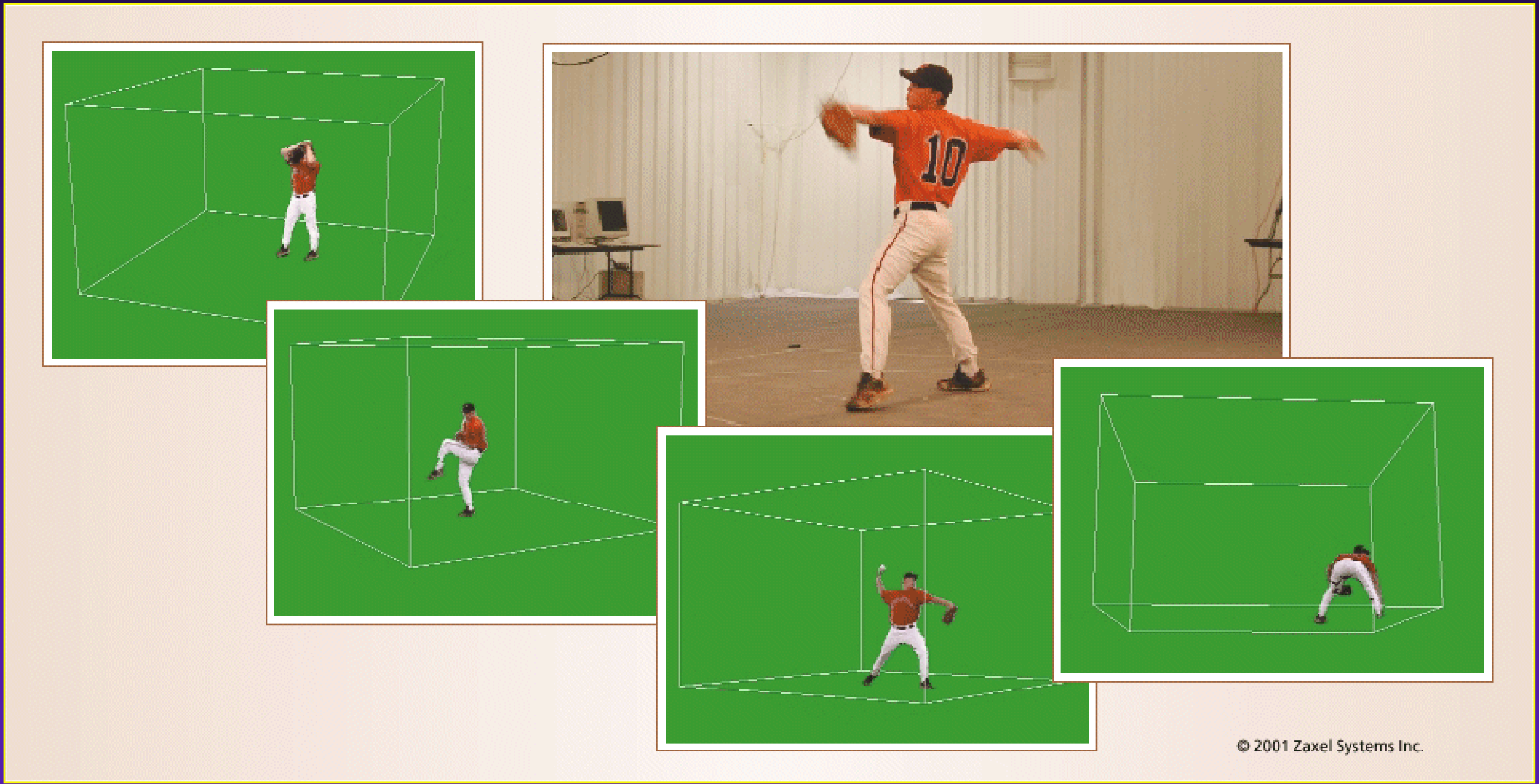
- How does AR conferencing differ ?
- Task
  - discussing images
  - 12 pairs of subjects
- Conditions
  - audio only (AC)
  - video conferencing (VC)
  - mixed reality conferencing (MR)



Results

- Subjective Results
  - AR conferencing can increase presence
  - AR conferencing can improve communication
  - AR more difficult to use than audio/video
    - Difficult to see everything
    - Communication asymmetries
- Confounding Factors
  - task - not strictly conversation
  - HMD - limited field of view, resolution
  - only two users

