HCI Research in Augmented Reality

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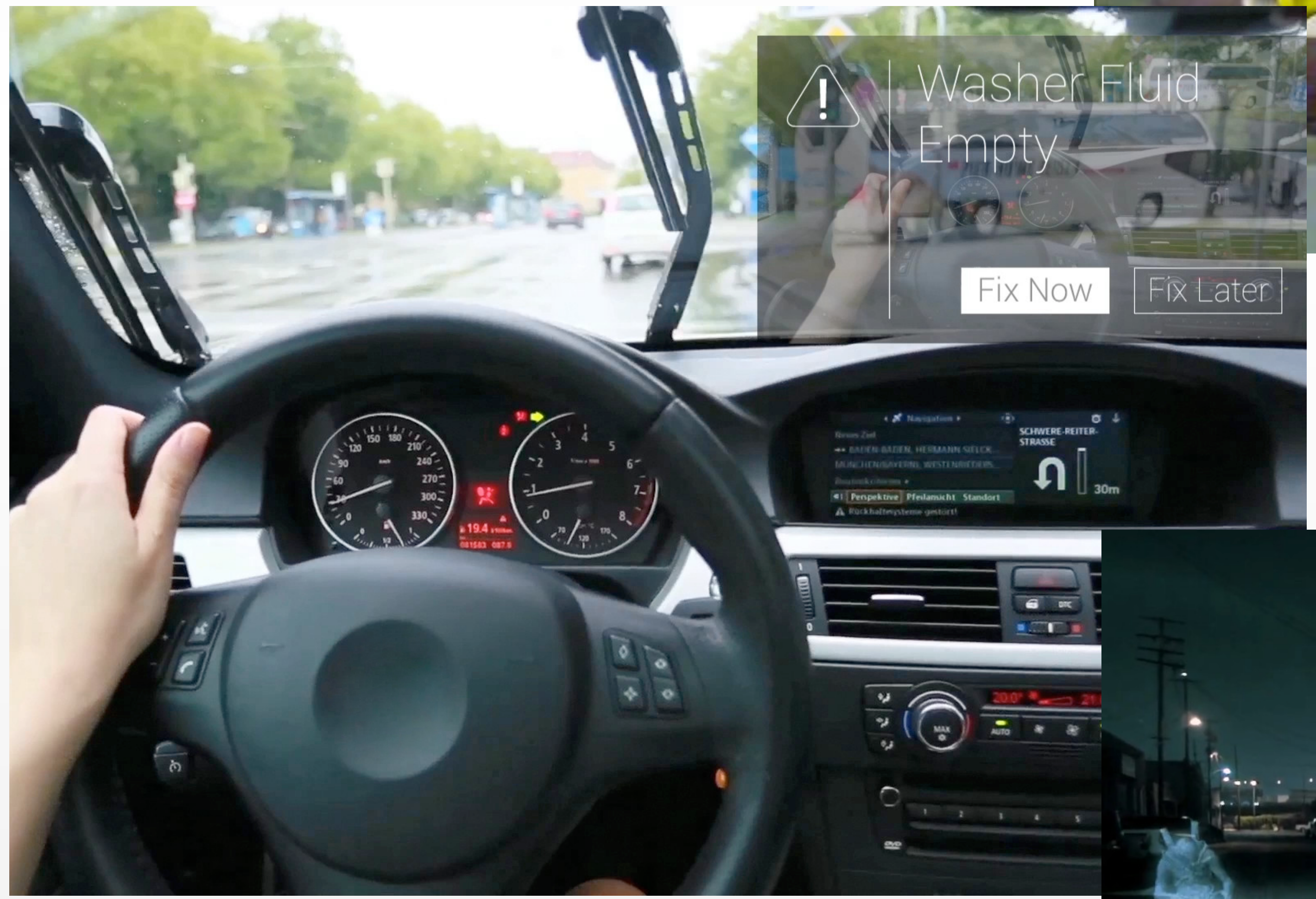
A New User Interface Paradigm

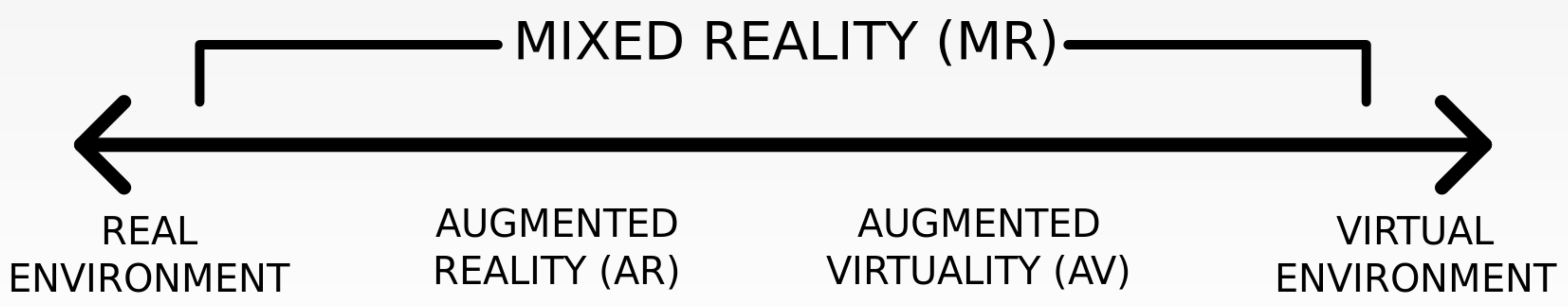
- Beginnings in 1960’s, then into research labs, and since 2005 in commercial applications
- Driven by improvement in display and tracking technologies
- Information is integrated into the user’s view of the real world
- No standard input devices
- Towards an invisible interface



Definition

- Characteristics for AR system [Azuma, 97]
  - Combines real and virtual objects in a real environment
  - Registers (aligns) real and virtual objects with each other
  - Runs interactively and in real time

Mixed Reality Continuum



- Reality–Virtuality continuum [Milgram & Kishino, 94]
  - In AV and VE/VR the surrounding environment is virtual, in AR the surrounding environment is real
  - Other AR variants: mediated reality, e.g., diminished reality

Diminished Reality

Herling ISMAR '10

AR Advantages

- Simplifying and enhance people’s lives by integrating virtual information in their surroundings
- Enhances people’s perception and interaction with the world
- Substitute missing senses
  - Example, augmenting the sight of blind users or users with poor vision by the use of audio

