LECTURE 9: AR INTERACTION

COMP 4010 – Virtual Reality
Semester 5 – 2017

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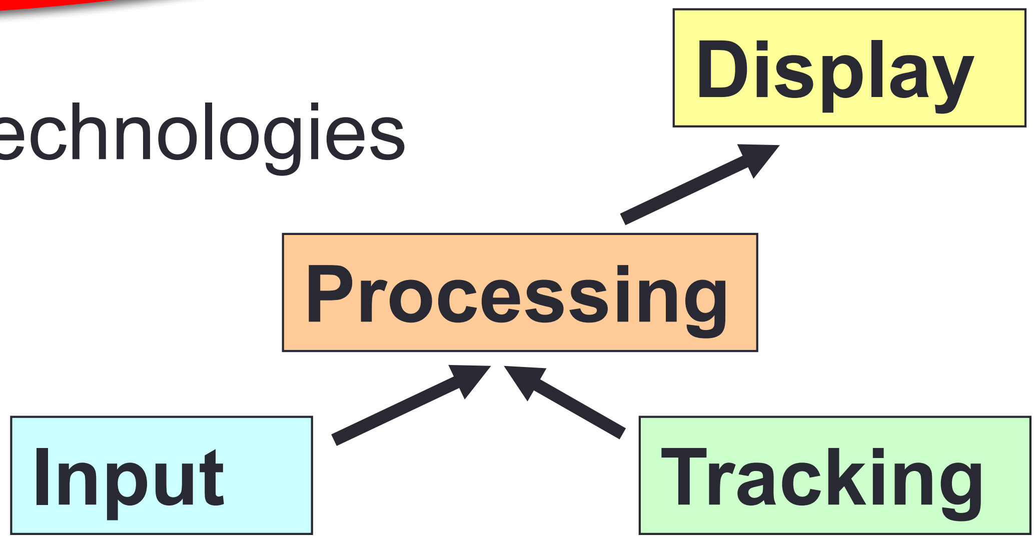
Augmented Reality Definition

- Defining Characteristics [Azuma 97]
  - Combines Real and Virtual Images
    - Both can be seen at the same time
  - Interactive in real-time
    - The virtual content can be interacted with
  - Registered in 3D
    - Virtual objects appear fixed in space

Azuma, R. T. (1997). A survey of augmented reality. Presence, 6(4), 355-385.

Augmented Reality Technology

- Combining Real and Virtual Images
  - Display technologies
- Interactive in Real-Time
  - Input and interactive technologies
- Registered in 3D
  - Viewpoint tracking technologies



AR INTERFACE DESIGN

Interface Design Path

1/ Prototype Demonstration

2/ Adoption of Interaction Techniques from other interface metaphors

Augmented Reality

3/ Development of new interface metaphors appropriate to the medium

Virtual Reality

4/ Development of formal theoretical models for predicting and modeling user actions

Desktop WIMP

AR Interaction

- Designing AR System = Interface Design
  - Using different input and output technologies
- Objective is a high quality of user experience
  - Ease of use and learning
  - Performance and satisfaction

Interacting with AR Content

- You can see spatially registered AR..

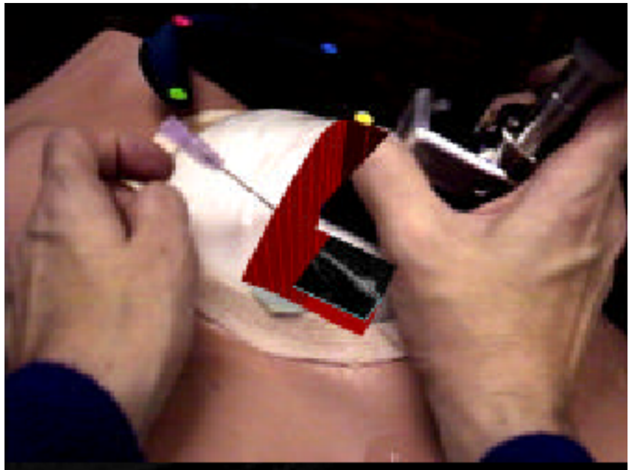
how can you interact with it?

Types of AR Interaction

- Browsing Interfaces
  - simple (conceptually!), unobtrusive
- 3D AR Interfaces
  - expressive, creative, require attention
- Tangible Interfaces
  - Embedded into conventional environments
- Tangible AR
  - Combines TUI input + AR display

AR Interfaces as Data Browsers

- 2D/3D virtual objects are registered in 3D
  - "VR in Real World"
- Interaction
  - 2D/3D virtual viewpoint control
- Applications
  - Visualization, training


State, et al. 1996

AR Information Browsers

- Information is registered to real-world context
  - Hand held AR displays
- Interaction
  - Manipulation of a window into information space
- Applications
  - Context-aware information displays

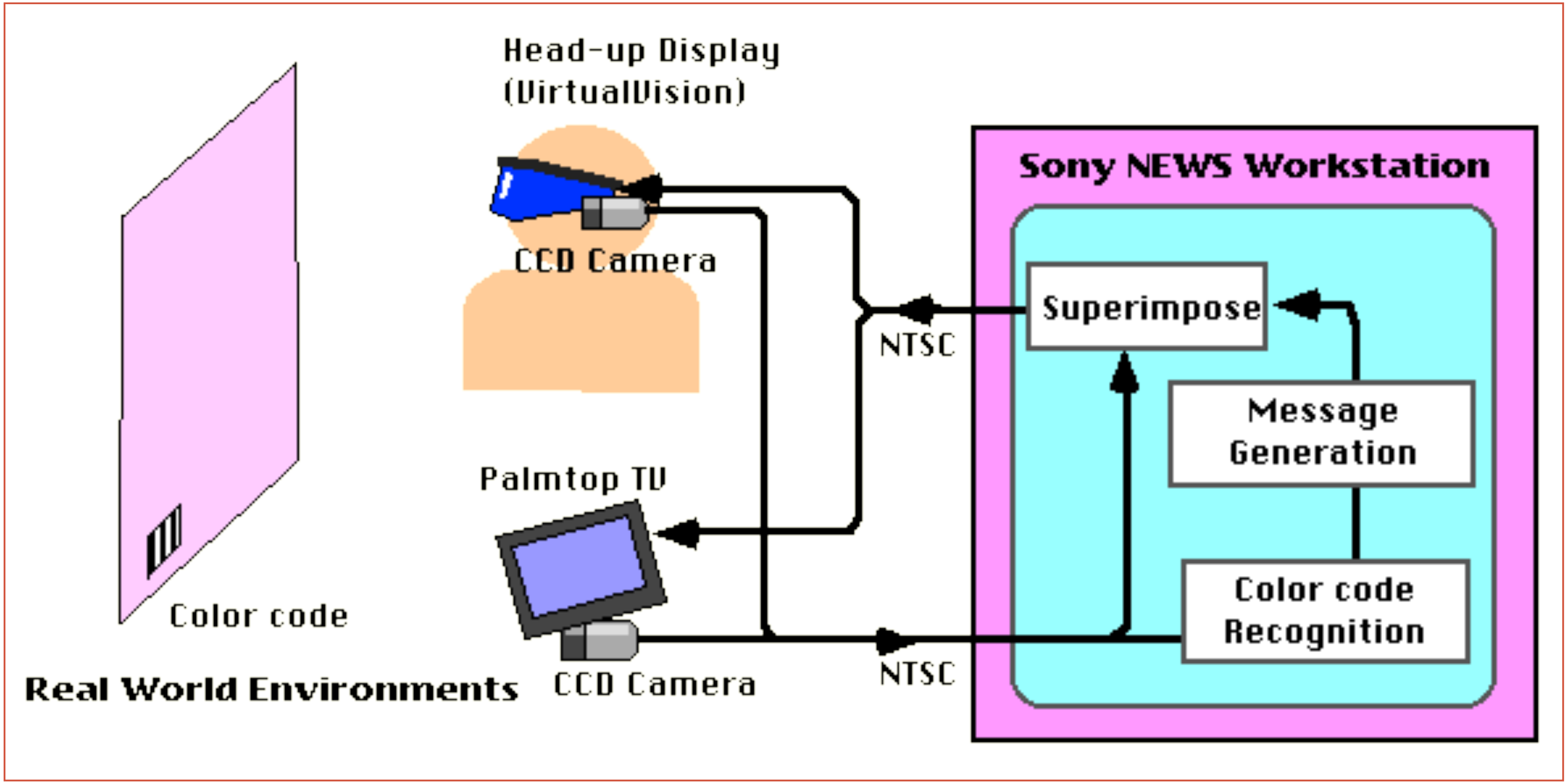
Rekimoto, et al. 1995

Rekimoto, J., & Nagao, K. (1995, December). The world through the computer: Computer augmented interaction with real world environments. In *Proceedings of the 8th annual ACM symposium on User interface and software technology* (pp. 29-36). ACM.

NaviCam Demo

https://www.youtube.com/watch?v=S6XKPEexRbU

Navicam Architecture



Current AR Information Browsers

- Mobile AR
  - GPS + compass
- Many Applications
  - Layar
  - Wikitude
  - Acrossair
  - PressLite
  - Yelp
  - AR Car Finder
  - …

Example Layar

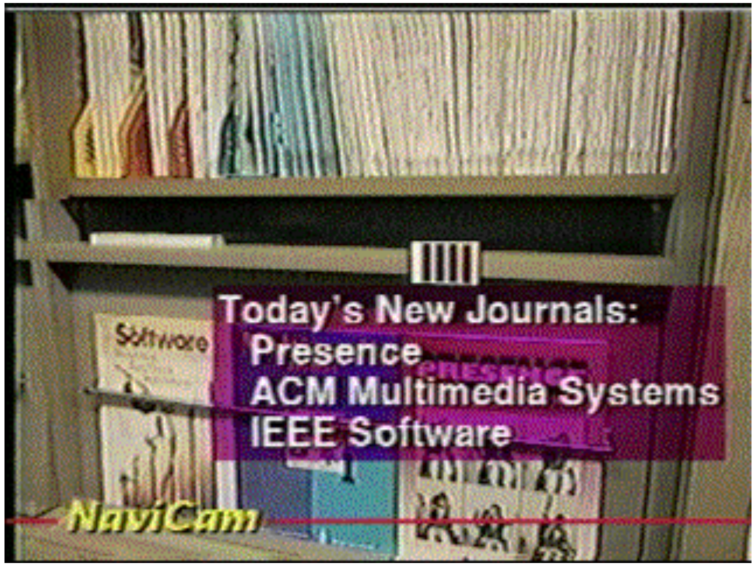
- AR Browser from Layar
  - http://www.layar.com
- AR browsing
  - GPS + compass
  - 2D/3D object placement
  - Photos/live video
  - Community viewing


Home
7
2
5
4
T-Rex attack
So they are still hiding out some-where...
5 comments


Cancel
Publish
+

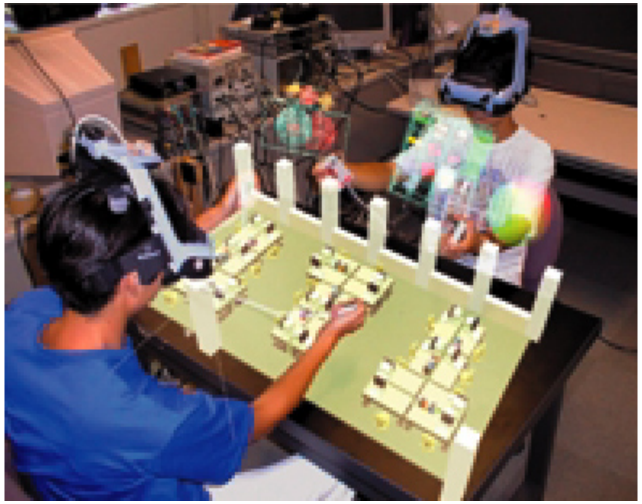
Advantages and Disadvantages

- Important class of AR interfaces
  - Wearable computers
  - AR simulation, training
- Limited interactivity
  - Modification of virtual content is difficult



