Navigation and Interaction

Interaction

- Interaction
  - Selection
    - User interacts by selecting a virtual object
  - Manipulation
    - User changes the virtual object in someway
  - Navigation
    - Control the position and viewing direction in the virtual environment
  - System control
    - User interacts with the system itself to perform functions outside the virtual environment
      - E.g., commands

System Control

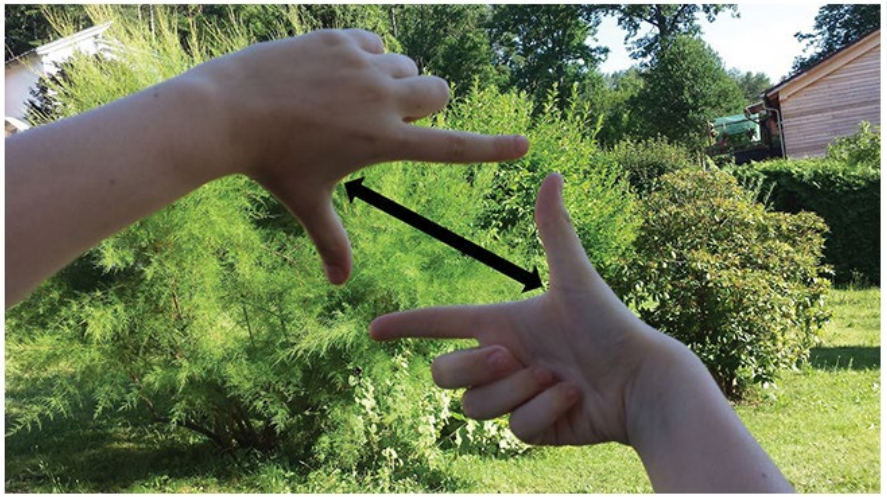
- System control
  - ➢ Conventional GUI elements and techniques
    - Menus, buttons, toolbars
      - E.g., drag-and-drop, double-click
  - ➢ Menus
    - Can be structured systematically
      - Positioning, representation and selection technique
        - » E.g., can be fixed or linked to position of a virtual object, or user, or real object
  - ➢ 3D widgets
    - 3D objects coupled with interaction behaviour
      - 3D geometry make their interactive functionality visible for the user
      - Can be inspired by real objects
      - Can be abstract objects, but functionality must be learned

System Control

- Tangibles (sometimes called props)
  - Real objects used as tools in the virtual environment
    - E.g., handle of a real tool
  - The number of tangibles in an application is limited
  - Assignment to interaction tasks less flexible
- Voice commands
  - Hands-free
  - No part of the virtual environment is hidden by objects required for interaction
  - User has to learn possible commands
- Gestures
  - Often no graphical representation to serve as a memory aid

Interaction

- Gestures
  - Gestural interaction using body or hand tracking
  - Tracking systems can recognise dynamic gestures
  - Gesture language
    - Very expressive
    - Requires more learning than conventional menu-based interfaces
    - Usually easy to learn
      - » But poor affordances, can be difficult to remember
    - Problem with self-occlusion from user's body

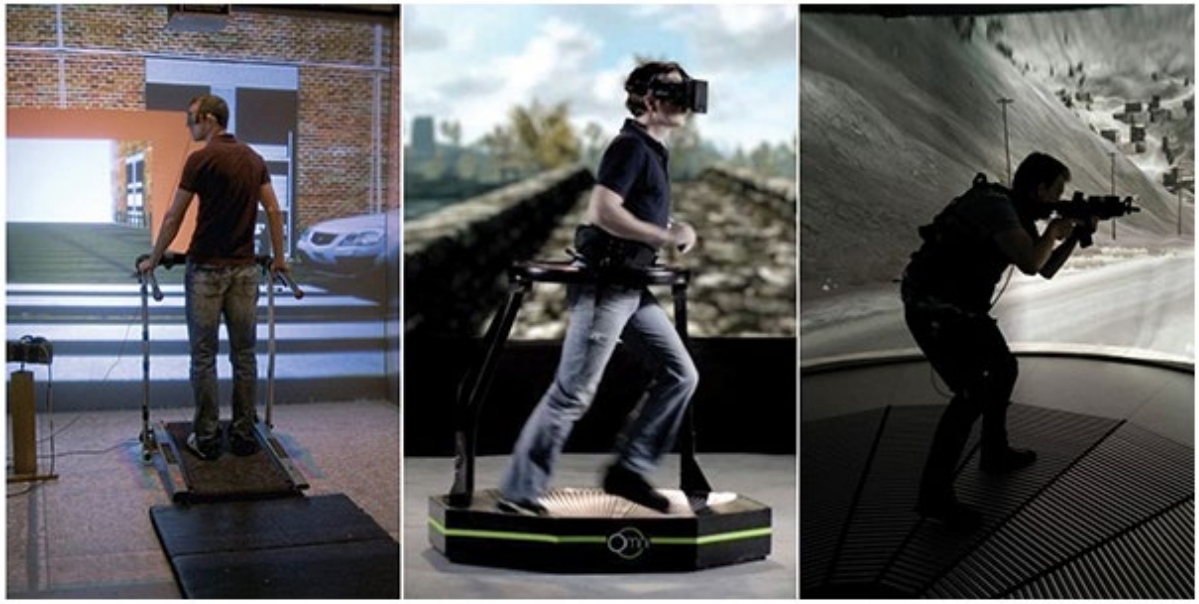


Navigation and Interaction

- Navigation and interaction
  - Fundamental to VR/AR applications
  - Crucial for overall sense of immersion
- 2D versus 3D
  - Standard 2D input devices limited usage
    - E.g., mouse, game controller
    - Not natural or intuitive
    - Fine for video game applications
      - Viewpoint is generally limited
      - Mostly limited along z-axis (up and down)

Navigation and Interaction

- Special purpose 2D input devices
  - E.g., treadmill for manual navigation
  - Combined with other mechanism for 6 DOF head movement



Credit: Images courtesy of Illinois Simulator Laboratory (University of Illinois), Czar via Wikimedia under a CC 2.0 license, and Johan Schmitz

Navigation and Interaction

- Manual interaction
  - Different kinds of scenarios
    - E.g., multi-user CAVE display
      - Interactive experiences where all use tracked HMDs
      - Only one person navigates
  - Most powerful sense of presence and engagement
    - First-person navigation and direction interaction
  - Important to note
    - For VR applications, users typically have no visual reference to real-world surroundings
      - Including standard input devices, e.g., mouse, keyboard, gaming controllers