Building Block of AR Systems

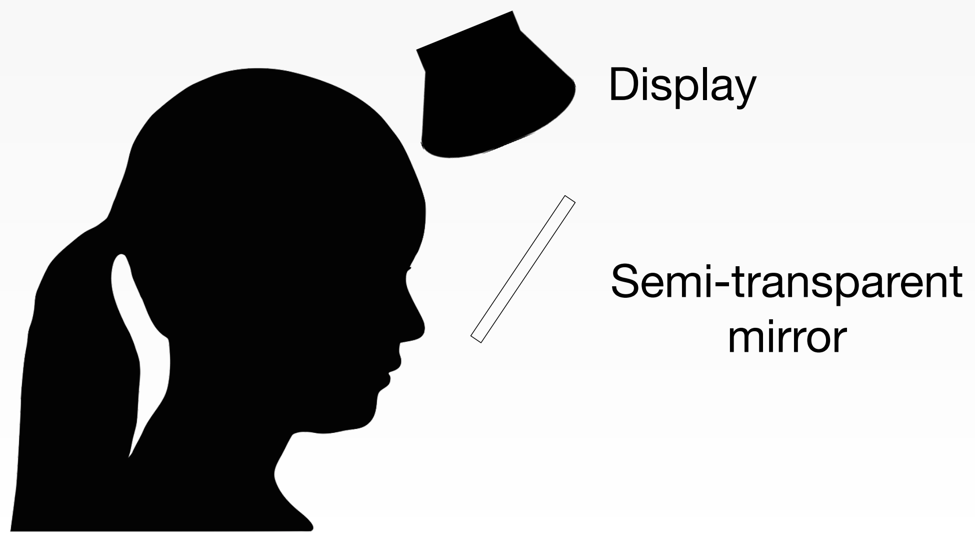
- Technologies
- Authoring tools
- Interaction techniques
- Applications
- Usability and experiences

Technologies

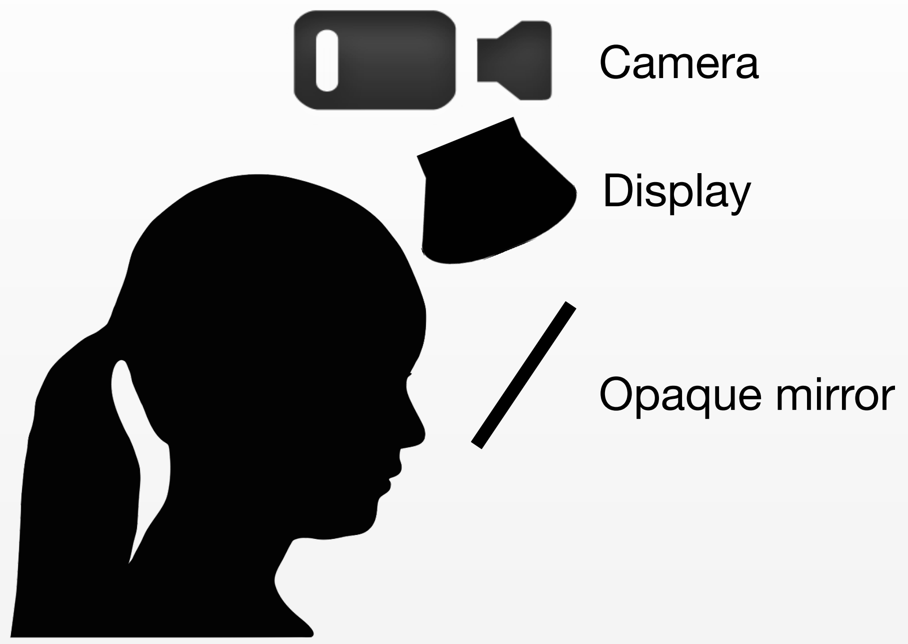
- Display technologies
  - Show virtual objects overlaying the real world in 3D space
  - Head mounted, spatial, handheld displays [Bimber & Raskar, 05]
- Tracking (and registration) technologies
  - To register virtual objects in 3D space and track user input
  - Track the (a) scene (b) the user's 6DOF viewpoint (head and/or eyes), (c) the user's hands/body for input, and (d) input devices

Head Mounted Displays

- Optical see-though (glasses or contact lenses)
  - Direct and better view of the world, safer
- Video see-through
  - Occlusion, wider field of view, better registration and calibration, no perceived delays
- Advantages: hands free interaction
- Disadvantages: wearing it (socially and physically), brightness



Optical see-through



Video see-through

Spatial and Handheld Displays

- Spatially aligned displays or projectors
  - Can be wearable
  - Advantages: provide public displays and project on irregular surfaces
  - Disadvantage: brightness, focus, resolution, FOV, and contrast
- Handheld displays
- Other displays: haptic, tactile and audio

[Mistry et al., SIGRAPH 09]

Comparison

[Carmigniani et al., 11]

	HMD Video see-through	**HMD Optical see-through**	**Projectors**	**Handheld**
Pros.	visual control, sync., less dependent on environment	more natural perception	displays directly onto physical objects' surfaces	portable, widespread, powerful, camera, tracking
Cons.	camera and processing, unnatural perception	time lag, jitter of virtual image	(+/-) not user dependent	small display

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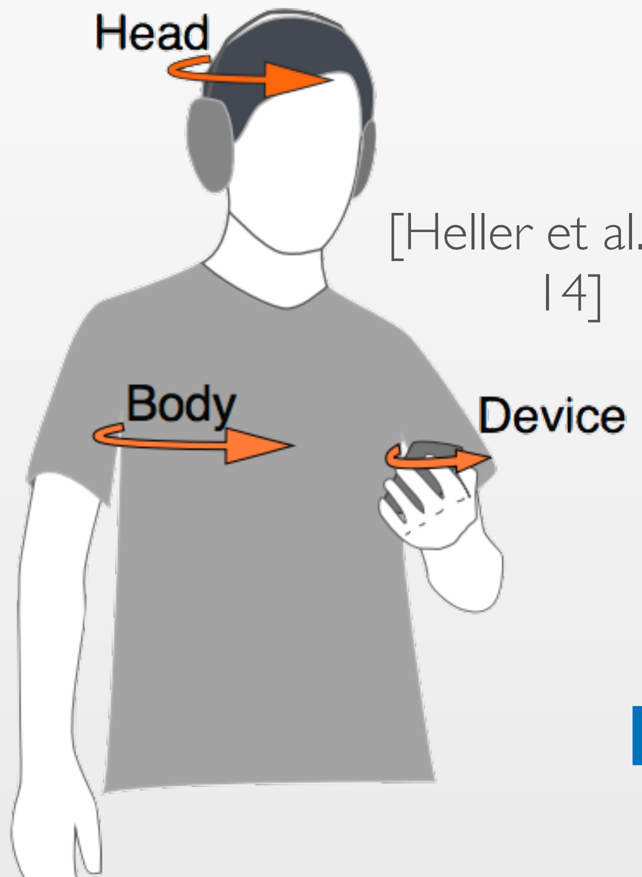
Tracking and Registar Technologies

- Track the user's viewpoint 6DOF (X, Y, Z, Roll, Pitch, Yaw) and update the appearance of virtual objects
- Register virtual objects in 3D and reduce lag
- Inertial sensors
  - Compasses, accelerometers, gyroscope, etc.
- Active sensors
  - GPS, Wifi, magnetic, ultrasonic, mechanical
- Optical/visual tracking
  - Marker-based, e.g., fiducial
  - Markless-based (infrared or camera) , e.g., computer vision methods and depth cameras

[Reitmayr et al., AUIC '03]



[Heller et al., CHI 14]

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Tracking Criteria and Challenges