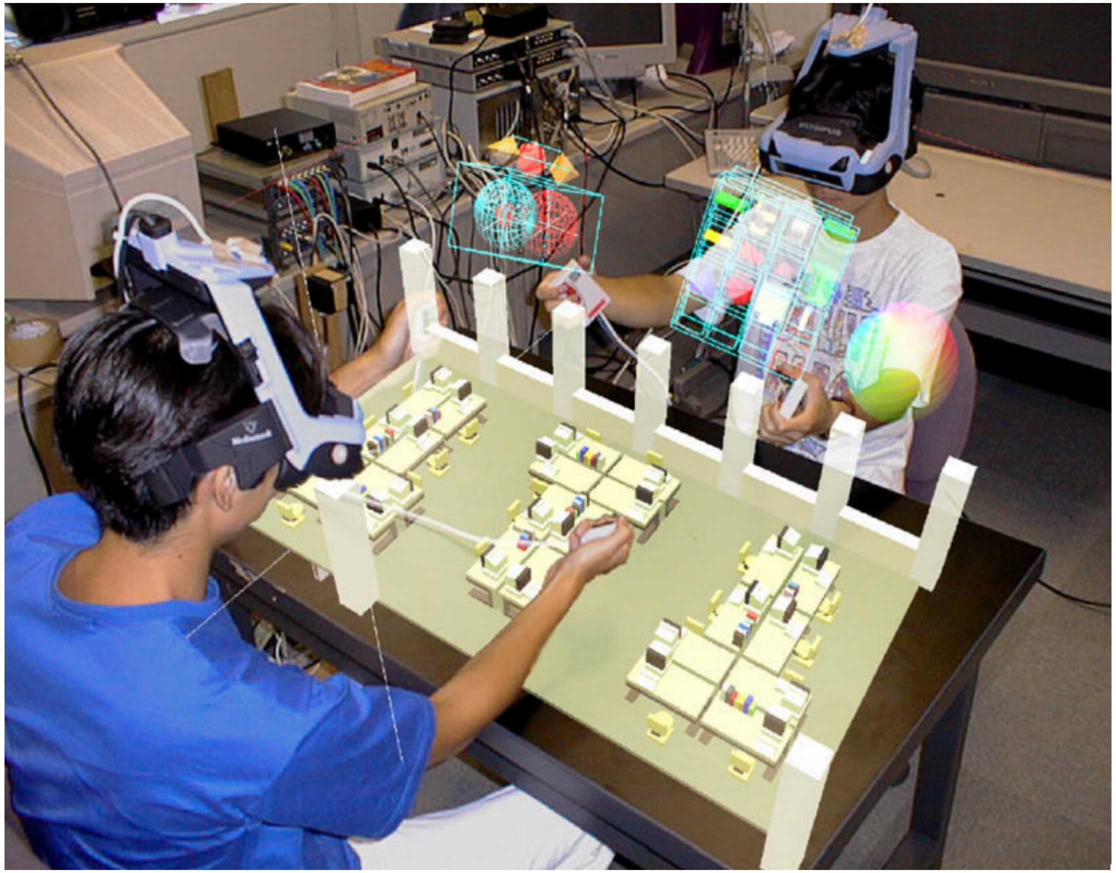
3D AR Interfaces

- Virtual objects displayed in 3D physical space and manipulated
  - HMDs and 6DOF head-tracking
  - 6DOF hand trackers for input
- Interaction
  - Viewpoint control
  - Traditional 3D user interface interaction: manipulation, selection, etc.



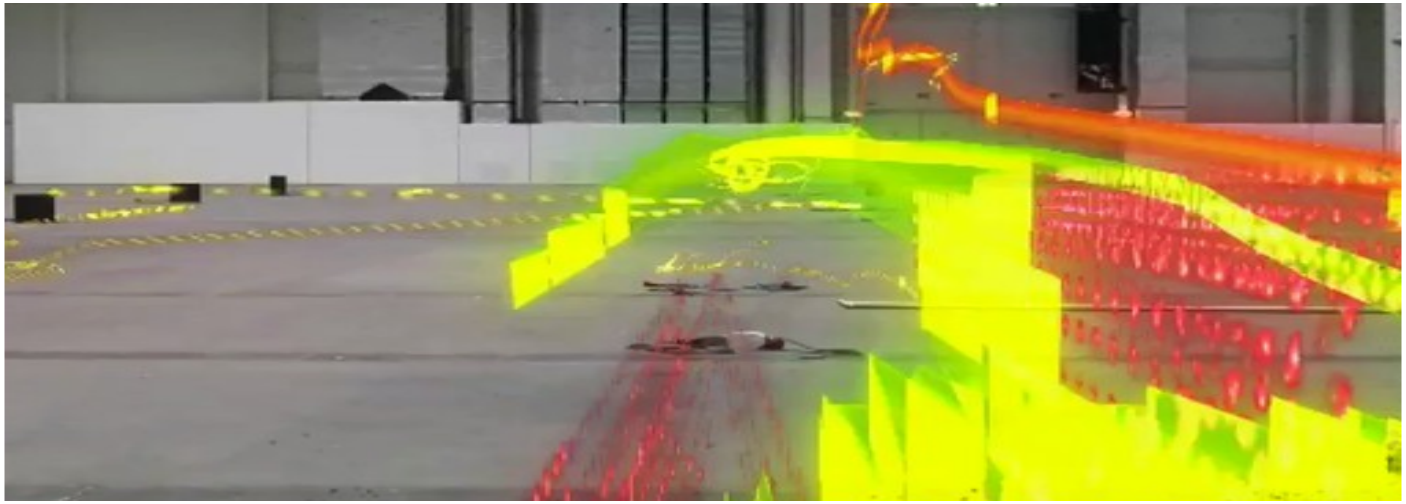
Kiyokawa, et al. 1998

AR 3D Interaction – VLEGO II



Kiyokawa, K., Iwasa, H., Takemura, H., & Yokoya, N. (1998, October). Collaborative immersive workspace through a shared augmented environment. In *Proc. SPIE* (Vol. 98, pp. 2-13).

Recent Example: AR Graffiti



https://www.youtube.com/watch?v=d4WZpYFRhg4

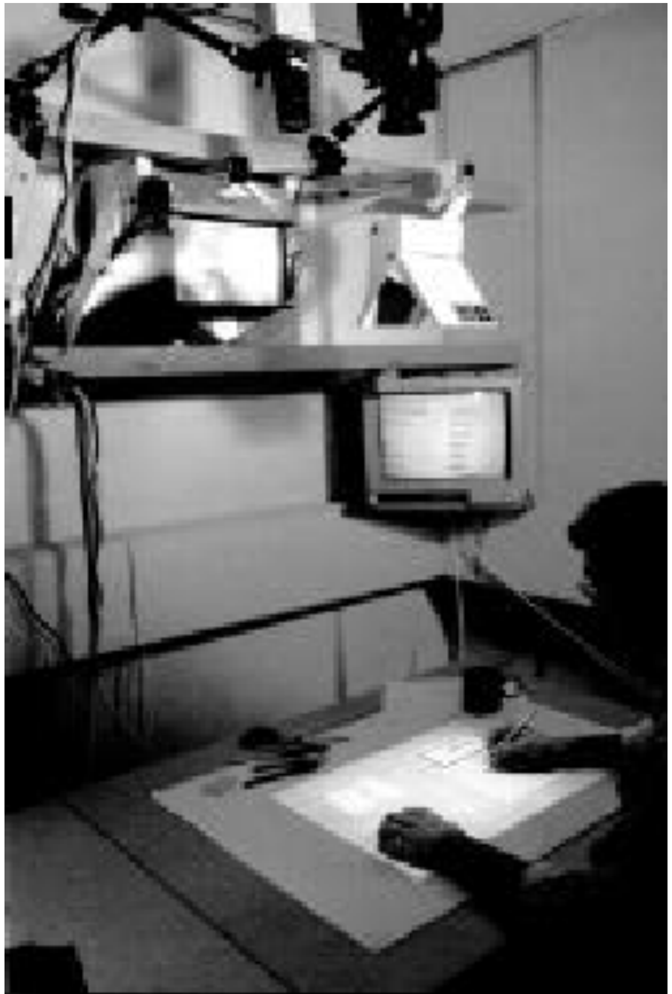
Advantages and Disadvantages

- Important class of AR interfaces
  - Entertainment, design, training
- Advantages
  - User can interact with 3D virtual object everywhere in space
  - Natural, familiar interaction
- Disadvantages
  - Usually no tactile feedback
  - User has to use different devices for virtual and physical objects

Oshima, et al. 2000

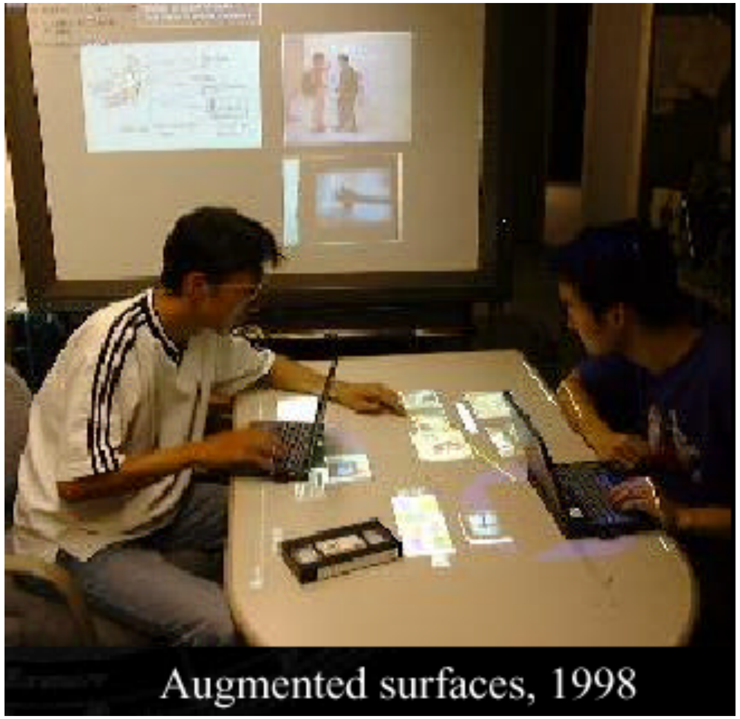
Augmented Surfaces and Tangible Interfaces

- Basic principles
  - Virtual objects are projected on a surface
  - Physical objects are used as controls for virtual objects
  - Support for collaboration


Digital Desk. 1993

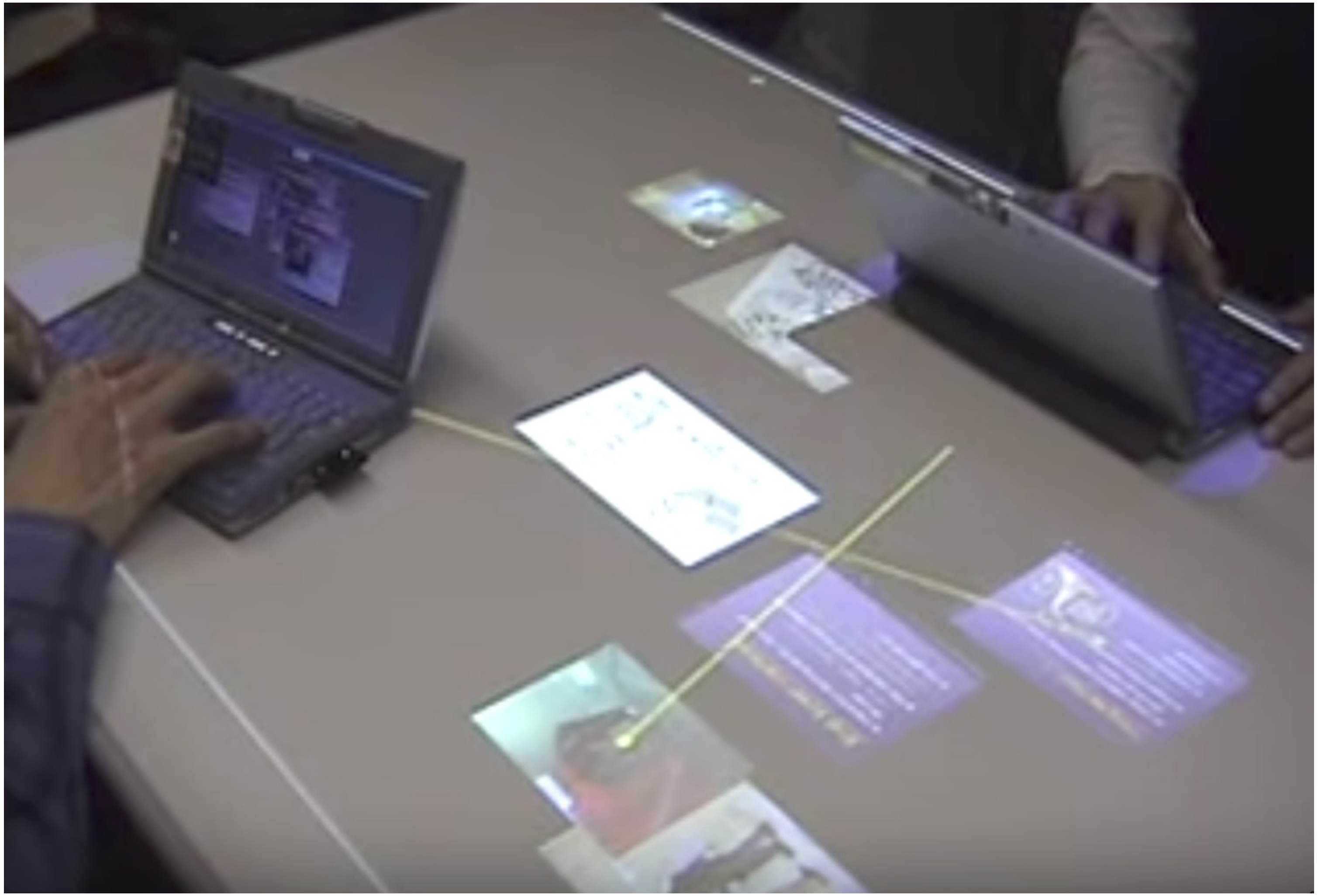
Augmented Surfaces

- Rekimoto, et al. 1999
  - Front projection
  - Marker-based tracking
  - Multiple projection surfaces



Rekimoto, J., & Saitoh, M. (1999, May). Augmented surfaces: a spatially continuous work space for hybrid computing environments. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems* (pp. 378-385). ACM.