Navigation and Interaction

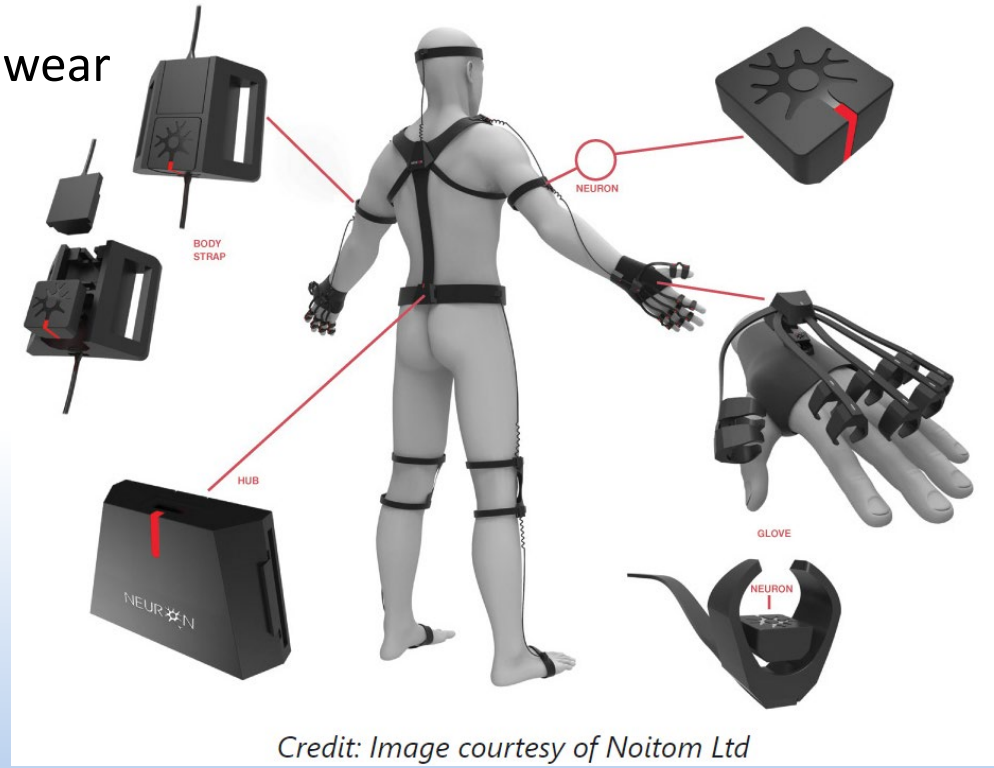
- Manual interaction
  - ➢ Hands are the most natural means of interaction
    - Data glove
      - – Can track individual finger movements
    - VR controller
      - – Can mimic certain hand using on touch sensors

Credit: Image courtesy of Cyberglove Systems, LLC

3D model of a hand controlled by a VR controller with touch sensors.

Navigation and Interaction

- Manual interaction
  - ➢ Full body suits
    - Expensive, availability
    - Cumbersome, difficult to wear
  - ➢ Motion capture (mocap)



Credit: Image courtesy of Noitom Ltd

Navigation and Interaction

- Brain interfaces
  - Navigating/interacting using electrical signals measured from the brain
  - Brain-machine interfaces (BMI)
    - E.g., EEG (electroencephalogram) system
    - Each user has unique brain pattern fingerprint
      - Must be trained by the user by thinking about certain actions

Credit: Images courtesy of Bruno Cordioli and Bownose via Flickr under a CC 2.0 license

Navigation

- Navigation
  - Two sub-areas
    - Wayfinding and travelling
- Wayfinding
  - Analysis, planning and decision about paths in the virtual world
  - Goal is to generate a cognitive map, i.e., simplified mental representation, of the virtual space
  - The process of wayfinding is unconscious
    - Resulting cognitive map different for each user
    - Support to enable user to acquire necessary spatial knowledge

Navigation

- Spatial knowledge
  - Landmarks
    - Prominent, often unique reference points in space
    - Easier to remember and distinguish from other objects
    - In AR, can add virtual objects as landmarks
  - Route/procedural knowledge
    - Sequence of points that form a route and what actions necessary to follow the route
      - » E.g., digital compass, signposts, waymarks
  - Overview knowledge
    - Interactive overview maps
    - World-in-miniature techniques

Navigation

- Travelling
  - Motor component of navigation
    - Basic actions needed to change position and orientation of the virtual camera
  - Exploration
    - User does not have a concrete goal
  - Search
    - User has a goal of reaching a defined position
  - Maneuvering
    - Finding exact position in the immediate vicinity of the user
    - Characterised by short and precise movements

Navigation

- Control techniques for travelling
  - ➢ Locomotion
    - Virtual camera controlled by specifying a direction