- Criteria
  - Accuracy, tethering, cost, 6DOF, nosiness, resolution/range
- Challenges
  - Jitter, occlusion, brightness, user and environment changes, latency, ease of calibration
- Choice of tracking technology depends on AR System (fixed/mobile, indoor/outdoor)

Authoring Tools

- Tracking libraries, e,g., ARToolKit, Vuforia (mobile), FLARToolKit (web browser)
- 3D rendering engine for designing virtual objects
- IDE for design AR scenes
- Compete systems,e.g., AMIRE, BuildAR, Metaio Creator
- Visual programming: AR to design AR, e.g., iaTAR [Lee et al., 04] use real objects to to design AR scenes

AR Systems and Experiences

- Categorising AR systems help make design deacons regrading the display, tracking technology, input technique and application
- Outdoor AR
  - Information browsers and navigation
- Indoor location based AR
- Handheld AR
- Web based AR
- Carmigniani and Furht categorized AR systems into five categories
  - Fixed indoor systems, fixed outdoor systems, mobile indoor systems, mobile outdoor systems, and mobile indoor and outdoor systems

AR Interaction

- Interaction tasks
  - 2D tasks: text entry, selection, position, and quantify [Foley]
  - 3D tasks: navigation, pointing and selection, manipulation (drag, rotate, scale), and data input [Bowman]
- Input devices
  - Tangibles, heterogeneous devices (other displays), specially designed devices
- Input modalities
  - Gestures, speech, eye tracking, brain signals
- Techniques or Metaphors

Viewpoint Control

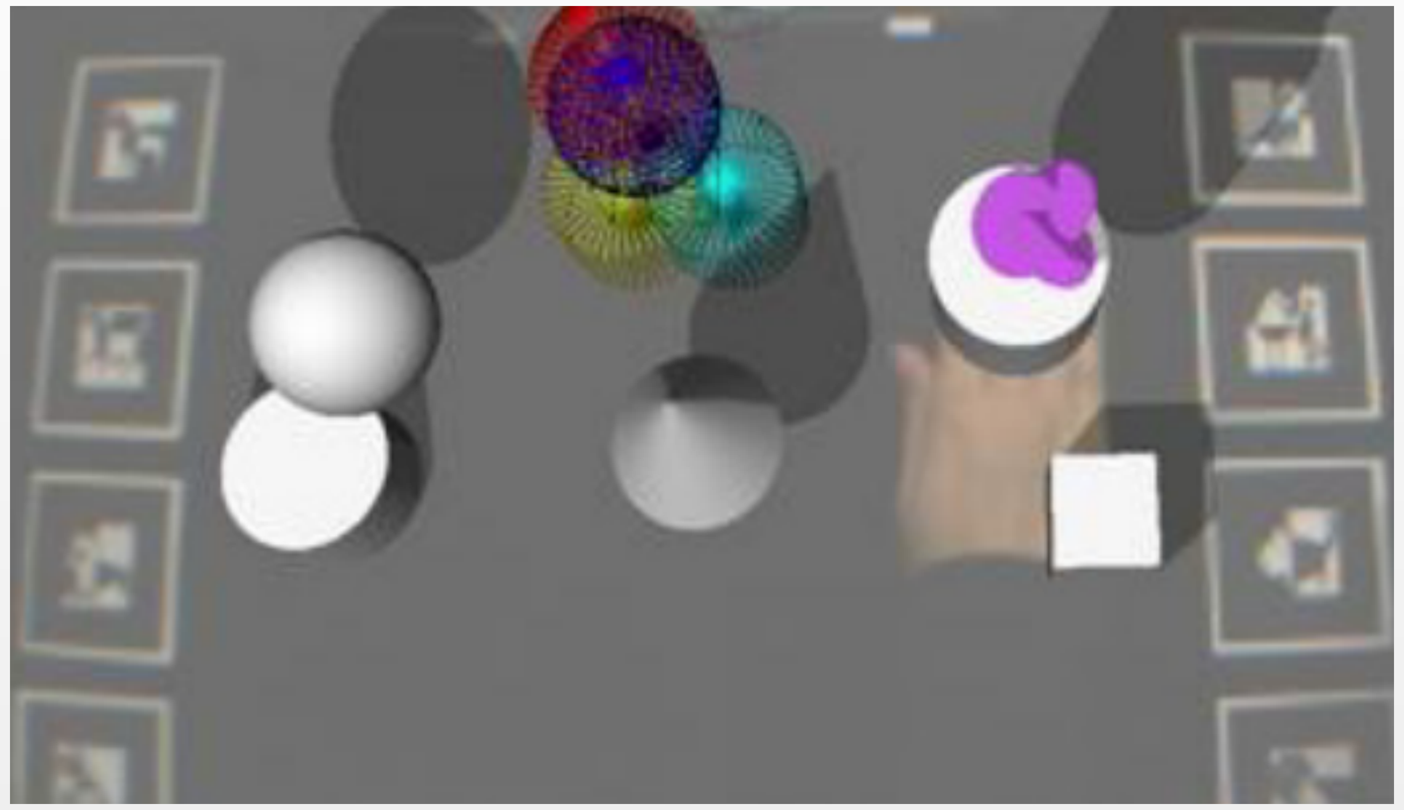
- Using basic 2D and 3D tasks
- Used in navigation apps, information browsers, guidance interfaces
- Manipulate the view of the AR environment but not the content

Free 3D Hand Interaction

- Track 6DOF of user head and hand
- Manipulate virtual objects in 3D space
- Natural interaction
- No tactile feedback

Multimodal Input

- Multimodal free hand and speech to control 3D virtual objects
- Experimental setup (Wizard of Oz) [Lee & Billinghurst, 08]
  - Tasks: change object color, location, and shape
  - IV: speech only, gesture only, multimodal
  - DV: time, error, preference
- Results
  - Multimodal was faster, and more preferred, with no difference in error count
  - Speech is good of quantity and modal commands, e.g., change color
  - Gestures are good for quality and spatial manipulation