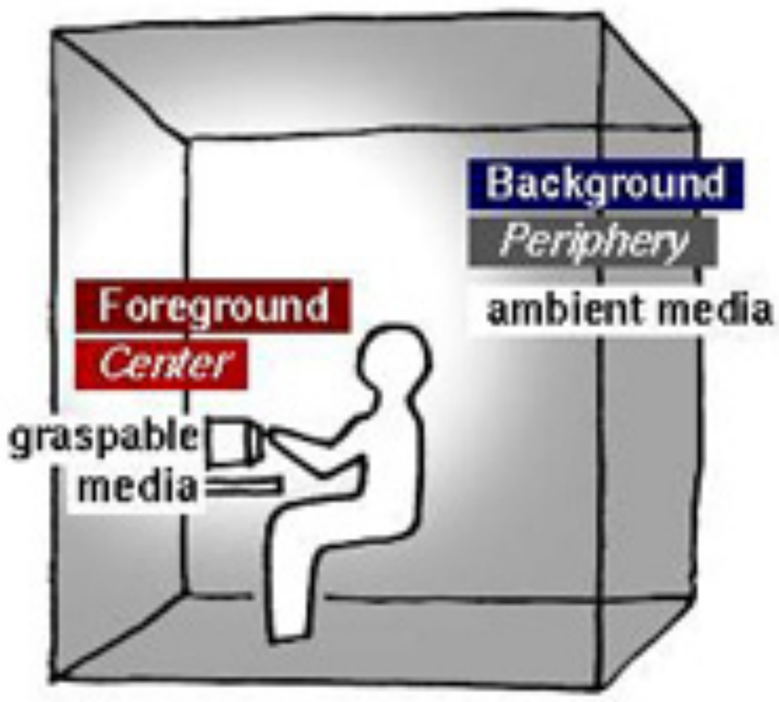
Augmented Surfaces Demo



https://www.youtube.com/watch?v=r4g_fvnjVCA

Tangible User Interfaces (Ishii 97)

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



drawing: Hiroshi Ishii

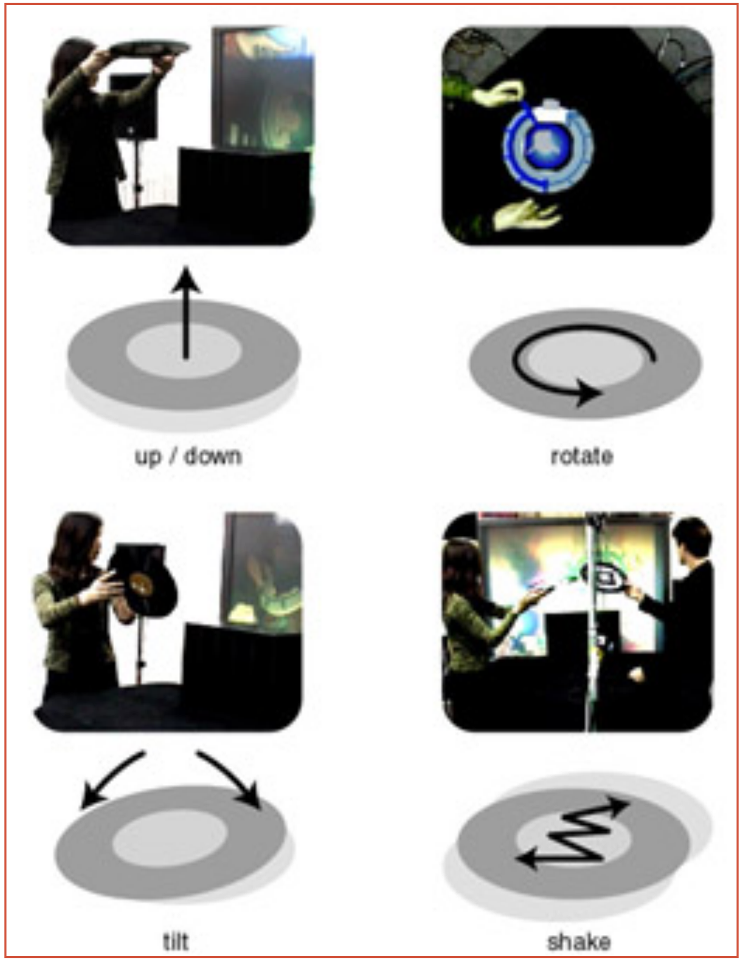
Ishii, H., & Ullmer, B. (1997, March). Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems* (pp. 234-241). ACM.

Tangible Interfaces - Ambient

- Dangling String
  - Jeremijenko 1995
  - Ambient ethernet monitor
  - Relies on peripheral cues
- Ambient Fixtures
  - Dahley, Wisneski, Ishii 1998
  - Use natural material qualities for information display

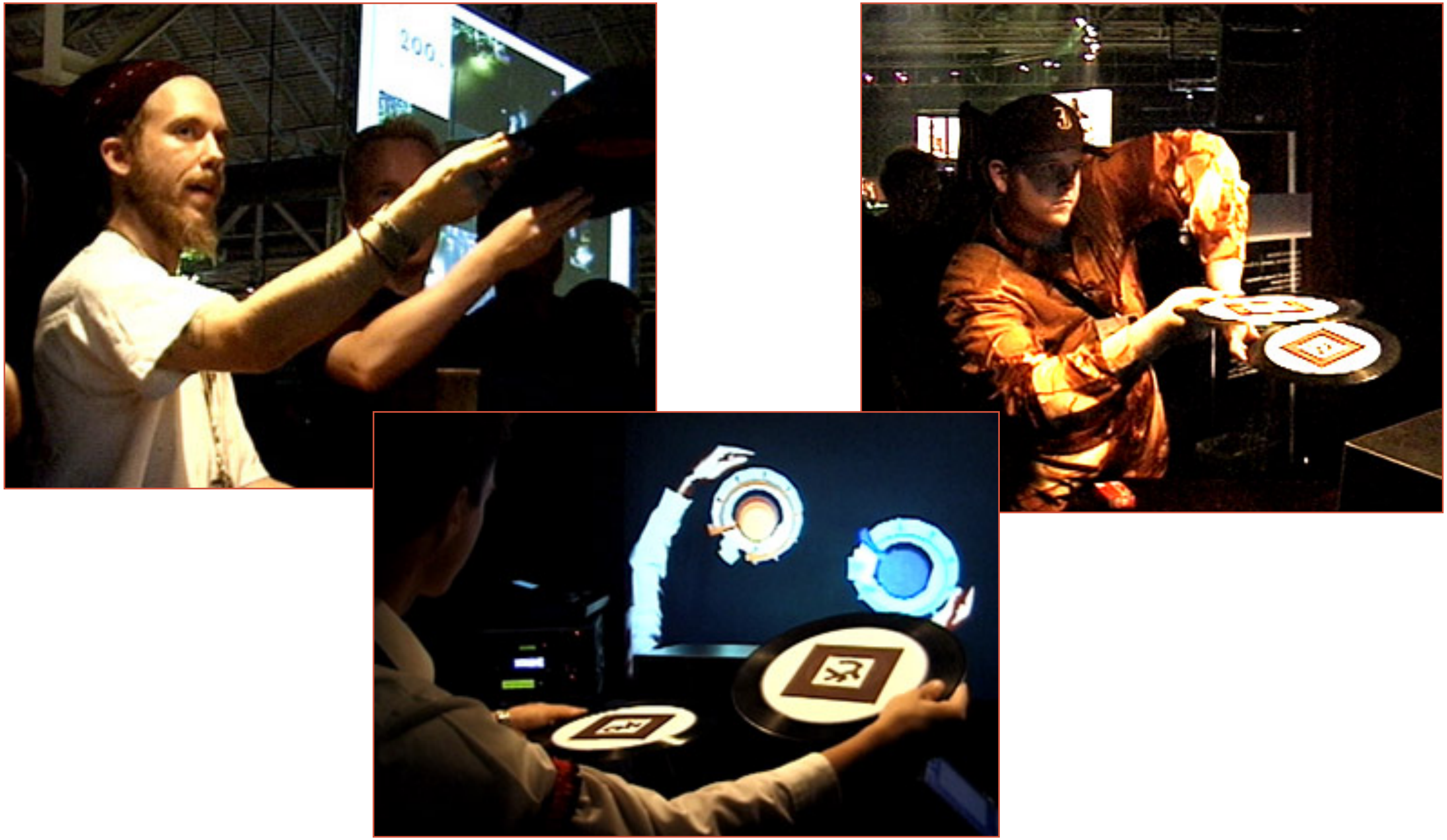
Tangible Interface: Argroove (2000)

- Collaborative Instrument
- Exploring Physically Based Interaction
  - Map physical actions to Midi output
    - Translation, rotation
    - Tilt, shake



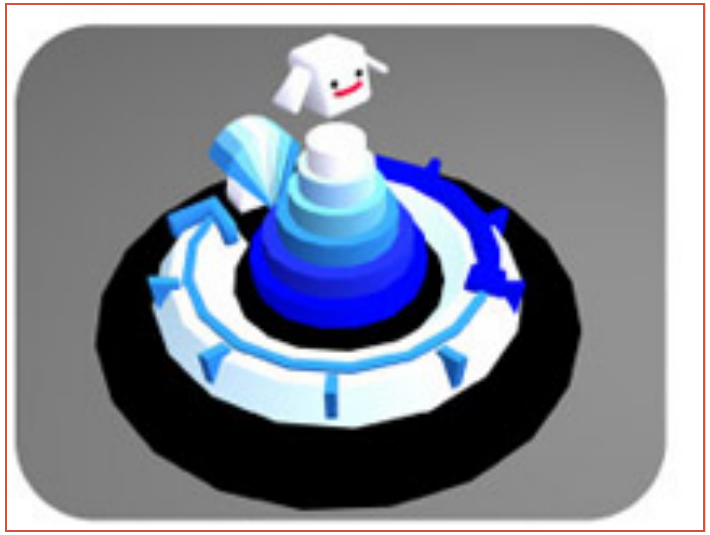
Poupyrev, I., Berry, R., Kurumisawa, J., Nakao, K., Billinghurst, M., Airola, C., ... & Baldwin, L. (2000). Augmented groove: Collaborative jamming in augmented reality. In *ACM SIGGRAPH 2000 Conference Abstracts and Applications* (p. 77).

ARgroove in Use

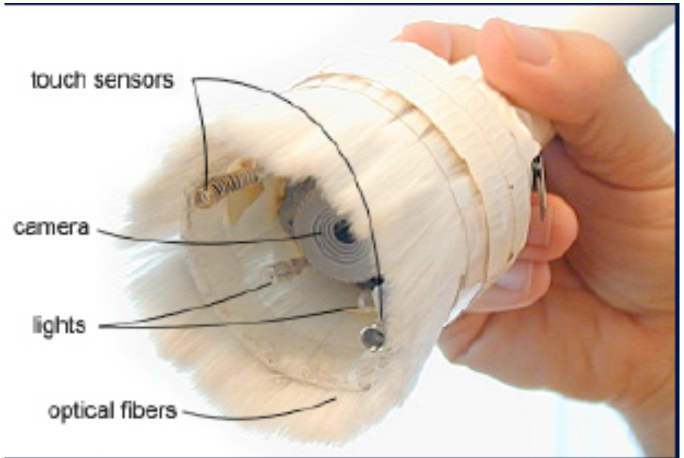


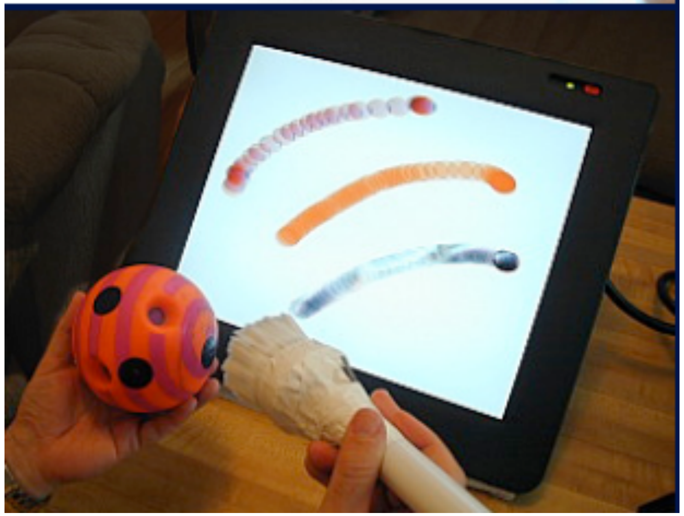
Visual Feedback

- Continuous Visual Feedback is Key
- Single Virtual Image Provides:
  - Rotation
  - Tilt
  - Height



i/O Brush (Ryokai, Marti, Ishii)





Ryokai, K., Marti, S., & Ishii, H. (2004, April). I/O brush: drawing with everyday objects as ink.
In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 303-310). ACM.