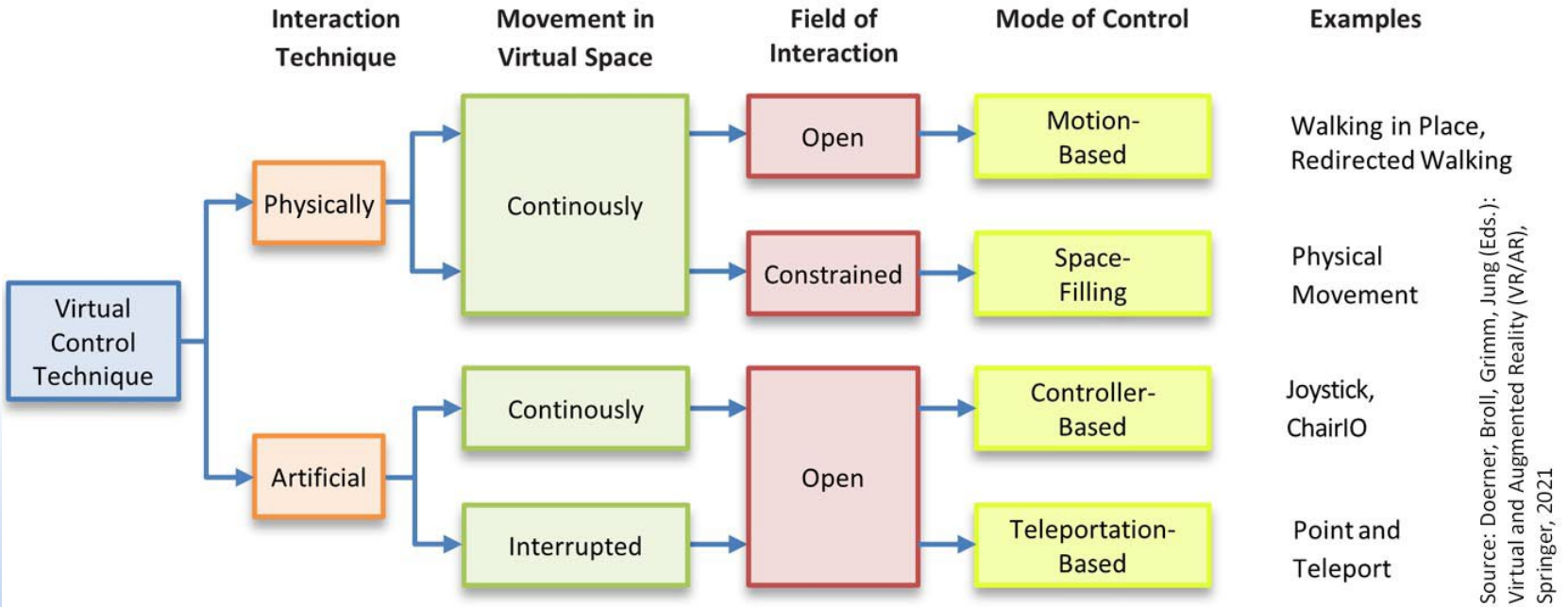


Fig. 6.3 Categorization of control techniques in virtual worlds.

Navigation

- Locomotion methods
  - Room-scale movement
    - Manual interaction
    - Natural free real-world movement
  - Seated down
  - Continuous movement
    - Controller-based movement
    - Causes **vection** (illusion of movement)
      - » Conflicting senses
      - » Simulator sickness
  - Teleporting
    - Instantaneously teleport to a location and/or face a certain direction

Navigation

- Walking technique
  - Walking in place
    - VR systems do not necessarily have large interaction space

Fig. 6.4 The figure shows a simple "walking in place" method where a user is tracked by a mobile motion capturing system. The body movements are detected by inertial sensors at the joints and control movement and orientation in the virtual environment. On the bottom left, the user's pre-distorted view (see Chapter 5), which is generated for both eyes, is shown. (© Christian Geiger, HS Düsseldorf. All rights reserved.)

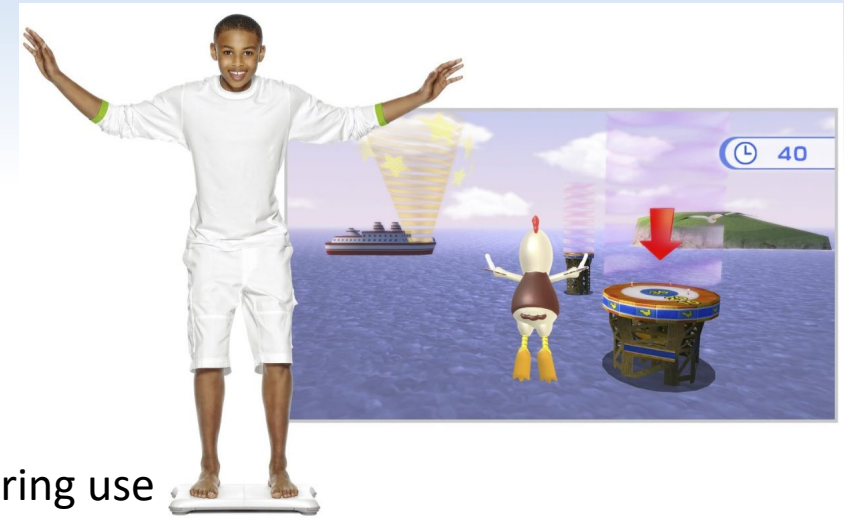
Navigation

- Leaning interfaces
  - Stimulates the sense of balance
  - User leans in desired direction
    - Comparable to steering a motorbike, skiing or skateboarding

Fig. 6.5 The ChairIO allows navigation in a virtual environment by leaning in the desired direction of movement. To implement this concept, a special chair was equipped with additional sensors according to Beckhaus et al. (2007). (© Steffi Beckhaus. All rights reserved.)

Navigation

- Isometric interfaces
  - Requires a holding force
  - Does not move when in use
  - E.g., Wii Balance Board
- Isotonic interfaces
  - No noticeable counterforce during use
    - » No resistance
  - E.g., Tony Hawk RIDE game board
- Elastic interface
  - Combine both isometric and isotonic
  - E.g., ChairIO



https://www.fishpond.com.au/Games/Wii-Fit-Plus-with-Balance-Board/9999141475681
https://www.wired.com/2009/11/tony-hawk-ride-review/

Navigation

- Teleportation
  - Reduces susceptibility to cybersickness
    - Path to the new position is not perceived
  - Abrupt change
    - Difficult to figure out user's location in their own cognitive map
    - User actively chooses the target and causes the abrupt change
  - Point and teleport method
    - Teleport to a point in the field of vision
    - Can be combine with limited room-scale movement

Selection

- Selection
  - More difficult in a 3D context than with 2D user interfaces
  - Pointing
    - Using index finger or input device
      - Aim at target to be selected
    - Non-trivial to identify selected 3D entity
      - Requires collision detection and/or ray-casting
    - Visual feedback
      - Highlighting selected object
      - Visually mark target point
        - » E.g., cursor, reticle
      - Virtual hand

Selection

- Direct versus indirect
  - Direct pointing devices used to position 3D cursor directly
    - Can define absolute coordinates
    - May cover parts of the virtual world relevant to the selection task
  - Indirect devices (e.g., mouse)
    - Change cursor using direction vectors relative to previous position
    - User's attention limited to one part of the overall space

Selection

- Selection techniques
  - Ray-casting
    - Most important and effective technique
    - Objects selected using a beam that points from a 3D cursor into the environment
    - Position and orientation of the beam are controlled by the user
    - All objects cut by the beam are candidates for selection
      - Object closest to the user selected
    - Manageable accuracy decreases with distance
  - Flashlight
    - A selection cone instead of a beam
    - All intersected objects collected as candidates
      - Distance can be an additional criterion