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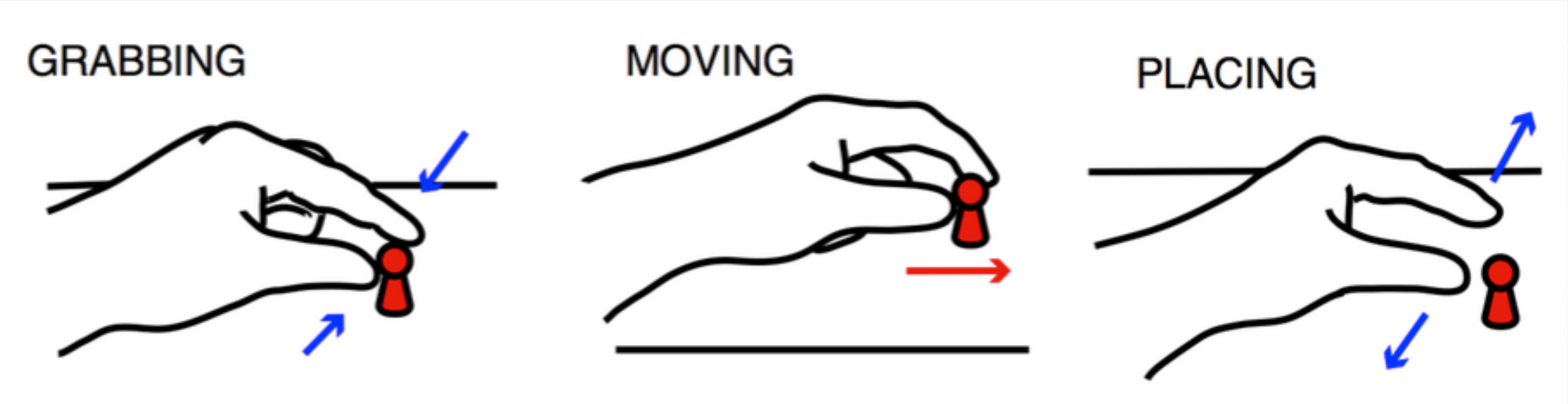
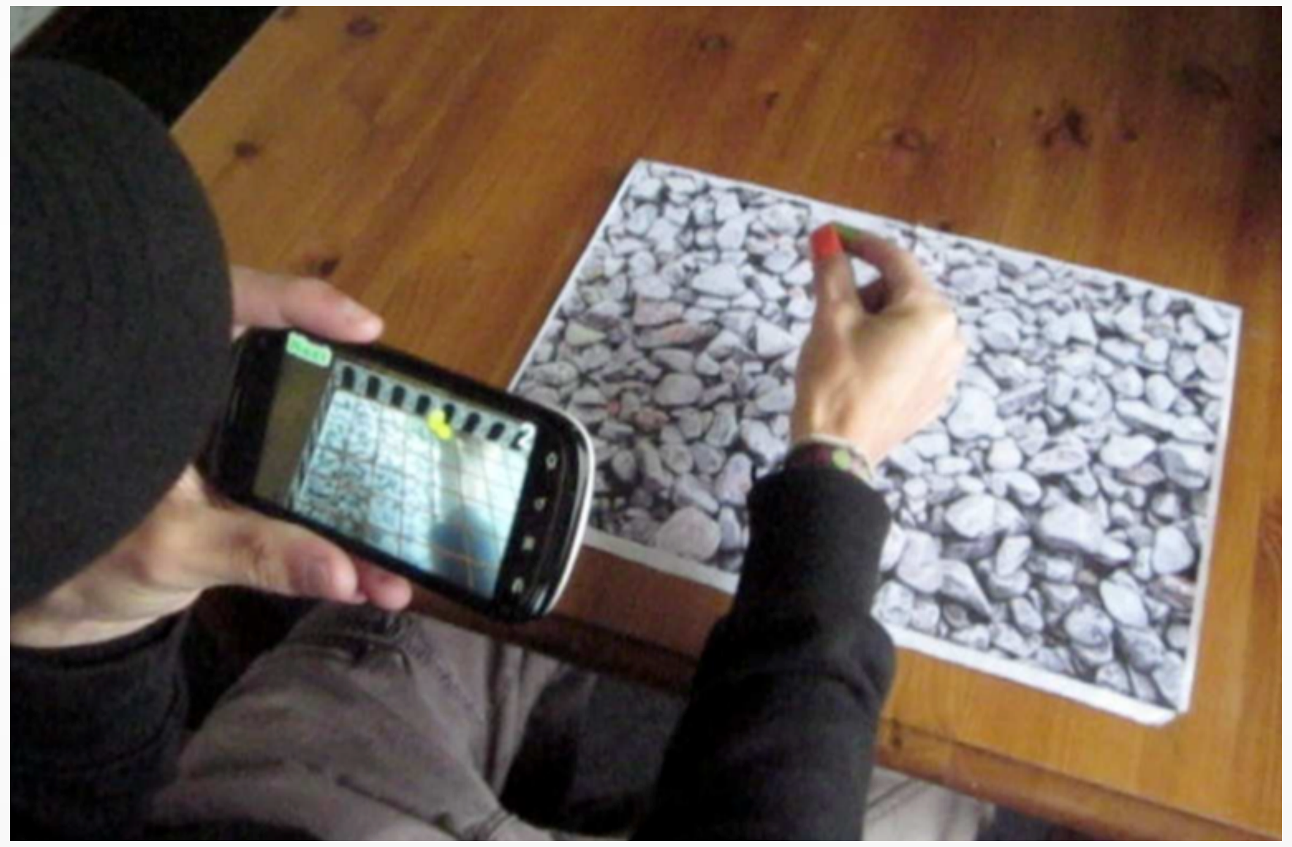
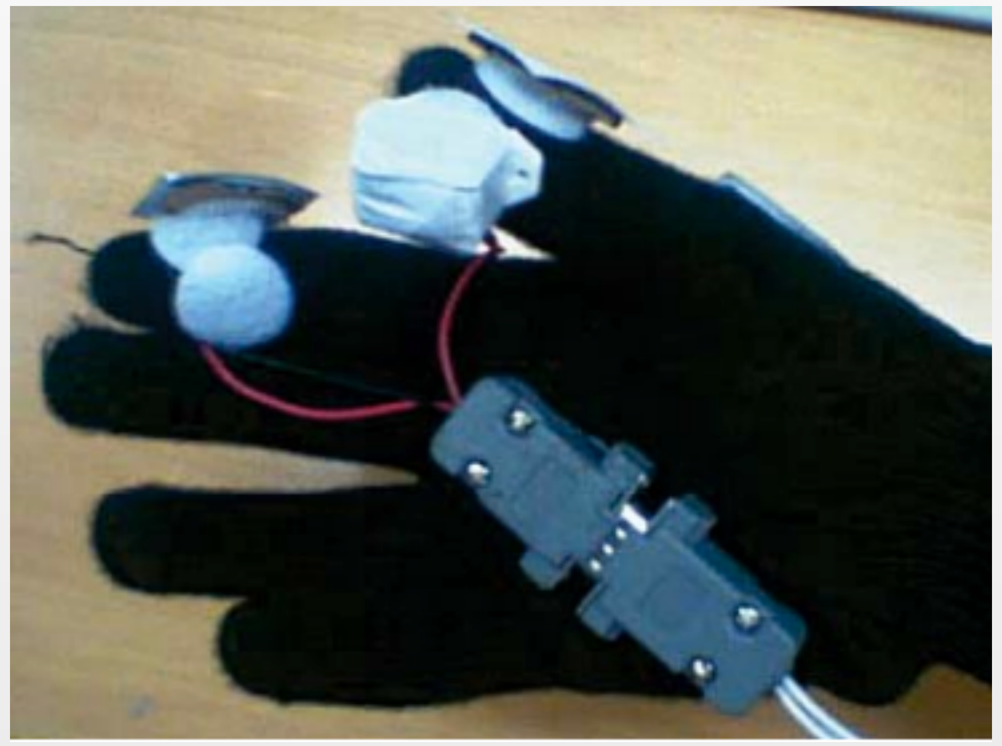
Handheld Finger Tracking