i/O Brush Demo

https://www.youtube.com/watch?v=04v_v1gnyO8

Other Examples

- Triangles (Gorbert 1998)
  - Triangular based story telling
- ActiveCube (Kitamura 2000-)
  - Cubes with sensors

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

TUI Limitations

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

Advantages and Disadvantages

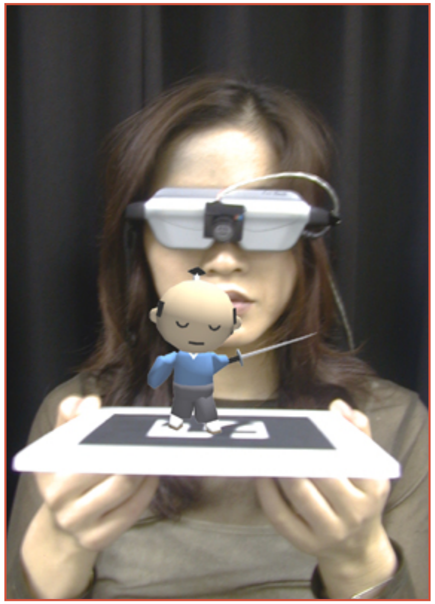
- Advantages
  - Natural - users hands are used for interacting with both virtual and real objects.
    - No need for special purpose input devices
- Disadvantages
  - Interaction is limited only to 2D surface
    - Full 3D interaction and manipulation is difficult

Orthogonal Nature of AR Interfaces

	3D AR	Augmented surfaces
Spatial gap	No interaction is everywhere	Yes interaction is only on 2D surfaces
Interaction gap	Yes separate devices for physical and virtual objects	No same devices for physical and virtual objects

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

Space vs. Time - Multiplexed

- Space-multiplexed
  - Many devices each with one function
    - Quicker to use, more intuitive, clutter
    - Real Toolbox

- Time-multiplexed
  - One device with many functions
    - Space efficient
    - mouse

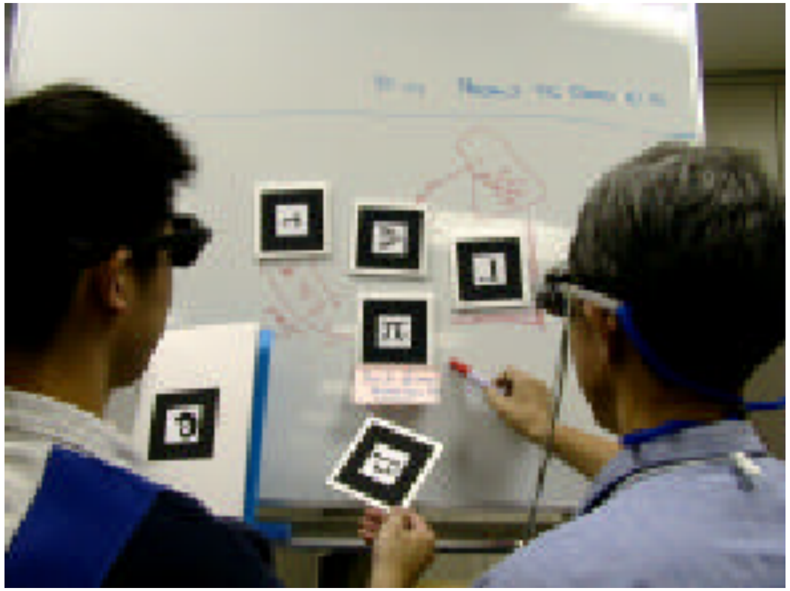
Tangible AR: Tiles (Space Multiplexed)

- Tiles semantics
  - data tiles
  - operation tiles
- Operation on tiles
  - proximity
  - spatial arrangements
  - space-multiplexed

Tiles, 2001

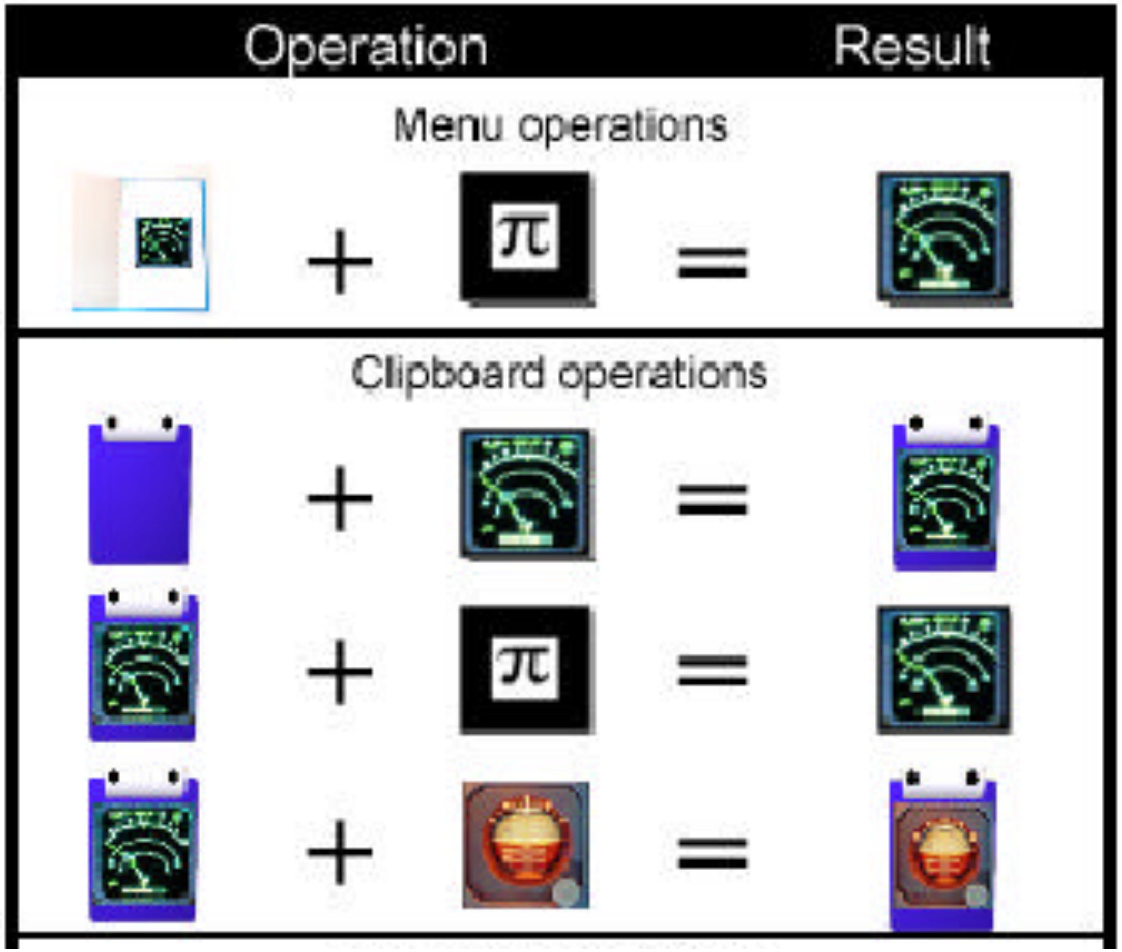
Poupyrev, I., Tan, D. S., Billinghurst, M., Kato, H., Regenbrecht, H., & Tetsutani, N. (2001). Tiles: A Mixed Reality Authoring Interface. In *Interact* (Vol. 1, pp. 334-341).

Space-multiplexed Interface



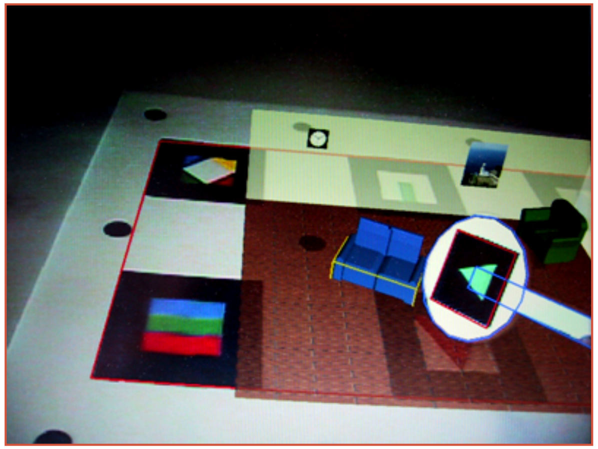
Data authoring in Tiles

Proximity-based Interaction



Tangible AR: Time-multiplexed Interaction

- 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



Kato, H., Billinghurst, M., Poupyrev, I., Tetsutani, N., & Tachibana, K. (2001). Tangible augmented reality for human computer interaction. In Proceedings of Nicograph 2001.

VOMAR Interface

Advantages and Disadvantages

- Advantages
  - Natural interaction with virtual and physical tools
    - No need for special purpose input devices
  - Spatial interaction with virtual objects
    - 3D manipulation with virtual objects anywhere in space
- Disadvantages
  - Requires Head Mounted Display

Wrap-up

- Browsing Interfaces
  - simple (conceptually!), unobtrusive
- 3D AR Interfaces
  - expressive, creative, require attention
- Tangible Interfaces
  - Embedded into conventional environments
- Tangible AR
  - Combines TUI input + AR display

DESIGNING AR SYSTEMS

Basic Design Guides

- Provide good conceptual model/Metaphor
  - customers want to understand how UI works
- Make things visible
  - if object has function, interface should show it
- Map interface controls to customer's model
  - infix -vs- postfix calculator -- whose model?
- Provide feedback
  - what you see is what you get!

AR Design Principles

- **Interface Components**
  - Physical components
  - Display elements
    - Visual/audio
  - Interaction metaphors

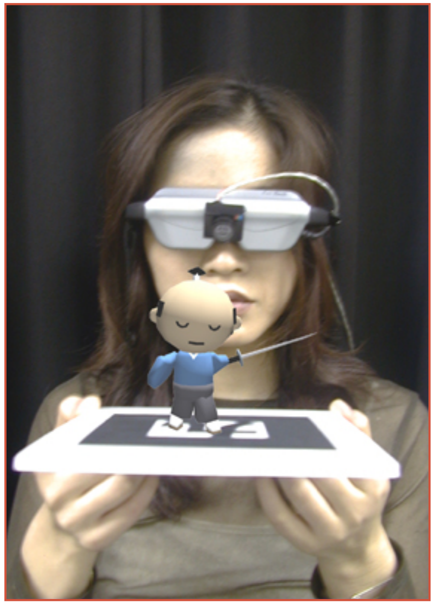
Physical Elements → Display Elements

Interaction Metaphor

Input **Output**

Tangible AR Metaphor

- 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 AR Design Principles

- Tangible AR Interfaces use TUI principles
  - Physical controllers for moving virtual content
  - Support for spatial 3D interaction techniques
  - Time and space multiplexed interaction
  - Support for multi-handed interaction
  - Match object affordances to task requirements
  - Support parallel activity with multiple objects
  - Allow collaboration between multiple users

AR Design Space

Reality

Virtual Reality

Augmented Reality

Physical Design

Virtual Design

Design of Objects

- Objects
  - Purposely built – affordances
  - “Found” – repurposed
  - Existing – already at use in marketplace
- Make affordances obvious (Norman)
  - Object affordances visible
  - Give feedback
  - Provide constraints
  - Use natural mapping
  - Use good cognitive model

Object Design

Affordances: to give a clue

- Refers to an attribute of an object that allows people to know how to use it
  - e.g. a button invites pushing, a door handle affords pulling
- Norman (1988) used the term to discuss the design of everyday objects
- Since has been much popularised in interaction design to discuss how to design interface objects
  - e.g. scrollbars afford moving up and down, icons afford clicking

Physical Affordances

- Physical affordances:

  How do the following physical objects afford?

  Are they obvious?

‘Affordance’ and Interface Design?

- Interfaces are virtual and do not have affordances like physical objects
- Norman argues it does not make sense to talk about interfaces in terms of ‘real’ affordances
- Instead interfaces are better conceptualized as ‘perceived’ affordances
  - Learned conventions of arbitrary mappings between action and effect at the interface
  - Some mappings are better than others

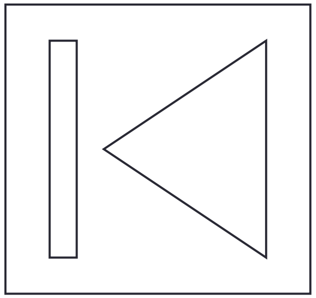
Virtual Affordances

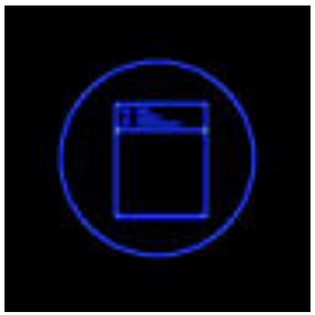
- Virtual affordances

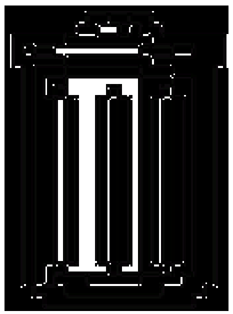
  How do the following screen objects afford?