Selection

- Go-go technique
  - Likely inspired by *Inspector Gadget*
  - Infinite extension of a virtual arm to which a virtual hand is attached
  - Allows the hand to be moved to place of interest
- HOMER
  - Hand-centred Object Manipulation Extending Ray-casting
  - Ray extrapolated from current hand position
    - If ray hits an object, the virtual hand is moved to the object's position

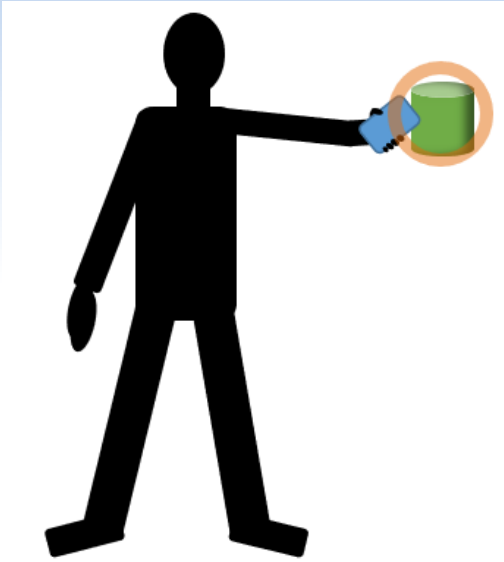
https://hero.fandom.com/wiki/Inspector_Gadget_(Inspector_Gadget)?file=Gadget+Hand.png

Selection

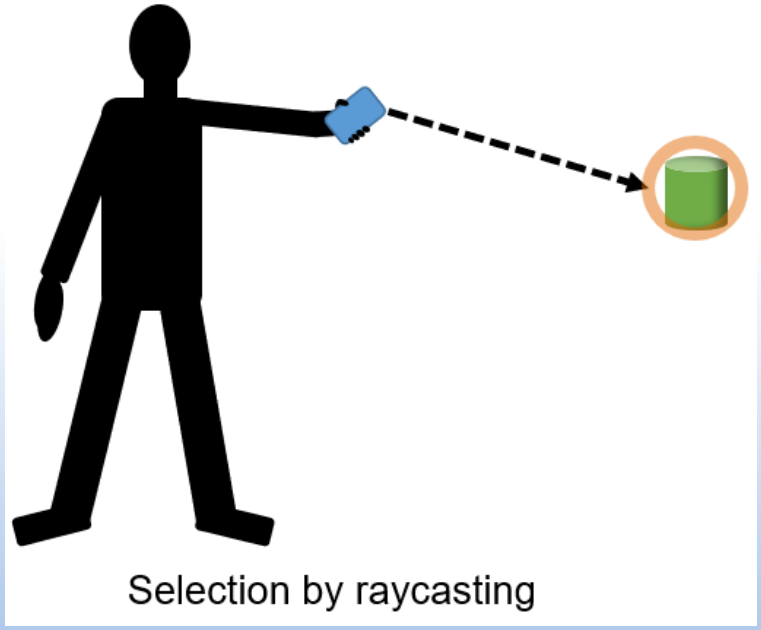
- Image layer technique
  - Uses virtual image layers
    - Similar to a mouse pointer
  - Objects behind an image plane are projected onto the plane
    - User selects objects on this virtual plane
  - For example
    - World-in-miniature (WIM) technique
      - » Scale down entire virtual environment to fit into user's field of view as a miniature model
      - » Exocentric technique
        - User leaves their own egocentric perspective
        - Unlike egocentric techniques like ray-casting, flashlight

Selection

- Selecting an object
  - ➢ Touching
    - Select by touching object
    - Limited range
    - Zero distance ray-cast
  - ➢ Ray-casting
    - Cast of ray of finite length for selection
    - Can interact with objects out of a user's normal reach



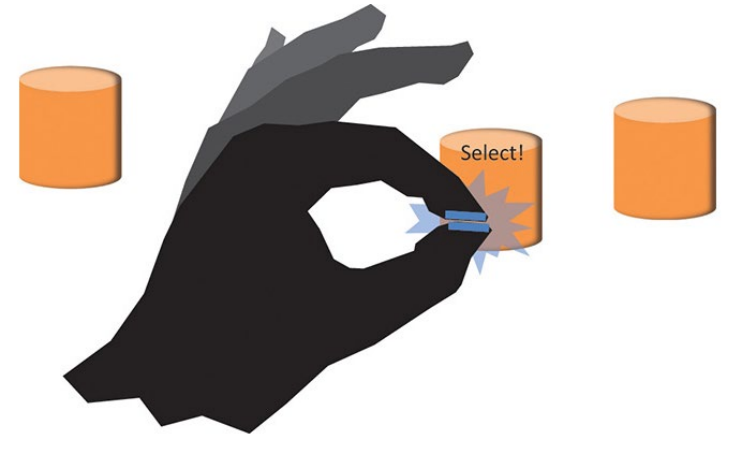
Selection by touching



Selection by raycasting

Selection

- Occlusion
  - Select using interaction object (e.g., finger) to occlude object from the virtual camera's viewpoint
  - Ray-cast originating from the viewpoint
- Finger controls
  - E.g., Pinch glove
    - Detects when a user presses fingertips together, interprets this gesture as a selection