- Compared finger tracking with touch input on mobile devices for a grab-move-place gesture [Hürst et al., 13]
- Finger tracking was slower and less accurate
  - Nature of interaction (grab vs. tap)
  - Reduced feedback (tactile and visual) when the user is reaching out to the virtual object
  - Absolute position of virtual objects in 3D
- A simple buzzer on the finger tips can provide valuable haptic feedback when finger tips intersect with virtual objects [Buchmann et al., 04]







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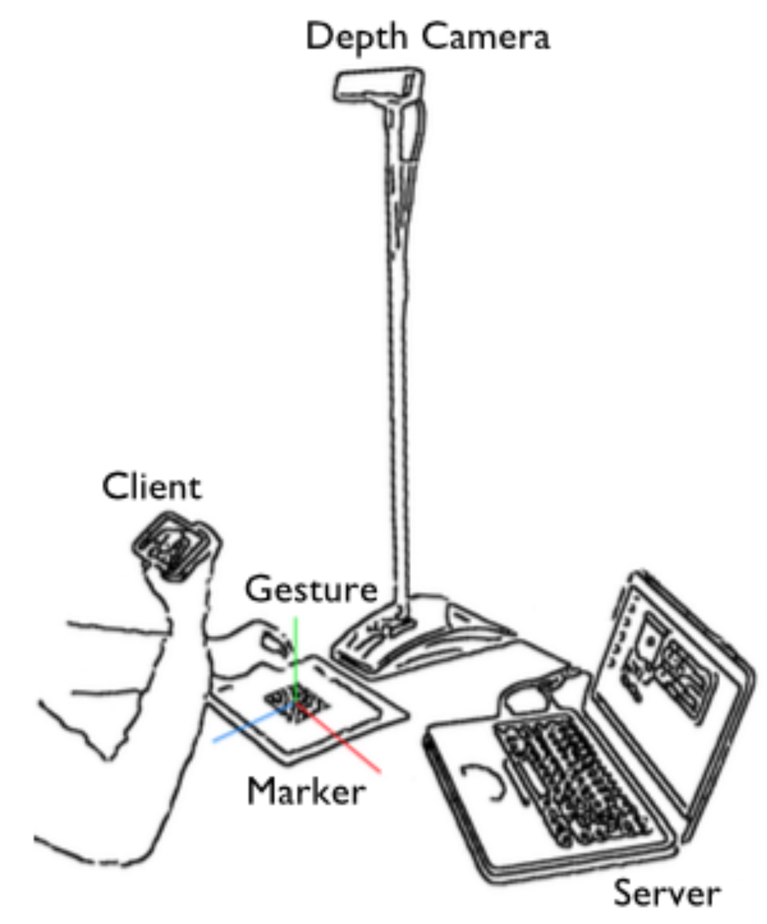
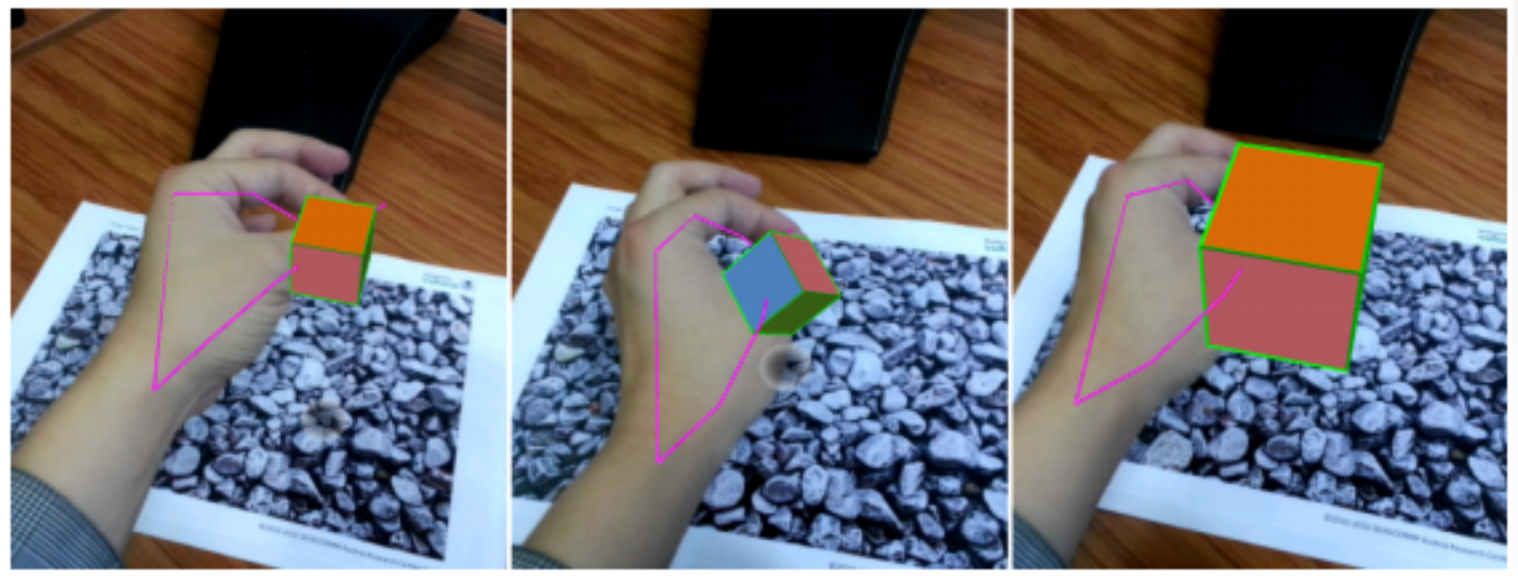
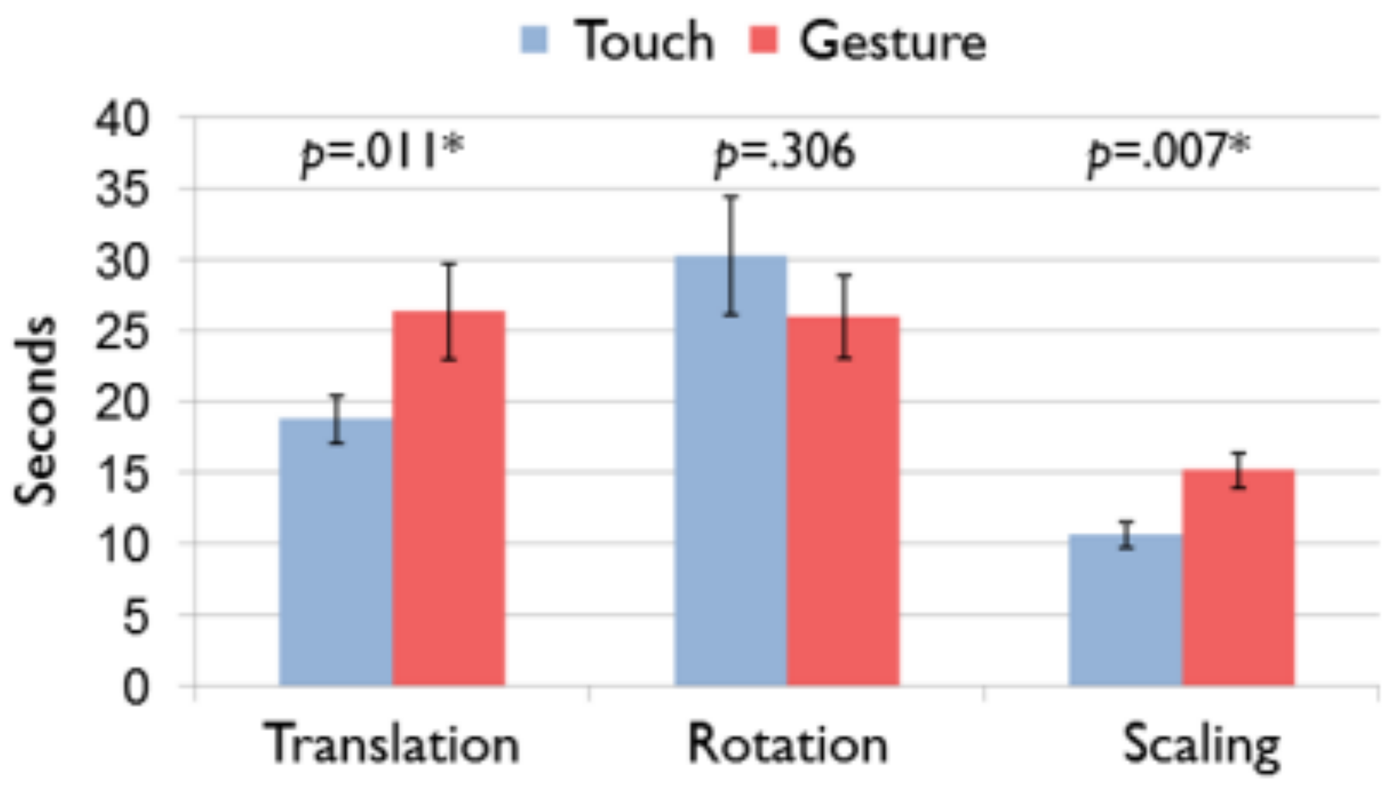
Handheld Hand Tracking