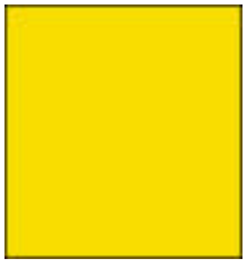
  What if you were a novice user?

  Would you know what to do with them?







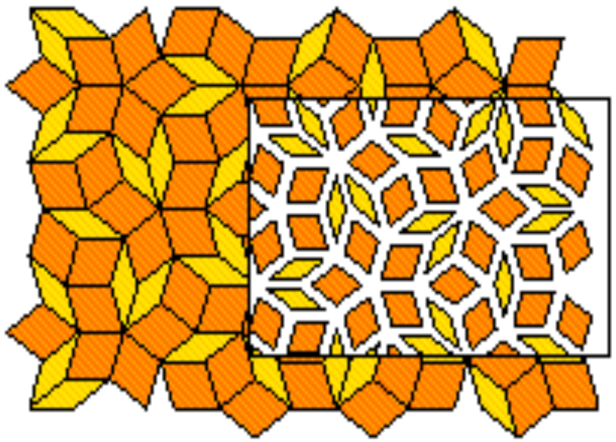


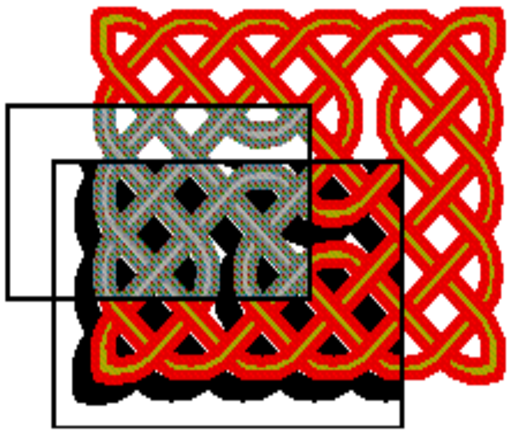
- AR is mixture of physical affordance and virtual affordance
- Physical
  - Tangible controllers and objects
- Virtual
  - Virtual graphics and audio

Case Study 1: 3D AR Lens

Goal: Develop a lens based AR interface

- MagicLenses
  - Developed at Xerox PARC in 1993
  - View a region of the workspace differently to the rest
  - Overlap MagicLenses to create composite effects

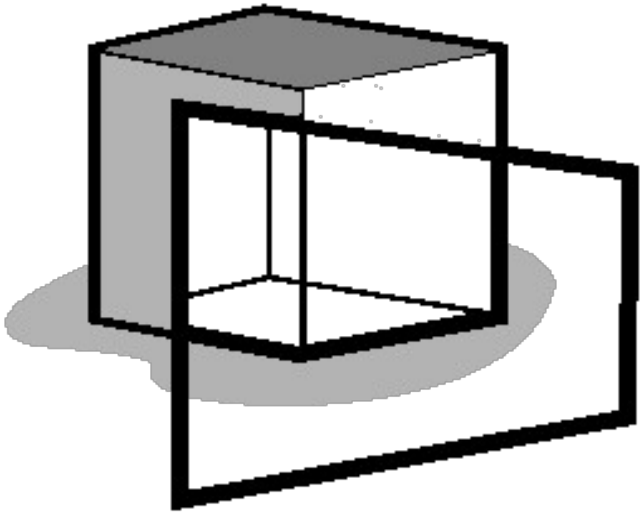


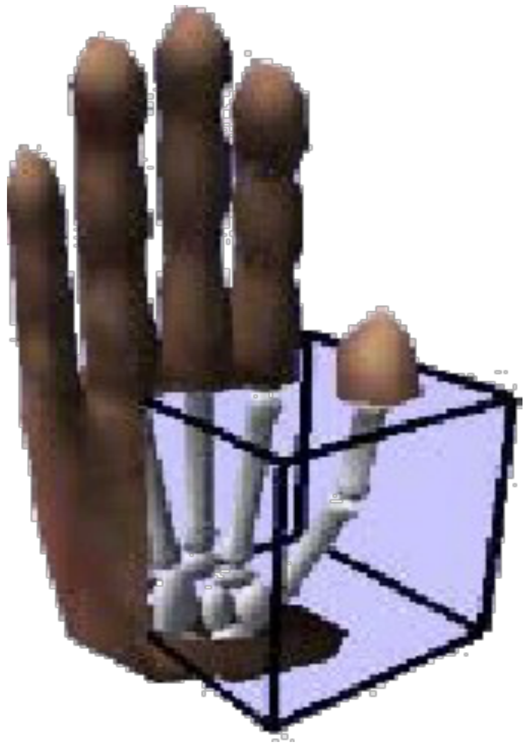


3D MagicLenses

MagicLenses extended to 3D (Veiga et. al. 96)

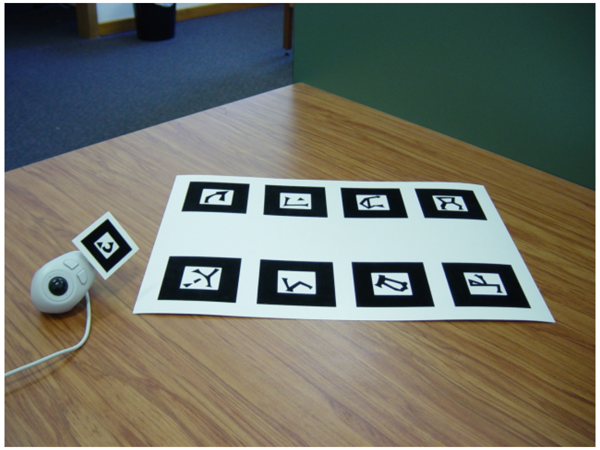
- Volumetric and flat lenses





AR Lens Design Principles

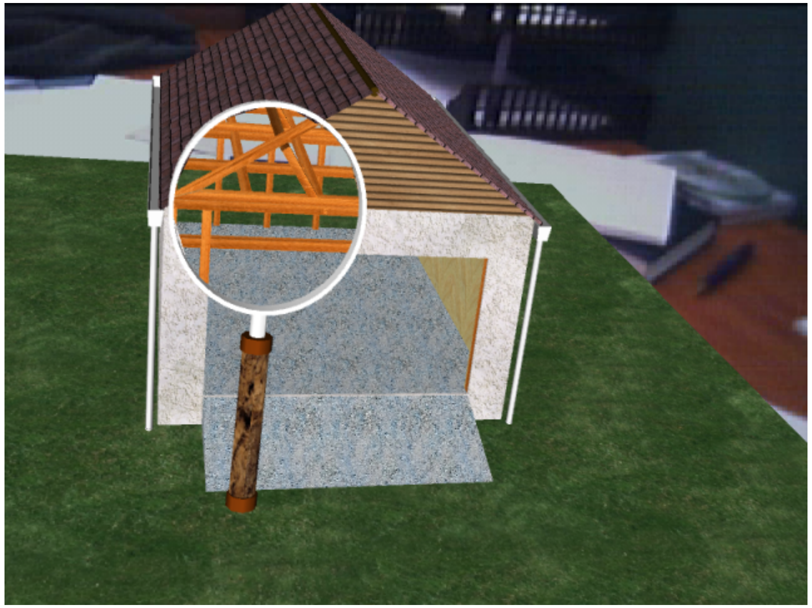
- Physical Components
  - Lens handle
    - Virtual lens attached to real object
- Display Elements
  - Lens view
    - Reveal layers in dataset
- Interaction Metaphor
  - Physically holding lens



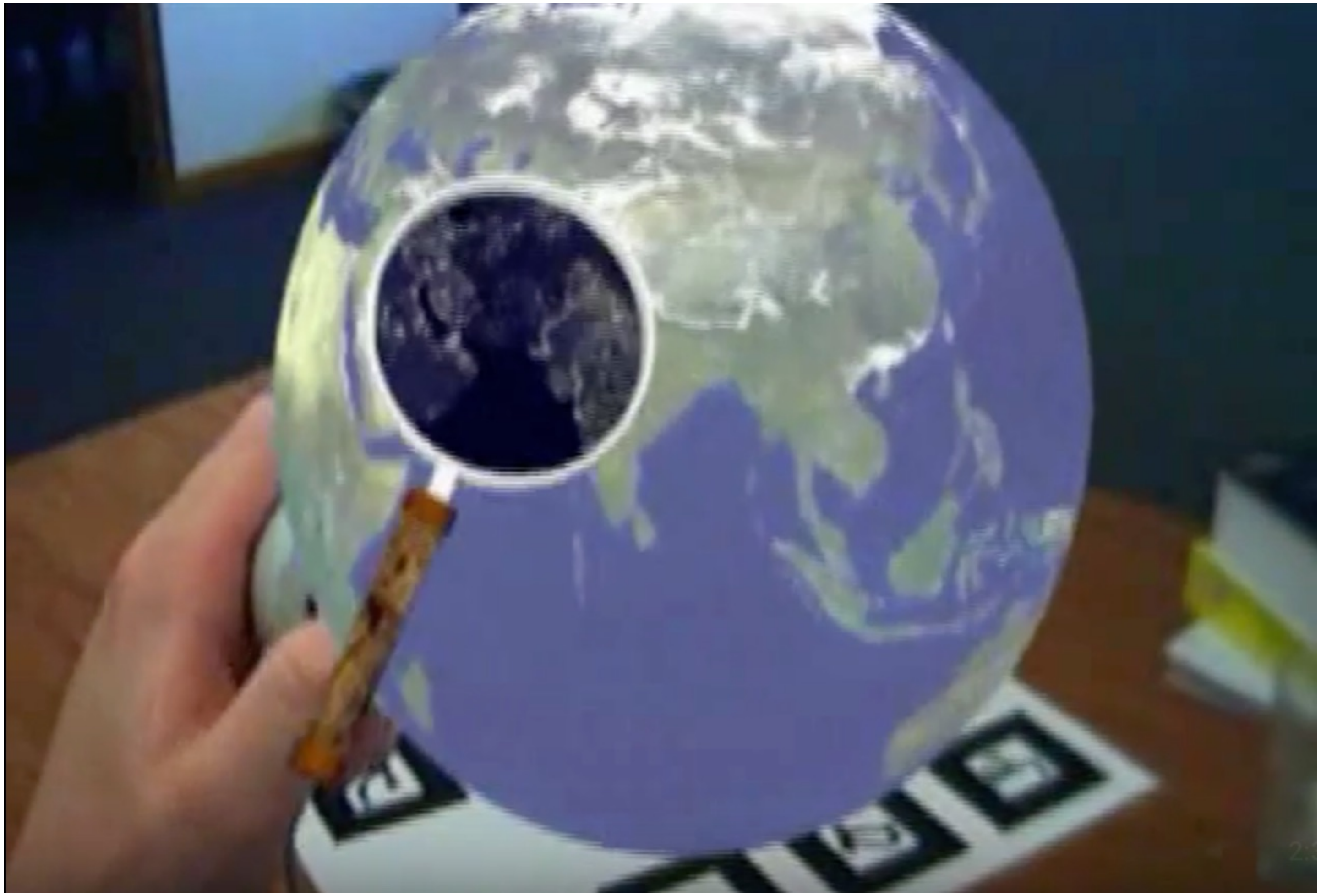
Looser, J., Billinghurst, M., & Cockburn, A. (2004, June). Through the looking glass: the use of lenses as an interface tool for Augmented Reality interfaces. In *Proceedings of the 2nd international conference on Computer graphics and interactive techniques in Australasia and South East Asia* (pp. 204-211). ACM.