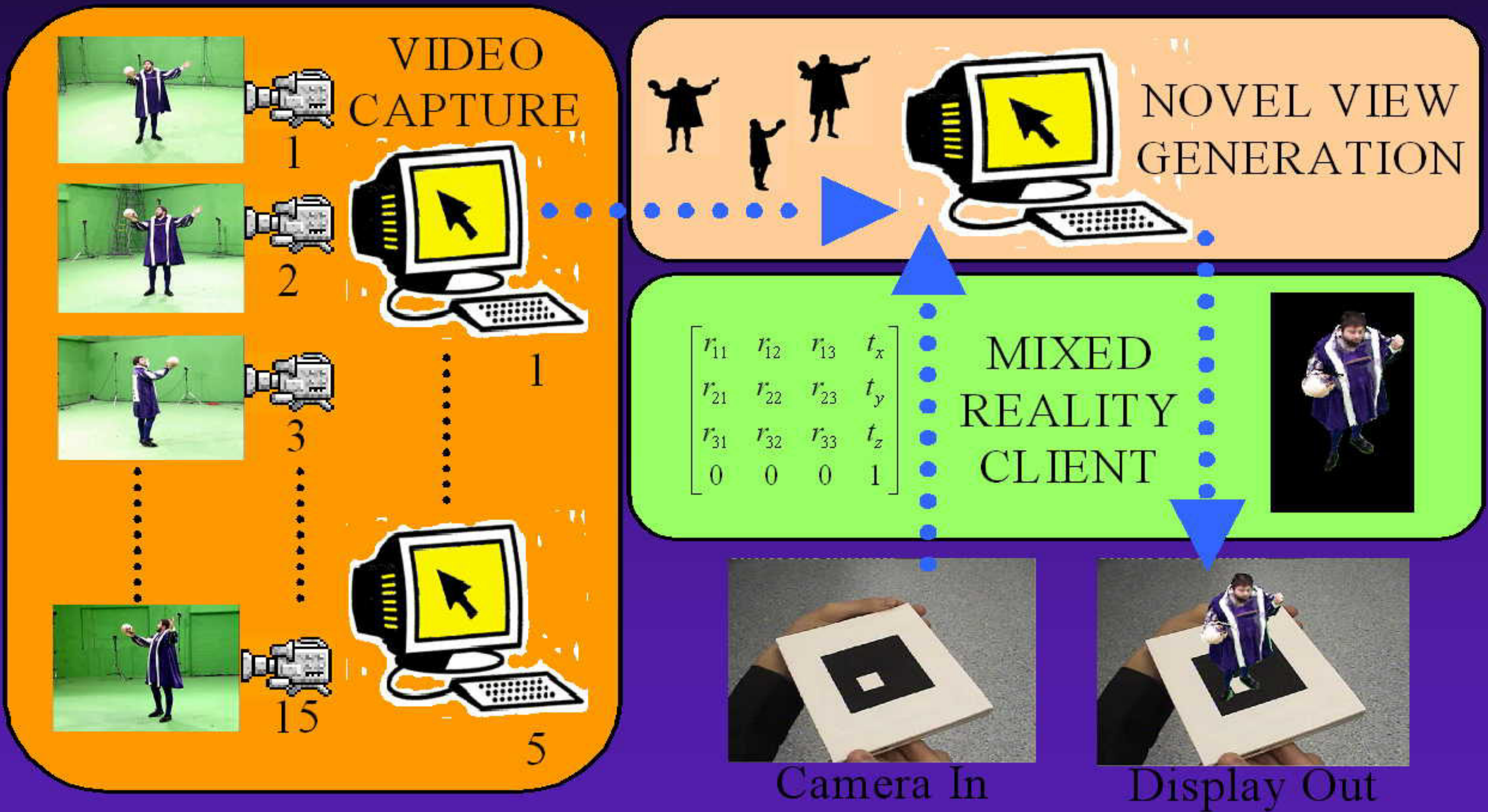
Virtual Viewpoint Generation



3D Live Video

Video 7

3D Live System



Lessons Learned

- Face to face collaboration
  - AR preferred over immersive VR
  - AR facilitates seamless/natural communication
- Remote Collaboration
  - AR spatial cues can enhance communication
  - AR conferencing improves video conferencing
  - AR supports transitional interfaces