Selection

- Interaction
  - ➢ Visual feedback is an important interaction cue

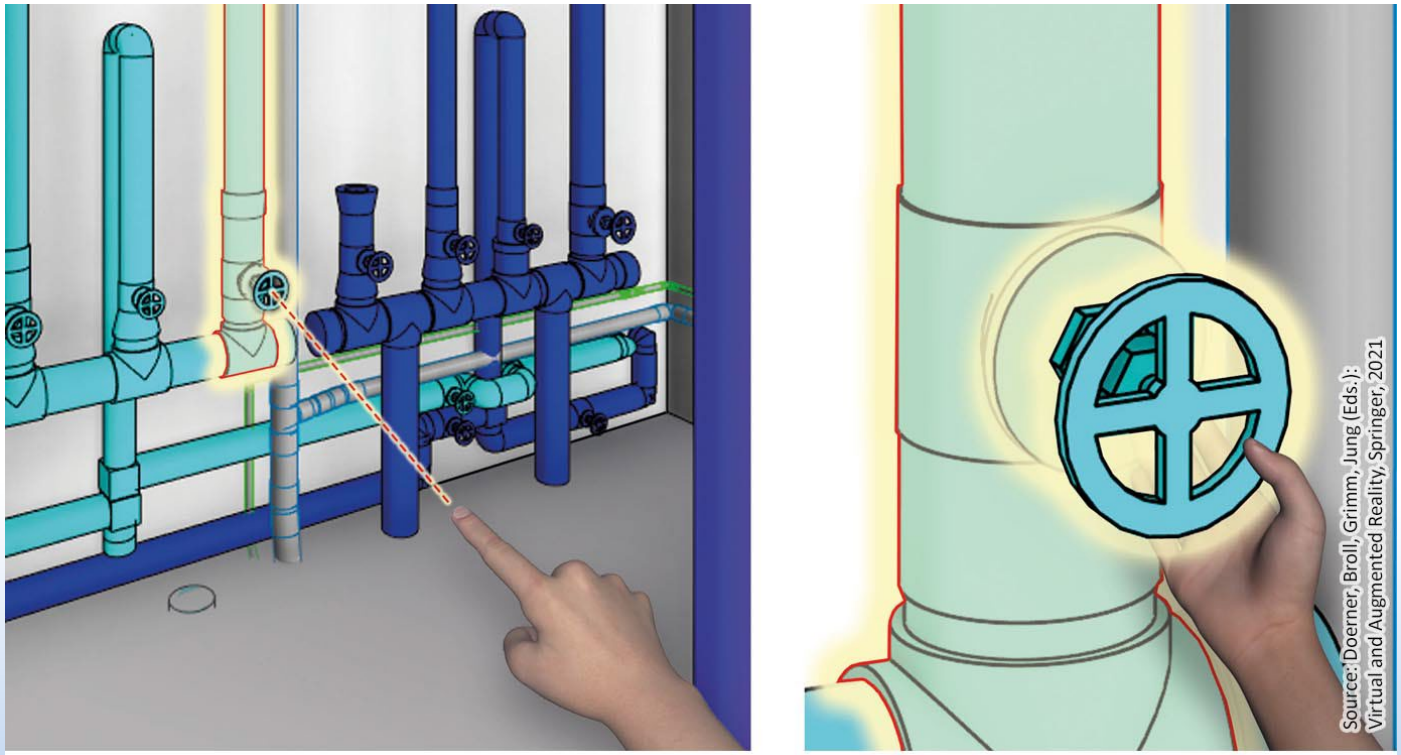


Fig. 6.1 Selection in VR and visual feedback. The selection process is realized (left) with a beam from the finger using ray-casting, or (right) by a virtual hand using collision detection.

Selection

- World-in-miniature

Fig. 6.2 Example of the selection of remote objects by a world-in-miniature. With this technique, users can select objects even if they are not in their field of view.

Manipulation

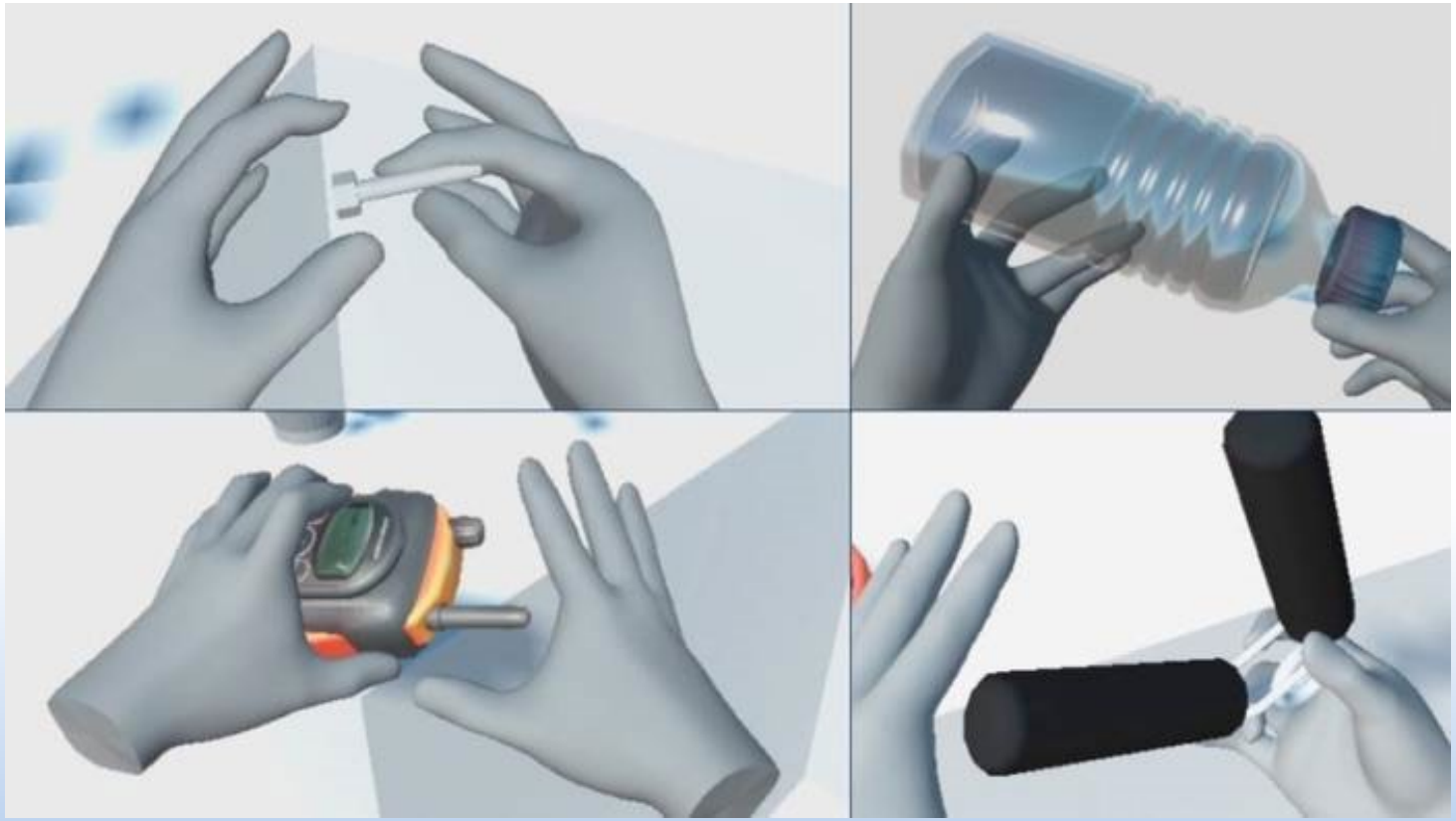
- Manipulation of objects
  - ➢ Follows on from selection
    - Selected object's properties changed by manipulation
      - E.g., change an object's location, orientation, size, velocity, appearance
    - Selection and manipulation techniques designed together for interaction
  - ➢ May not have a direct equivalent in the real world
  - ➢ Can be exocentric or egocentric
  - ➢ Suitability of technique depends on
    - Desired functionality and concept underlying an application
      - E.g., in simulation and training application desirable to reference reality using realistic interaction technique