- Compared hand tracking with touch input on mobile devices for 3D manipulation tasks [Bai et al., 14]
- 3D gesture are slower but more preferred
  - Touch 3 axis moments faster than locating object in 3D space and 1 spatial movement for scaling and translation
  - No significant differences in placement errors
  - 3D easy to learn but causes physical stress

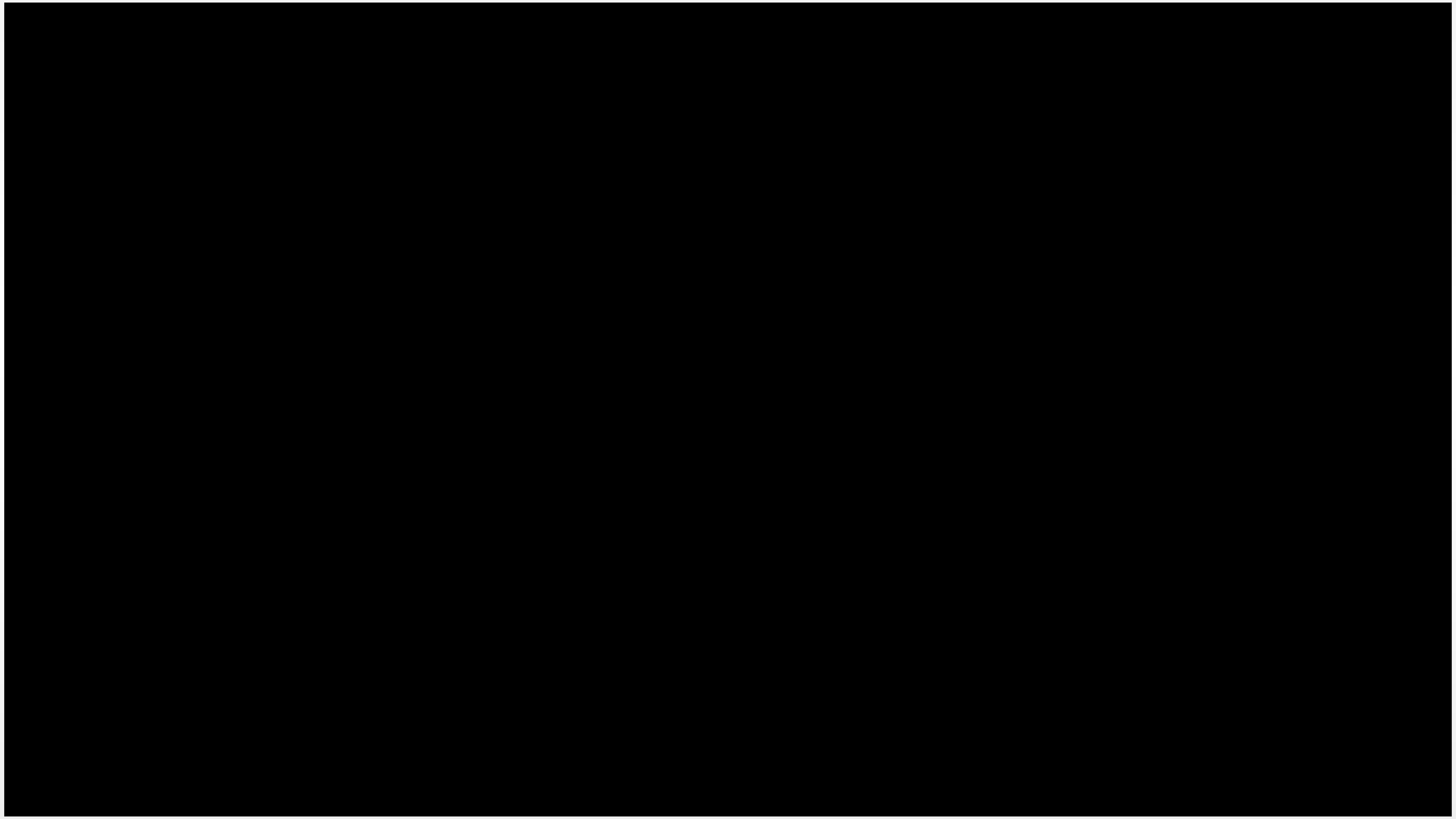






Task completion time (error bar: SE).