3D AR Lenses: Model Viewer

- Displays models made up of multiple parts
- Each part can be shown or hidden through the lens
- Allows the user to peer inside the model
- Maintains focus + context

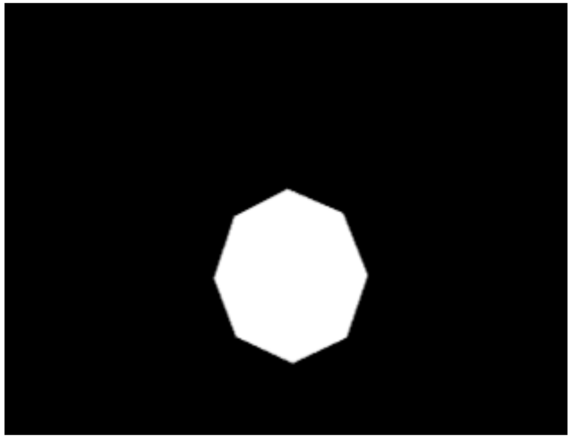


AR Lens Demo



https://www.youtube.com/watch?v=3zIq_qb8CSE&t=66s

AR Lens Implementation



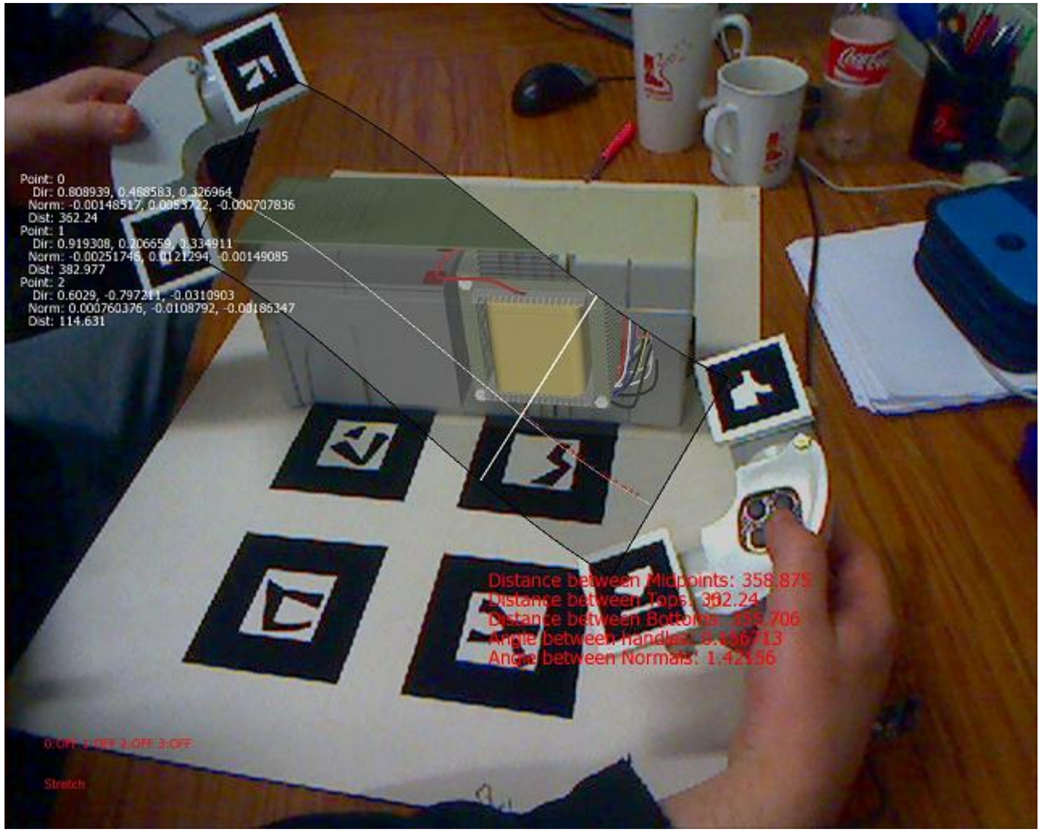
Stencil Buffer

Outside Lens

Inside Lens

Virtual Magnifying Glass

AR FlexiLens

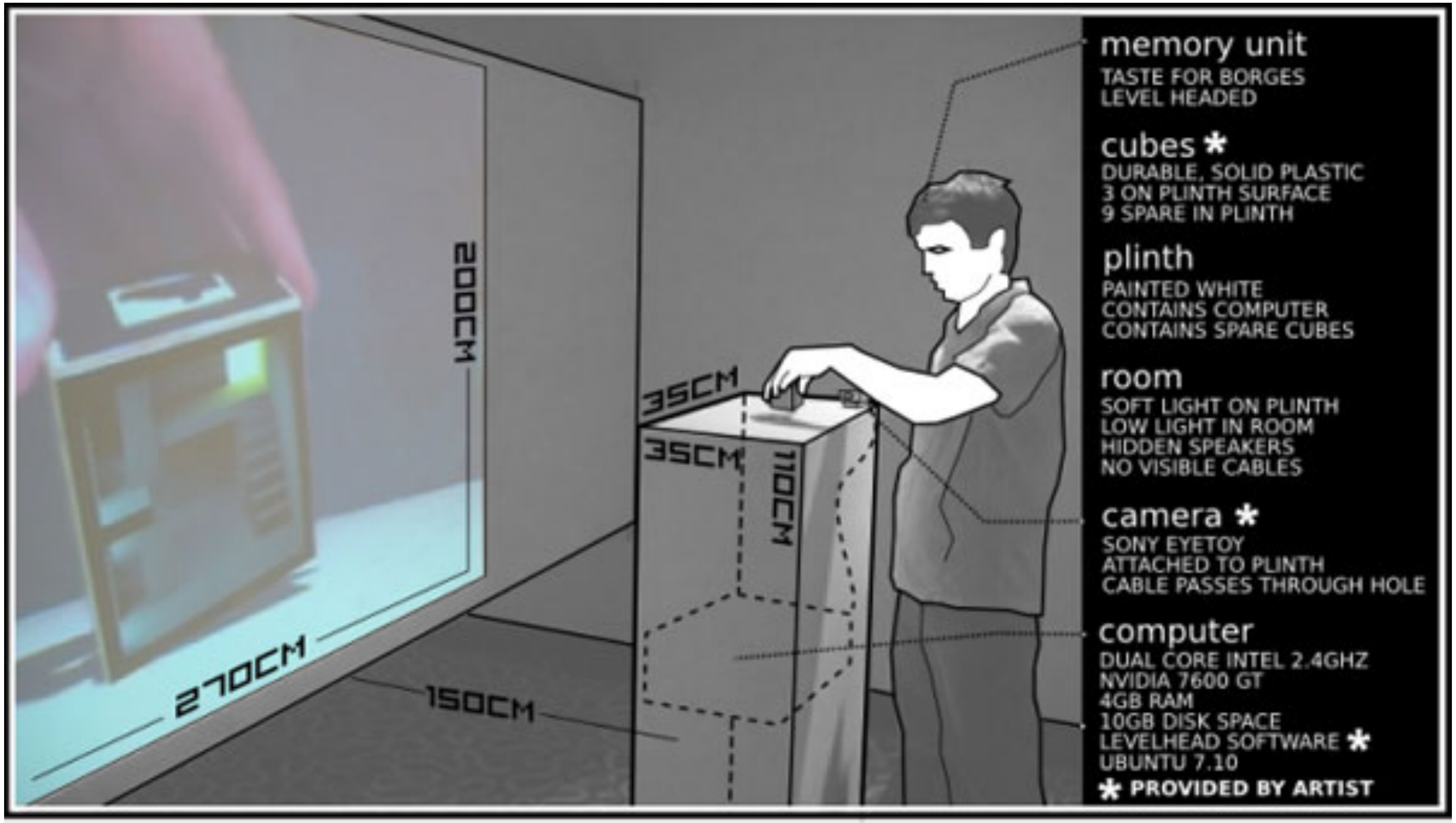


Real handles/controllers with flexible AR lens

Techniques based on AR Lenses

- Object Selection
  - Select objects by targeting them with the lens
- Information Filtering
  - Show different representations through the lens
  - Hide certain content to reduce clutter, look inside things
- Move between AR and VR
  - Transition along the reality-virtuality continuum
  - Change our viewpoint to suit our needs

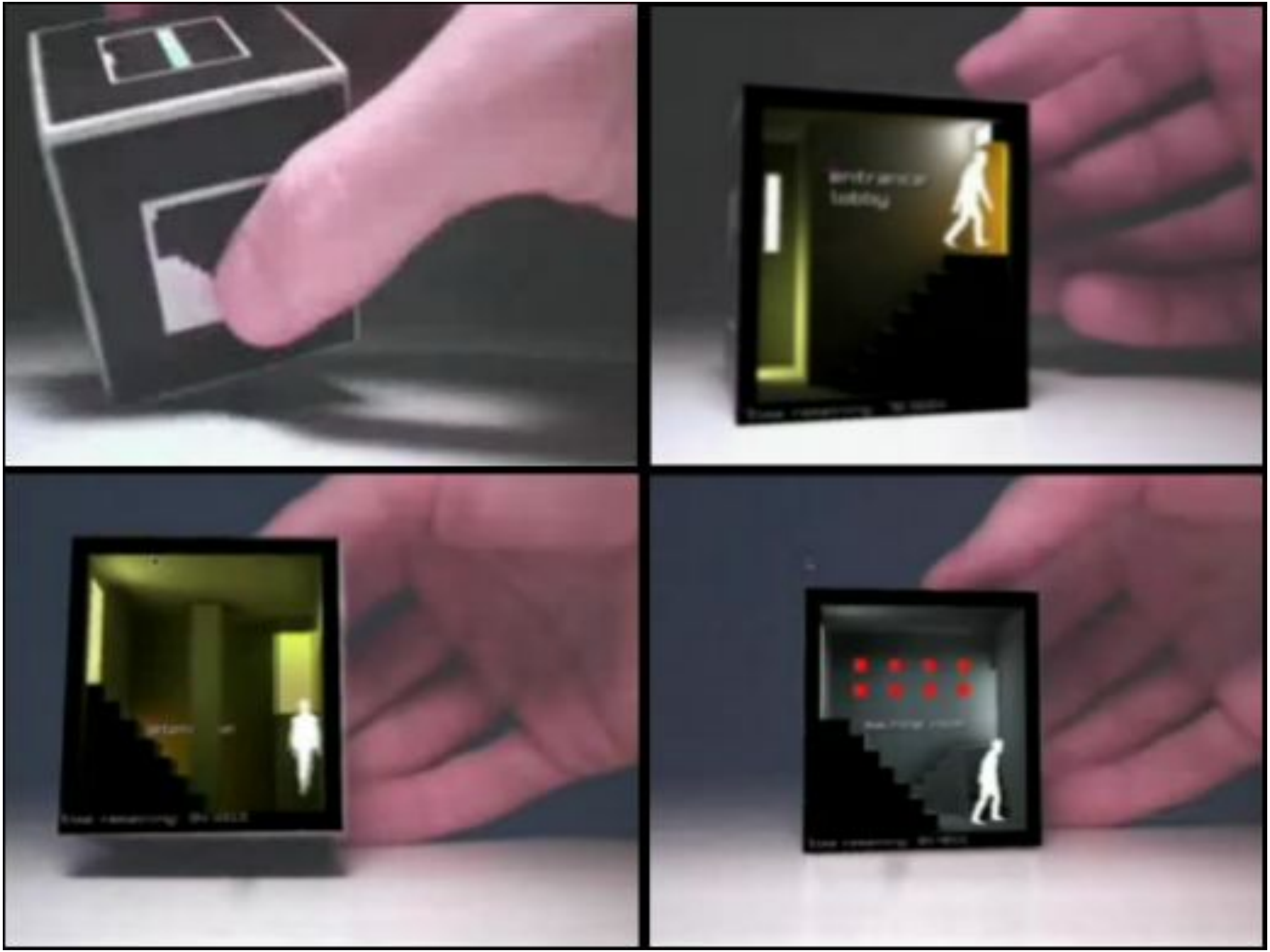
Case Study 2 : LevelHead



- Block based game

Case Study 2: LevelHead

- Physical Components
  - Real blocks
- Display Elements
  - Virtual person and rooms
- Interaction Metaphor
  - Blocks are rooms

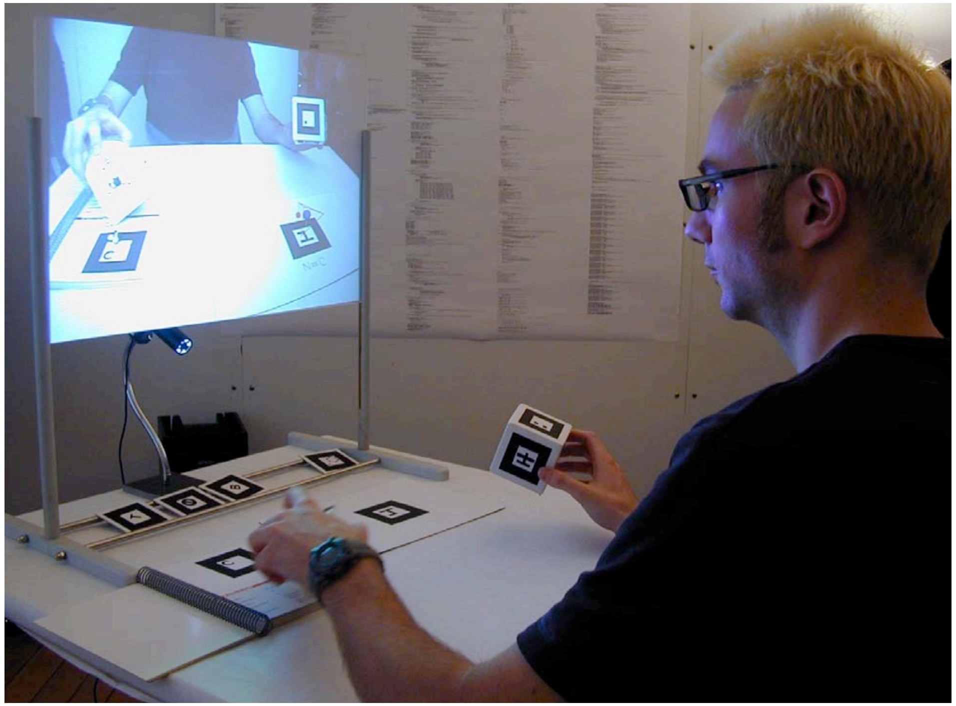

Entrance
lobby

LevelHead Demo

https://www.youtube.com/watch?v=5ks1u0A8xdU&t=74s

Case Study 3: AR Chemistry (Fjeld 2002)