Manipulation

- Manipulation techniques
  - Arcball
    - An object is conceptually enveloped in a sphere
      - Interactions in the form of rotations around the centre of the sphere transferred to the virtual object
      - Rotation of sphere can be mapped to 2D interaction
    - Solely allows manipulation of an object's orientation
  - Virtual hand
    - Similar to interaction with real objects
    - Natural user interface
      - Restricted to objects within a user's reach

Manipulation

- For example
  - VirtualGrasp by Gleechi



https://www.auganix.org/gleechi-announces-availability-of-its-virtualgrasp-technology-to-enable-developers-to-add-more-natural-hand-interactions-to-vr-experiences/

Manipulation

- Pointing gestures
  - Highly suitable for selecting distant objects
    - Ray-casting/flashlight technique
  - Pointing at objects intuitive and natural
  - Direct transfer of gestures to manipulation often difficult
    - Precise positioning and orientation difficult
- Transmission of hand movements
  - Interpret movements of the user's hand
  - For example
    - Pointing gesture to select object
    - Object moves into the hand of the user for manipulation
    - Upon completion, object returned to its starting point

Manipulation

- Alternatively
  - User can be teleported to the object's location
  - Manipulation via virtual hand technique

➢ Voodoo dolls

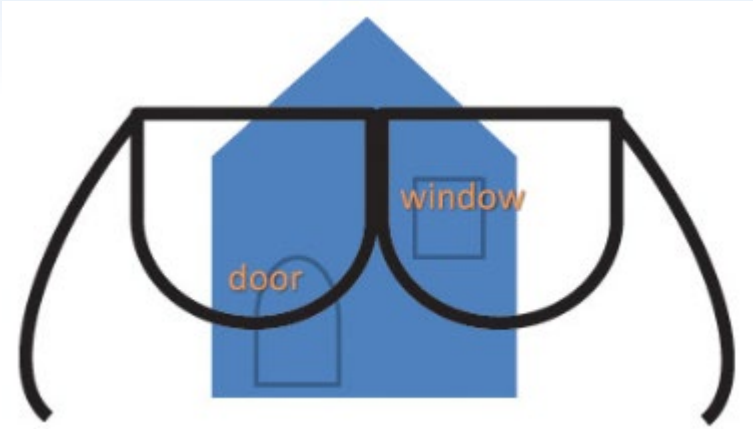
- Exocentric technique
- User interacts with a small scaled copy of selected object
- Scaling ensures the user can manipulate objects of different sizes

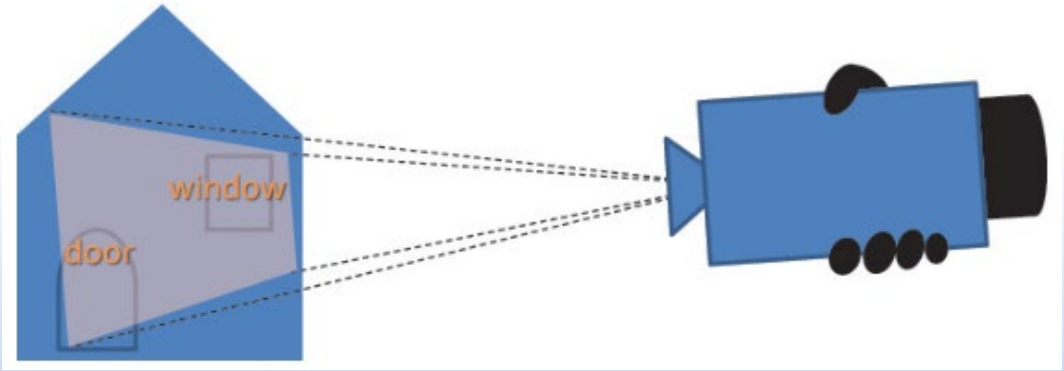
Interaction

- Skeleton tracking
  - User body motions transformed into arrows
  - Dance, sports, artistic expression

Interaction

- AR interaction
  - ➢ Displays
    - HMDs
    - Handheld
    - Projected
      - E.g., a flashlight application