Handheld Device Interaction



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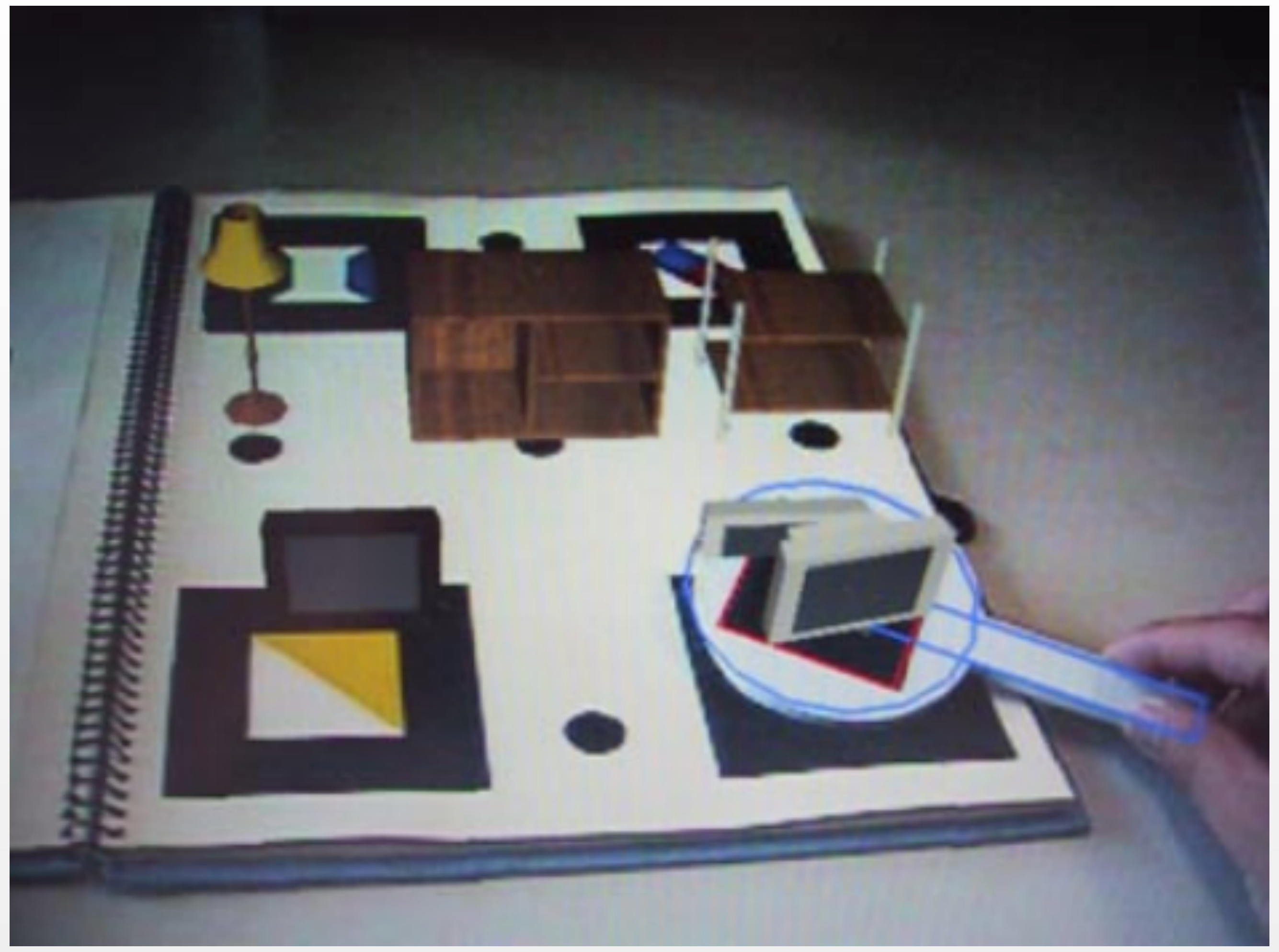
Tangible AR

[Kawashima et al., ISMAR 01]



- Combine TUI with AR
- User physical objects to control virtual objects
- 1:1 or 1:* physical virtual mapping

Natural Interface

- Interfaces for treatment exposure (Kinect) [Corbett-Davies et al., 13]
- Model the scene
- Track the body
- Apply physical simulation engine on virtual objects

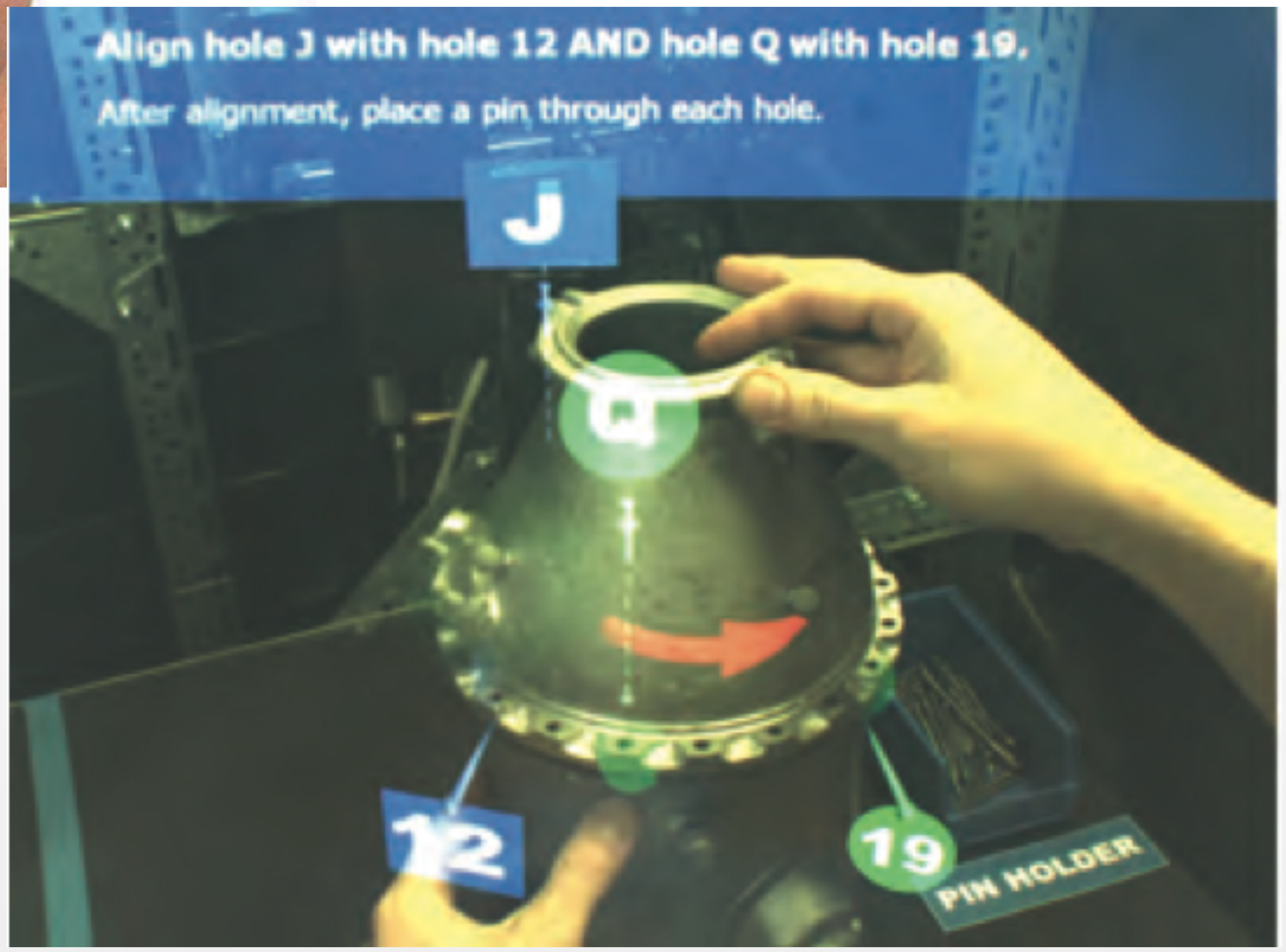
Applications

Applications

- Entertainment
- Marketing
- Medical
- Maintenance and assembly
- Training
- Museums guides
- Navigation