- Tangible AR chemistry education

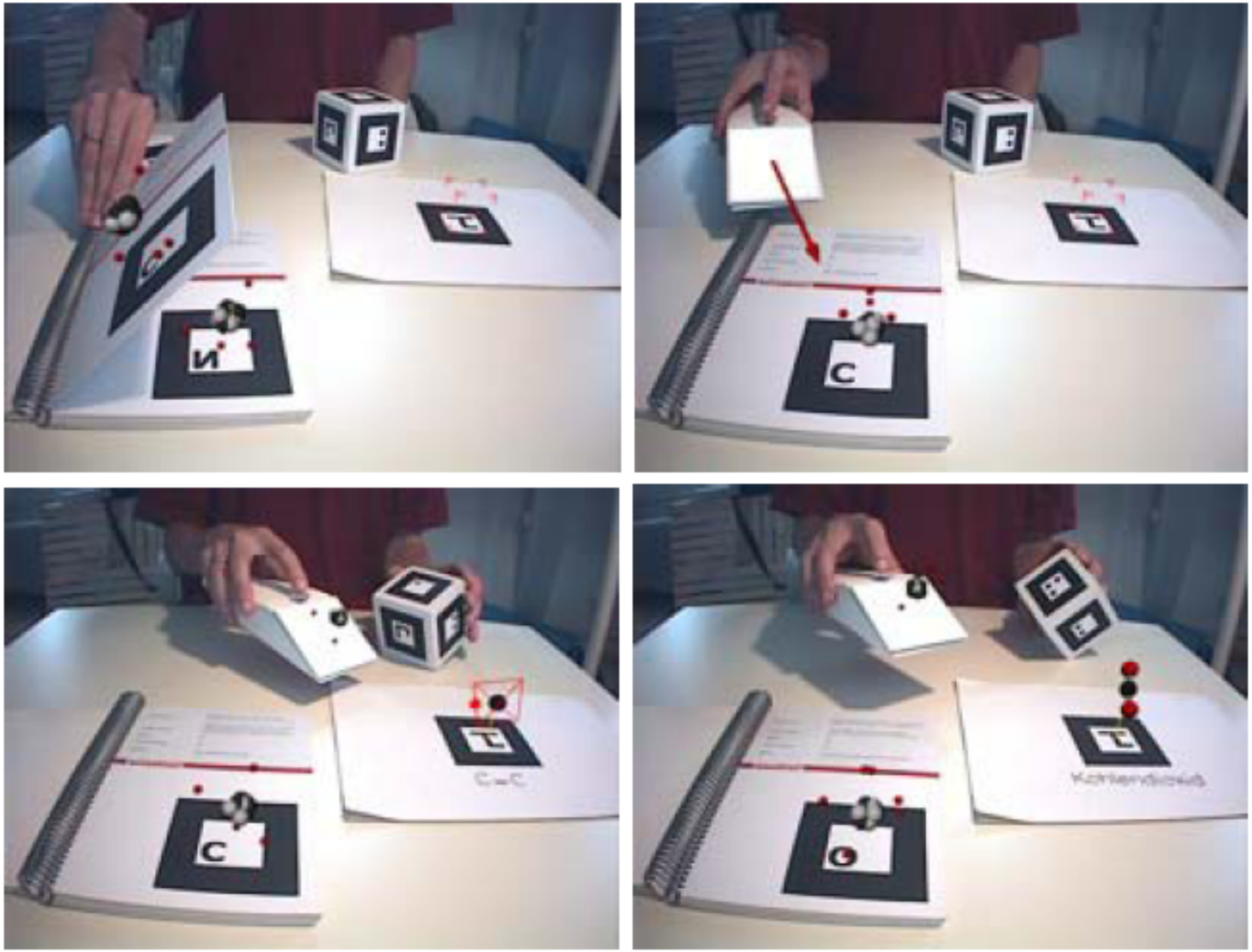


Fjeld, M., & Voegtli, B. M. (2002). Augmented chemistry: An interactive educational workbench. In *Mixed and Augmented Reality, 2002. ISMAR 2002. Proceedings. International Symposium on* (pp. 259-321). IEEE.

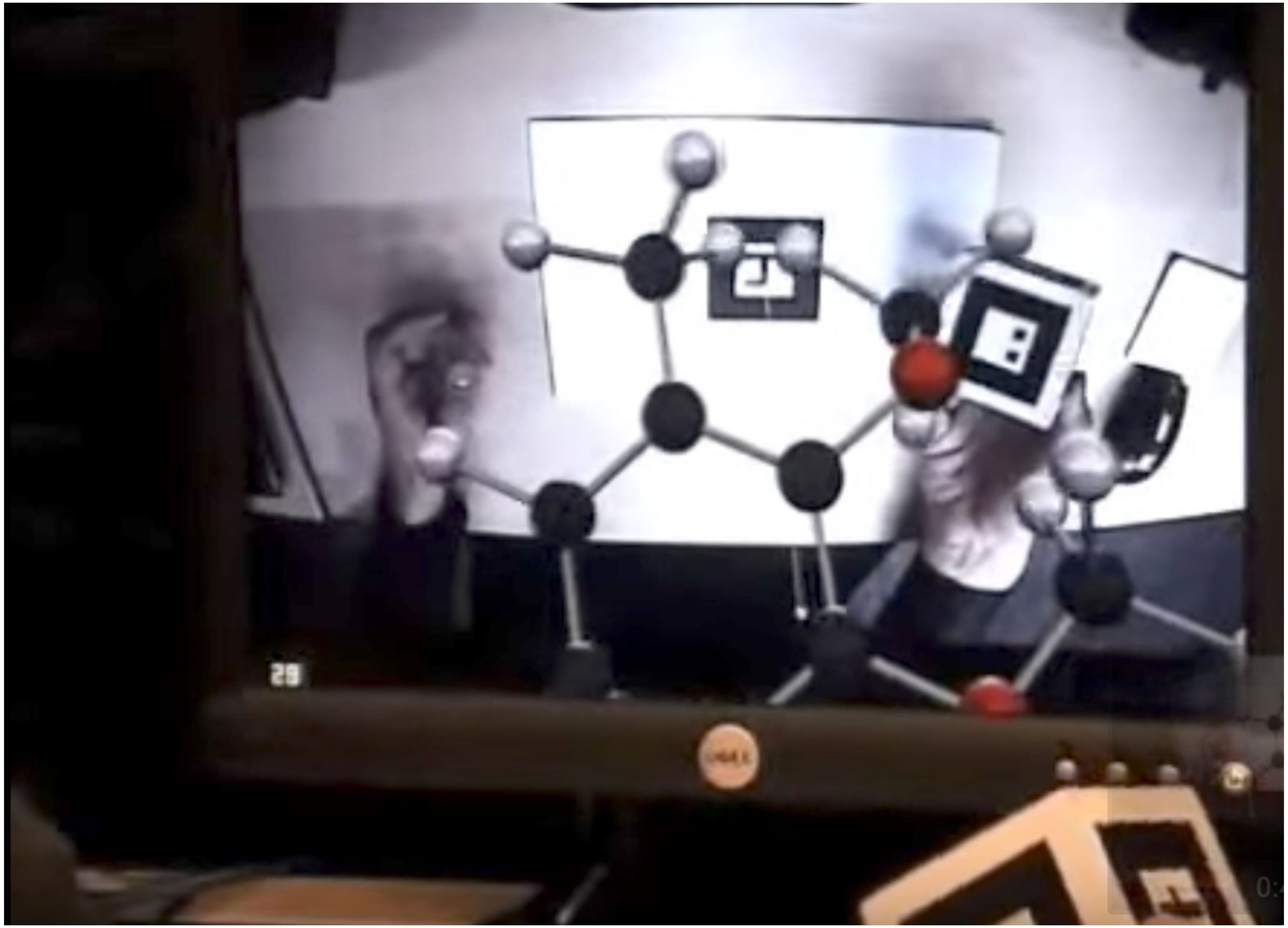
Goal: An AR application to test molecular structure in chemistry

- Physical Components
  - Real book, rotation cube, scoop, tracking markers
- Display Elements
  - AR atoms and molecules
- Interaction Metaphor
  - Build your own molecule

AR Chemistry Input Devices



AR Chemistry Demo



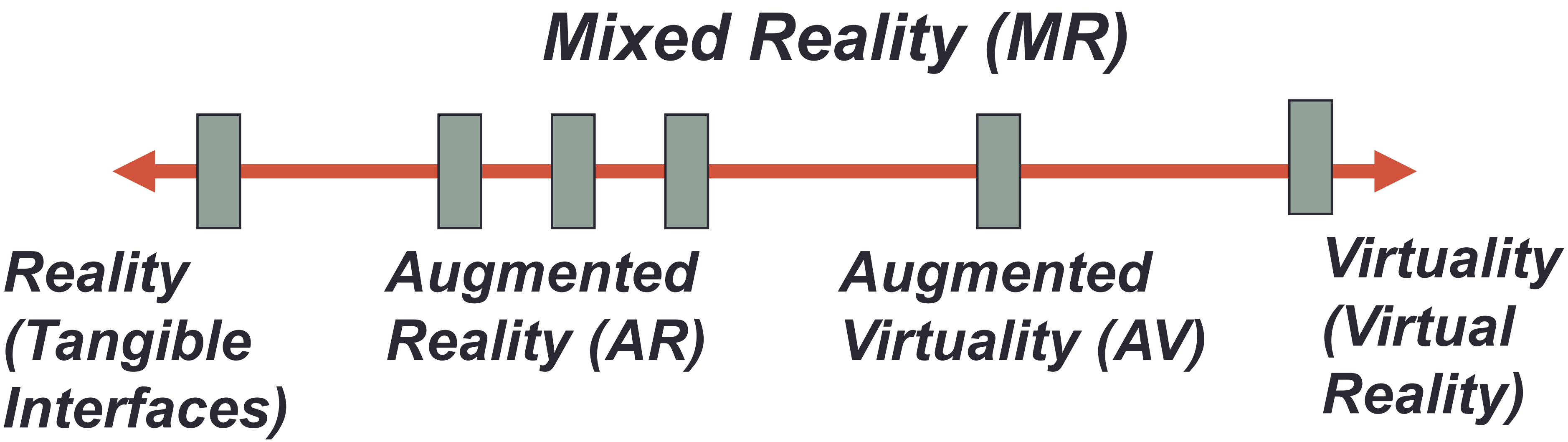
https://www.youtube.com/watch?v=2kIsb4BNb-k

Case Study 4: Transitional Interfaces

Goal: An AR interface supporting transitions from reality to virtual reality

- Physical Components
  - Real book
- Display Elements
  - AR and VR content
- Interaction Metaphor
  - Book pages hold virtual scenes

Milgram's Continuum (1994)



Central Hypothesis

- The next generation of interfaces will support transitions along the Reality-Virtuality continuum

Transitions

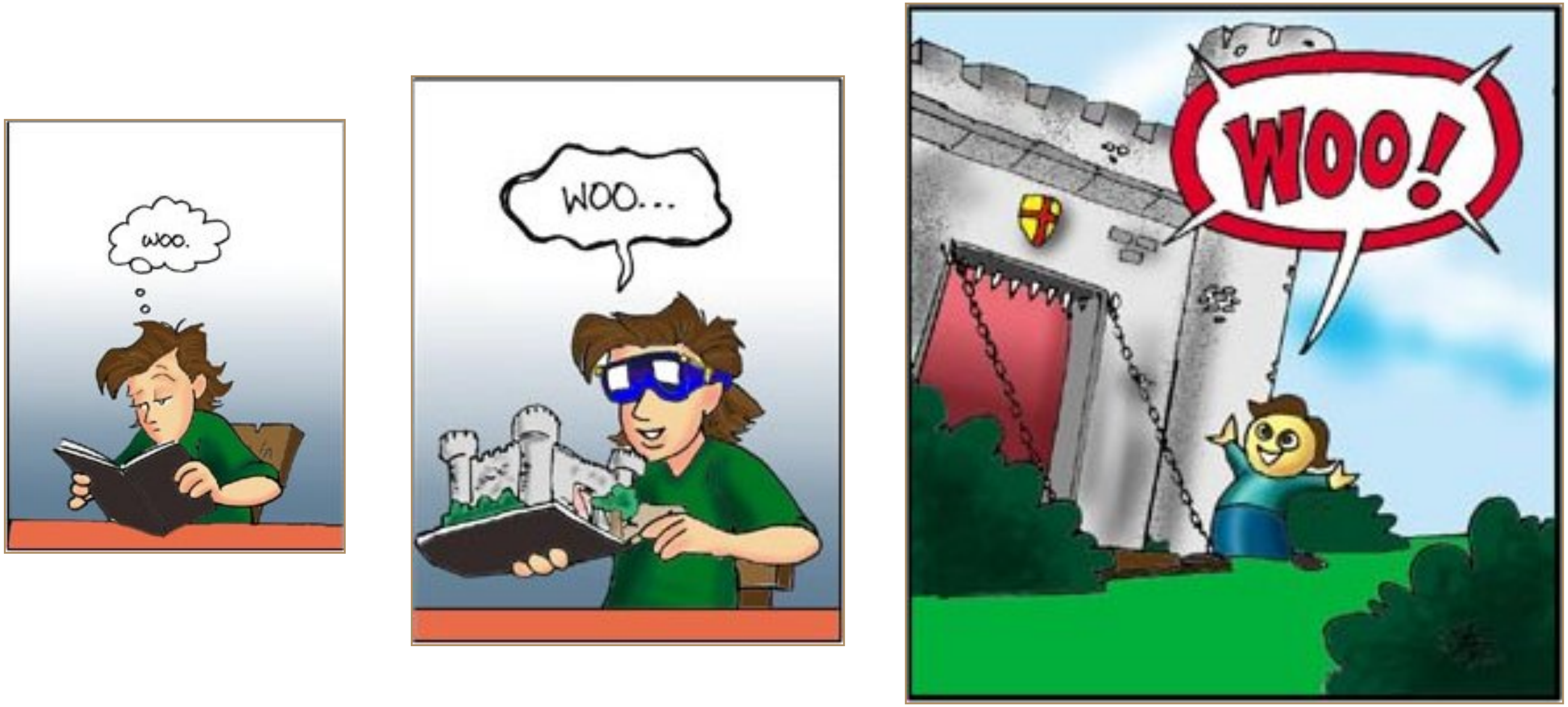
- Interfaces of the future will need to support transitions along the RV continuum
- Augmented Reality is preferred for:
  - co-located collaboration
- Immersive Virtual Reality is preferred for:
  - experiencing world immersively (egocentric)
  - sharing views
  - remote collaboration

The MagicBook

- Design Goals:
  - Allows user to move smoothly between reality and virtual reality
  - Support collaboration

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). The MagicBook: a transitional AR interface. *Computers & Graphics*, *25*(5), 745-753.