Interaction

- End-to-end latency
  - ➢ Can impact effective interaction

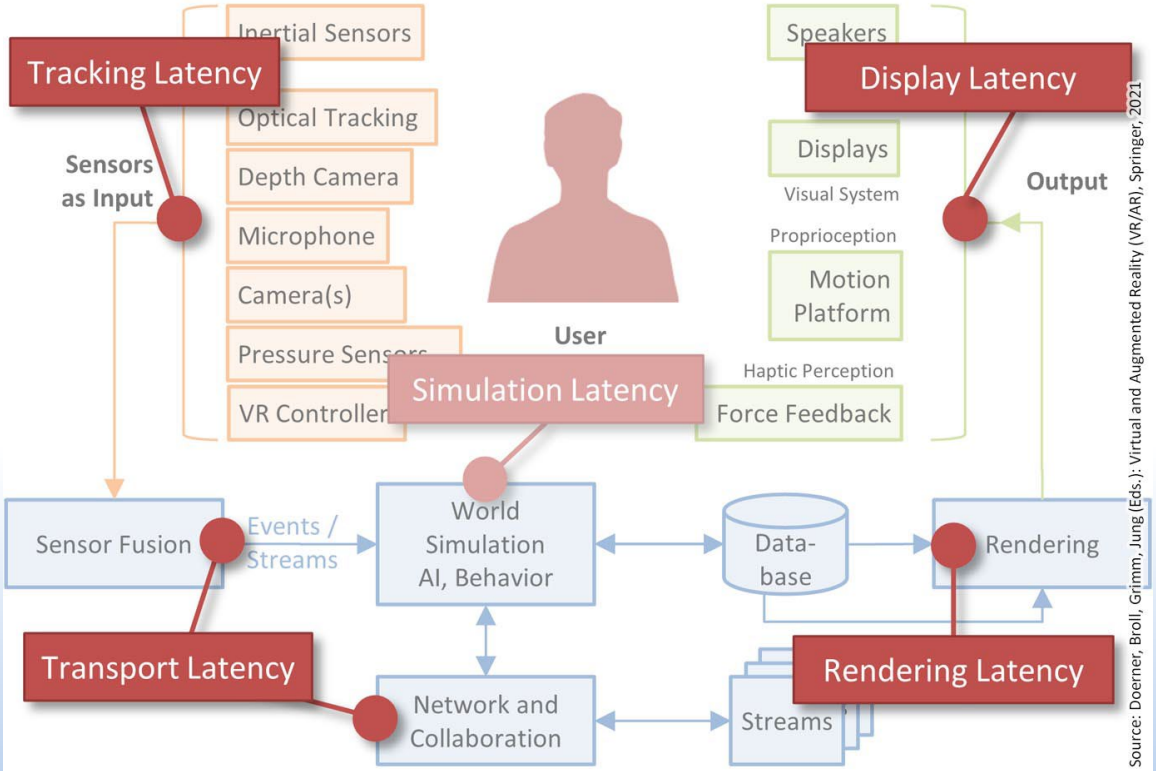


Fig. 7.1 Latencies occur at various points in a VR system.

Navigation

- Wayfinding
  - ➢ Signpost system
    - Outdoor navigation
      - AR user to follow route consisting of waypoints
    - Indoor navigation
      - Highlights the next doorway along path
      - Shows a 3D arrow pointing in the direction of destination

Image: Gerhard Reitmayr, Daniel Wagner

Navigation

- Navigation support
  - ➢ A study comparing map usage
    - Darker colours – more users engaged with interface
    - Conventional map interface
      - Usage is uniformly high along the entire path
    - AR interface
      - Mostly used at nodes, when a decision needed to be made

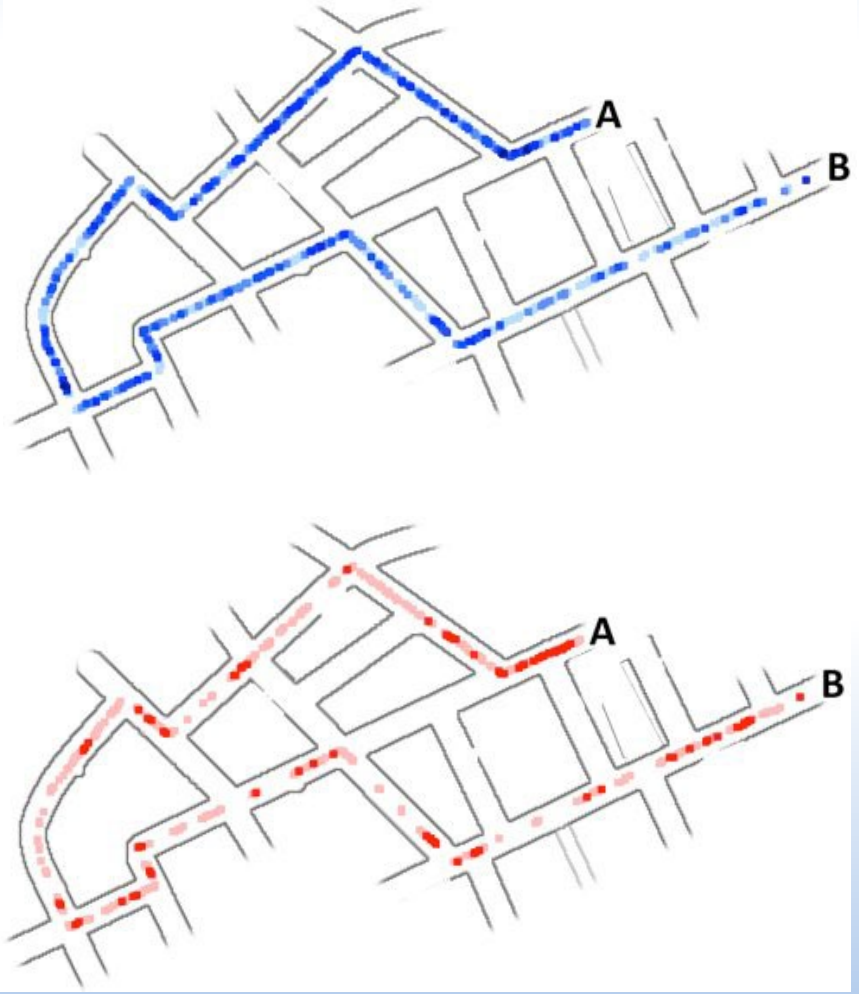


Image: Alessandro Mulloni

Navigation

- Decision making
  - Route visualized in VR while user walks
  - Upon reaching a decision node
    - Whole path which aligns with environment is shown
  - After departing from node, switches back to VR display

Image: Alessandro Mulloni

Navigation

- Context compass
  - Band at the bottom of the screen representing possible directions
    - Overlay arrow visible when display aligned with the correct orientation
    - When not aligned user can use the compass context to find the off-screen arrow