A Word from our Sponsors

Come to Seattle

ISWC 2002

International Symposium on Wearable Computers

Seattle, Washington, USA

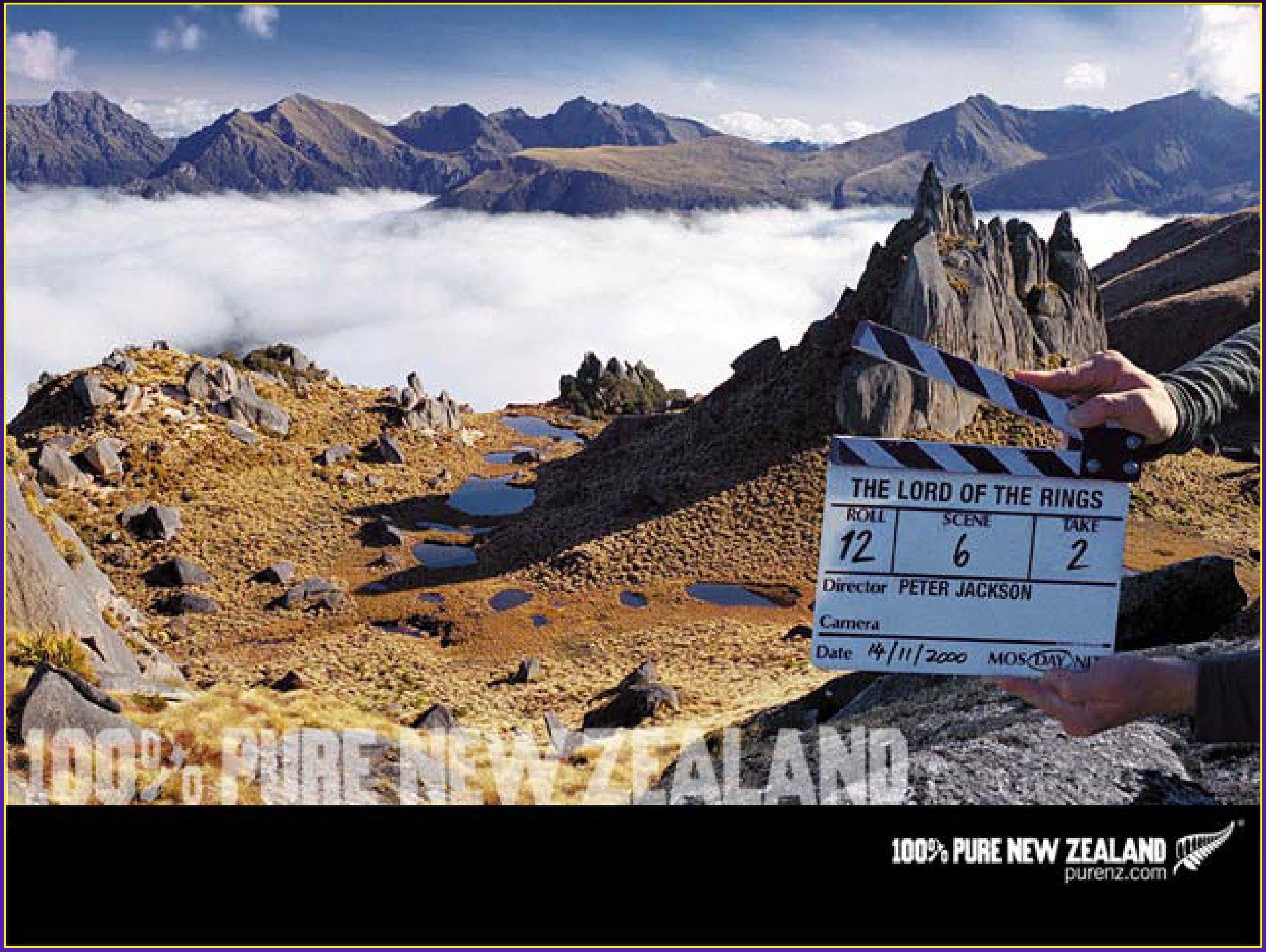
Oct 7^{th} - Tutorials/Workshops

Oct 8^{th}-10^{th} – Paper Presentations

Demos, Fashion show, Gadget show

http://iswc.tinmith.net/

Come to New Zealand



PostDoc Jobs !