MagicBook Metaphor



MagicBook Demo

https://www.youtube.com/watch?v=tNMljw0F-aw&t=42s

Features

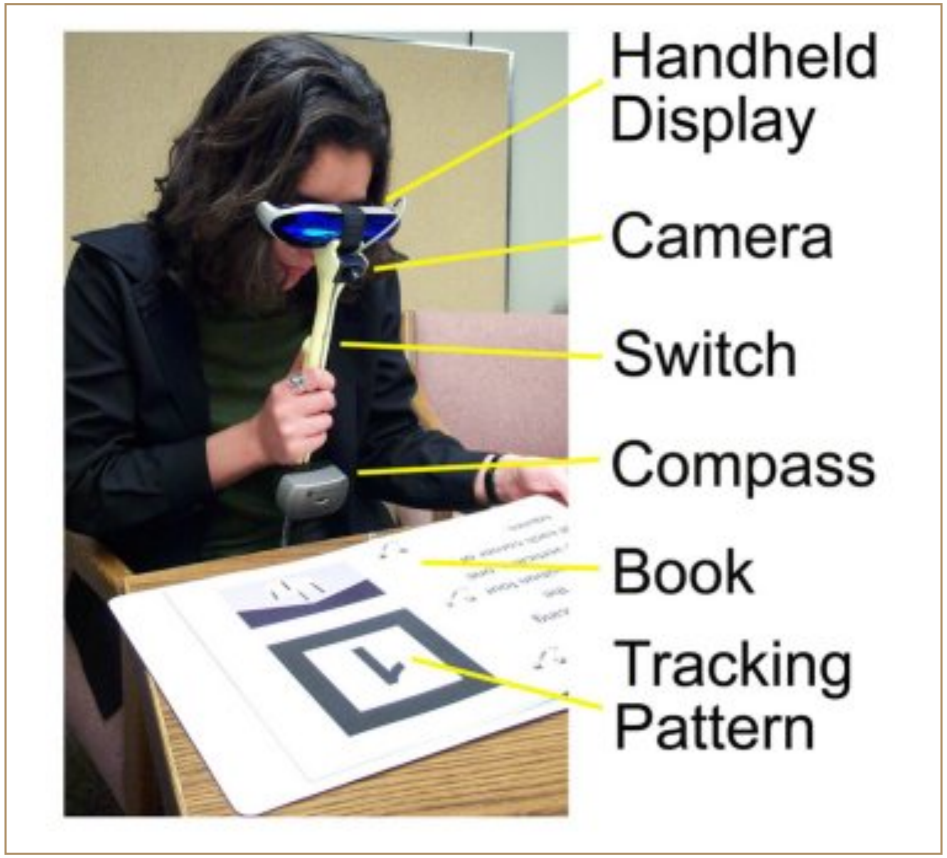
- Seamless transition between Reality and Virtuality
  - Reliance on real decreases as virtual increases
- Supports egocentric and exocentric views
  - User can pick appropriate view
- Computer becomes invisible
  - Consistent interface metaphors
  - Virtual content seems real
- Supports collaboration

Collaboration in MagicBook

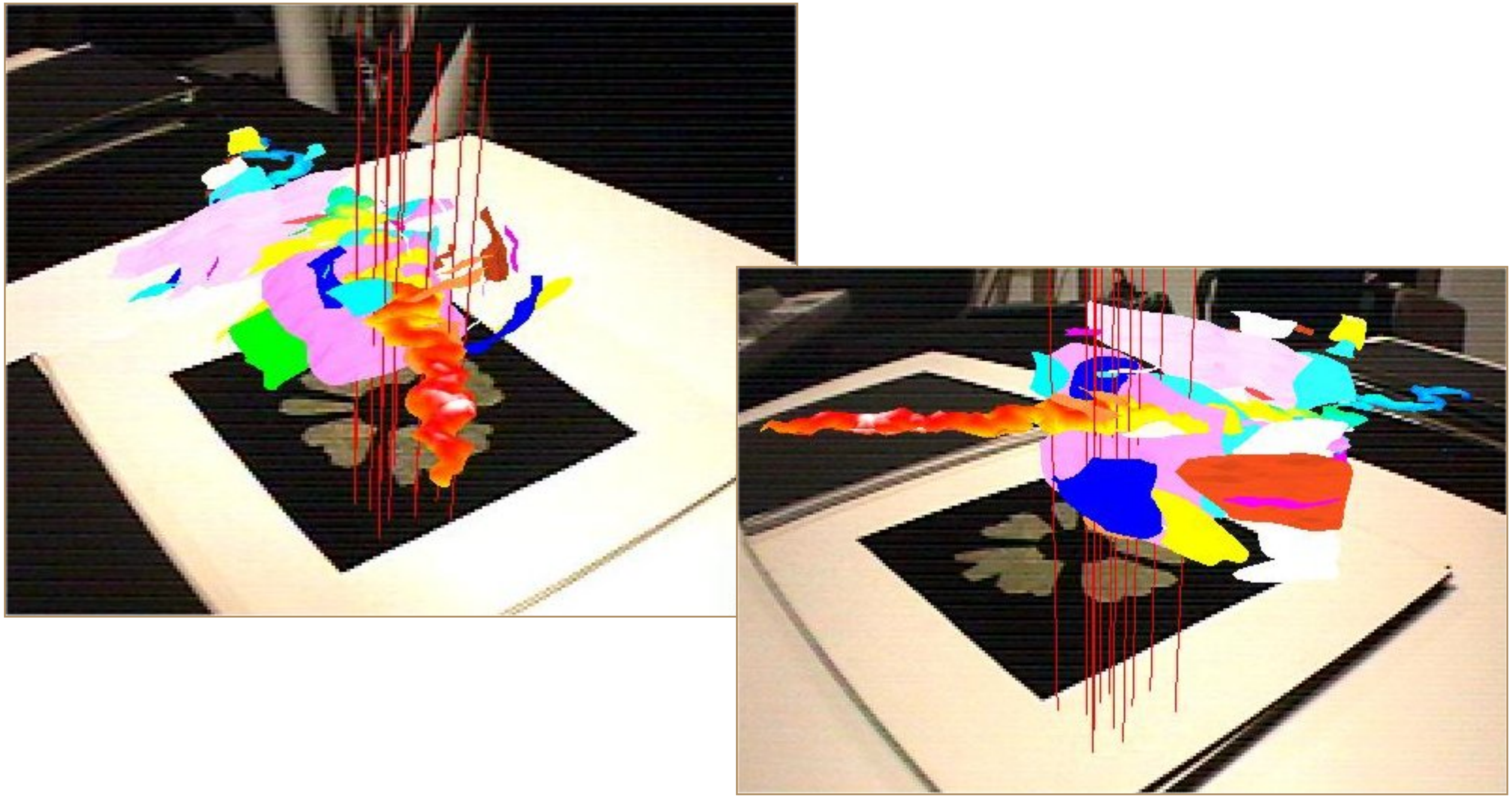
- Collaboration on multiple levels:
  - Physical Object
  - AR Object
  - Immersive Virtual Space
- Egocentric + exocentric collaboration
  - multiple multi-scale users
- Independent Views
  - Privacy, role division, scalability

Technology

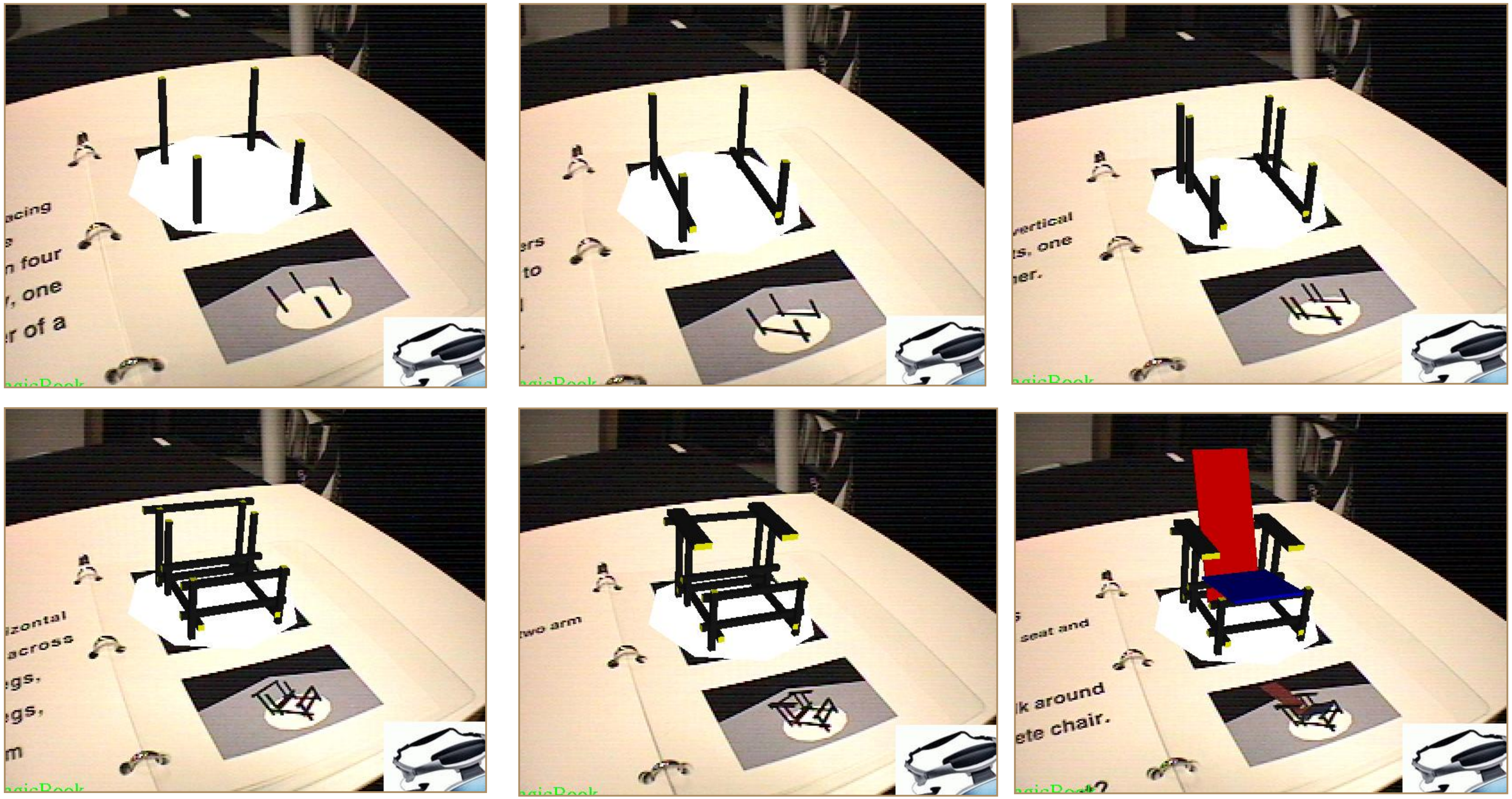
- Reality
  - No technology
- Augmented Reality
  - Camera – tracking
  - Switch – fly in
- Virtual Reality
  - Compass – tracking
  - Press pad – move
  - Switch – fly out



Scientific Visualization



Education



Summary

- When designing AR interfaces, think of:
  - Physical Components
    - Physical affordances
  - Virtual Components
    - Virtual affordances
  - Interface Metaphors
    - Tangible AR or similar

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