[Bichlmeier et al., ISMAR 07]

[Anderson at al., UIST 13]



Training Apps

[Marner et al., 3DUI 10]

Training Apps

[Anderson et al., UIST 13]

Museum and Exhibit Navigators

- Rich information
- On the move
- Support several languages
- No need to wait in line

Bichlmeier IEEE '07

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Geographic and Navigation Information Systems

- Augmented Maps
  - Represent the environment in a more natural and representative fashion
- Augmented Territories
  - Augment the environment itself to enhance users' interaction
  - Sea navigation
  - Road navigation
  - Augmenting underground constructions
  - Indoor navigation

Blaupunkt

User Evaluation

User Evaluation

- A problem in AR research: not many user-based experiments
  - Technology is still not perfect
  - Depends on human perception, ergonomics, and attention models
  - Difficult to conduct in a well-controlled manner that is repeatable and reliable (On-off prototypes and variability)
  - Lack of suitable methods for evaluating AR interfaces
  - Who is the user? What problem are we solving? Who can evaluate the system?

Usability Tests vs. User Studies

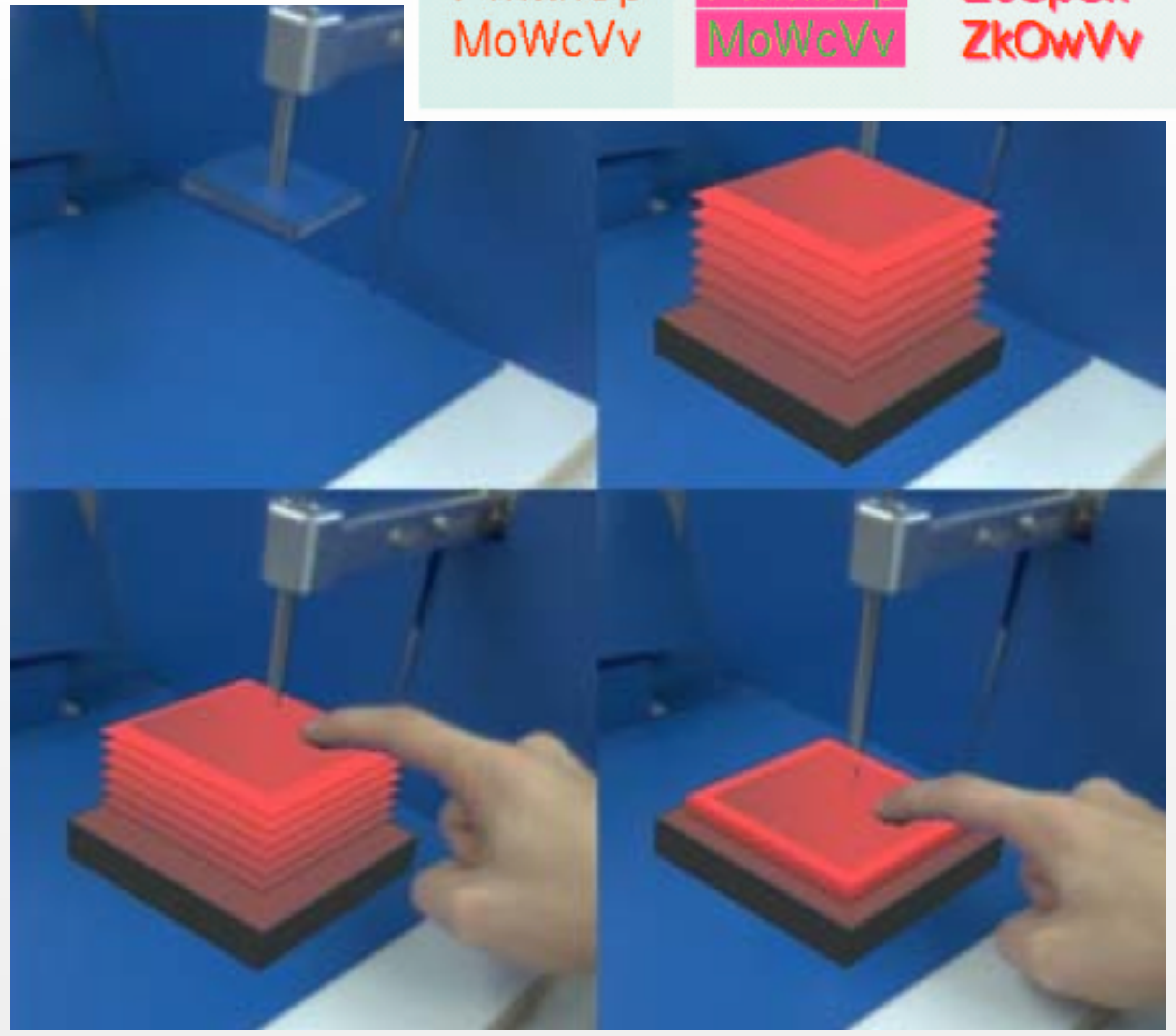
- Usability tests
  - Learnability, Efficiency, Memorability, Errors, and Satisfaction (Nielsen)
  - Early on in the research project, using e.g., think aloud method or heuristic evaluation
  - Allow for rapid iterative design
  - Cannot be generalized
- User studies to answer research questions
  - For example, user interaction (efficiency or accuracy), behaviour, collaboration, ergonomics, performance, experience, etc
  - Incremental knowledge

User-based Studies in AR

- Based on work conducted by Swan and Gabbard VR 05, most AR user evaluations fit into one of four categories:
  - Low-level tasks: understanding human perception and cognition in AR contexts
  - User task performance: how AR technology could impact underlying tasks
  - Examine user interaction and collaboration
  - System usability

Evaluation Methods in AR

- Objective measurements
    - Measured numbers, reliable and repeatable, e.g., completion time, accuracy, object position
- Subjective measurements
    - Subjective judgment of people, e.g., from questionnaire and rankings



[Knörlein et al., ISMAR 09]

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Evaluation Methods in AR

[Morrison et al., CHI 09]

- Qualitative analysis
  - Data is gathered through observations and interviews
- Non User-Based techniques
  - Such as cognitive walkthroughs or heuristic evaluations with experts
- Informal testing
  - Reporting observations gathered during demonstration

“The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.”

–Ivan Sutherland in 1965

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