- HIT Lab (New Zealand)
  - Christchurch, New Zealand
- 2 positions (1-5 years)
  - Computer graphics
  - 3D interface design
  - Interactive Experiences
  - EE hardware design
- MagicBook Hardware + Software

Conclusion + Future Work

Conclusions

- AR techniques can be used to develop fundamentally different collaborative interfaces
  - Provide spatial audio and visual cues
  - Removes separation between task and communication space
  - Hybrid user interfaces
  - Transitions users between reality and virtual reality

Future Work

- High Fidelity Remote AR Conferencing
  - Fully 3D virtual video views
- Effect of Display Characteristics on Collaboration
  - Differing Displays
    - Stereo vs. non-stereo,See-through vs. non see-through
  - Differing Delays
    - 100 ms, 300 ms, etc cf. Video conferencing
- Hybrid Interfaces
  - Moving data between displays, using legacy applications
- Rigorous Evaluation Studies
- Additional Metrics
  - Cognitive measures, shared understanding

More Information

- HIT Lab. New Zealand
  - http://www.hitlabnz.org/
- ARToolKit
  - http://www.hitl.washington.edu/artoolkit/
- Email
  - Mark Billinghurst
    - mark.billinghurst@hitlabnz.org

Thanks

- People
  - HIT Lab Staff and Students
  - Hirokazu Kato
    - Hiroshima City University
  - Ivan Poupyrev
    - Sony CSL
  - Kiyoshi Kiyokawa
    - Communication Research Laboratory, Tokyo
- Company
  - Chevron, Lockheed Martin, British Telecom, US Navy

Transitional Interfaces

Milgram's Continuum (1994)

Mixed Reality (MR)

Reality (Tangible Interfaces)

Augmented Reality (AR)

Augmented Virtuality (AV)

Virtuality (Virtual Reality)

Transitions

- Interfaces of the future will need to support transitions along the RV continuum
- Augmented Reality is preferred for:
  - co-located collaboration
- Immersive Virtual Reality is preferred for:
  - experiencing world immersively (egocentric)
  - sharing views
  - remote collaboration

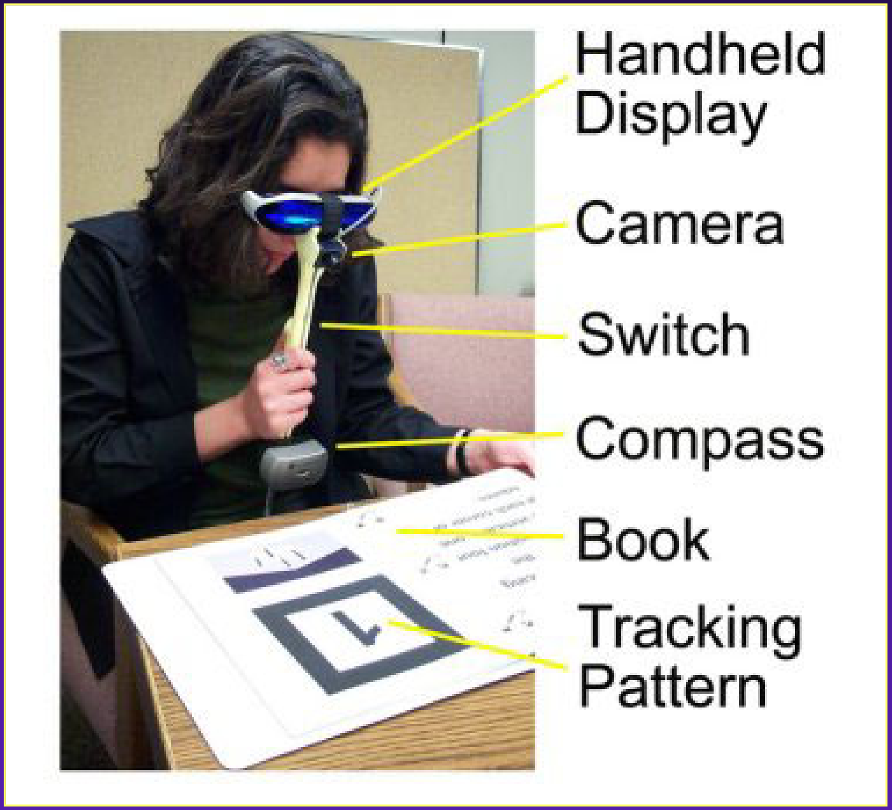
MagicBook Metaphor

MagicBook Video

Video 8

Technology

- Reality
  - No technology
- Augmented Reality
  - Camera – tracking
  - Switch – fly in
- Virtual Reality
  - Compass – tracking
  - Press pad – move
  - Switch – fly out



Collaboration in the MagicBook

Egocentric

Exocentric

Collaboration

- Collaboration on multiple levels:
  - Physical Object
  - AR Object
  - Immersive Virtual Space
- Egocentric + exocentric collaboration
  - multiple multi-scale users
- Independent Views
  - Privacy, role division, scalability