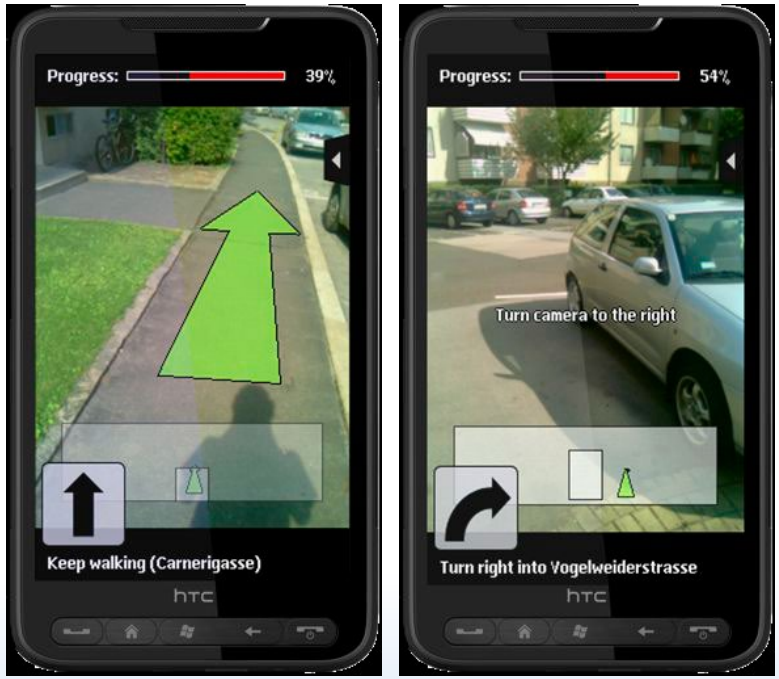
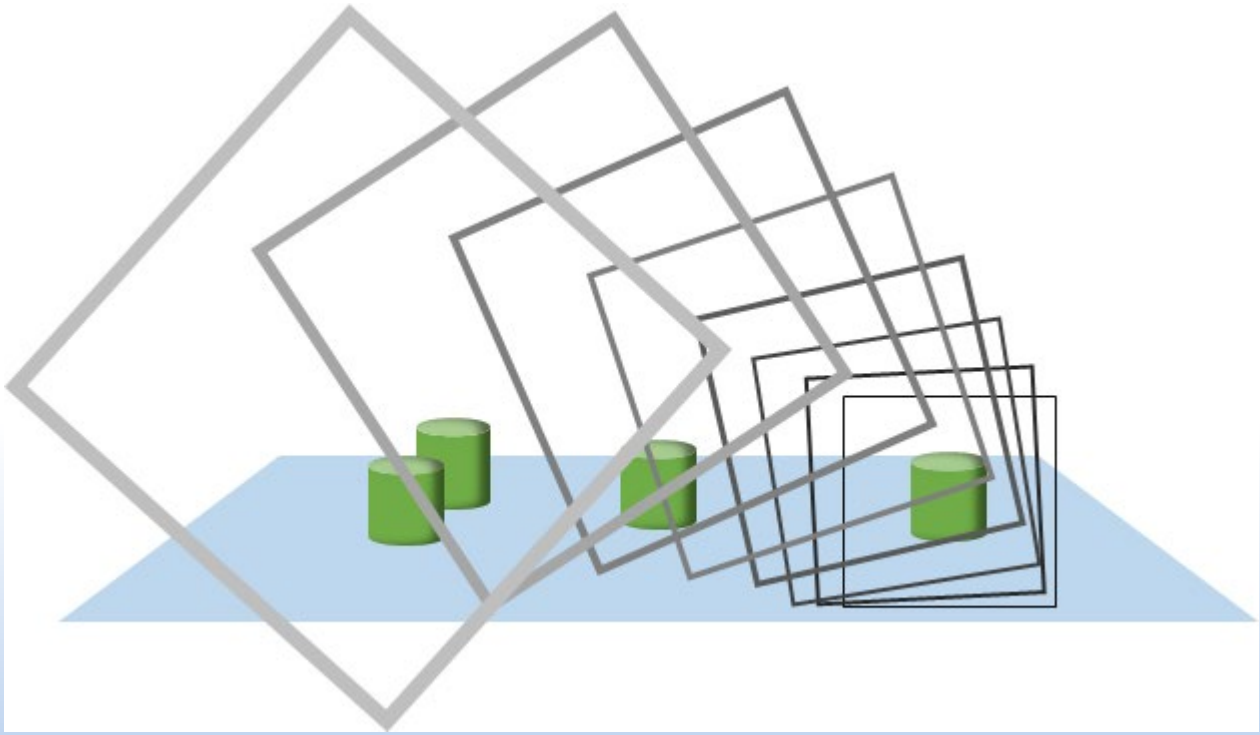


Image: Alessandro Mulloni

Navigation

- Attention funnel
  - A tunnel visualisation directs a user's attention toward a specific object at the tunnel's end



Interaction

- Handy AR
  - ➢ Outstretched hand
    - Coordinate reference system for interaction with objects
  - ➢ Virtual objects can be attached to hand for inspection and manipulation
  - ➢ Actions triggered by making fist gesture

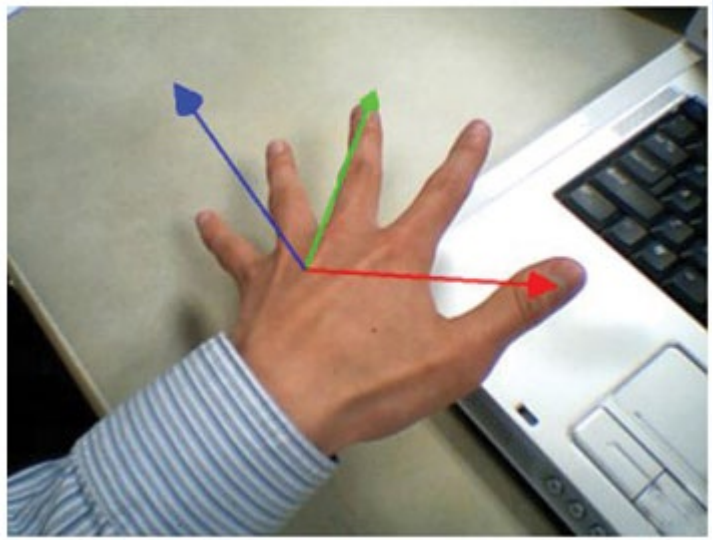


Image: Taehee Lee

Interaction

- Free-space gestures
  - Precision often suffers from lack of physical support
    - Affects delicate operations
- Touch based interfaces
  - Passive haptic feedback
  - Touchscreen
    - Touch surface combined with a display
    - Screen can show interactive information registered to touching fingers
    - Registration only in 2D
    - Fingers occlude object of interaction
      - » “fat finger problem”
        - Hard to aim precisely

Interaction

- Touch
  - LucidTouch
    - Simulates a semi-transparent screen
    - Touch interface on the back
      - Fingers do not occlude
  - Virtual touchscreen
    - Using a projector-camera system
    - E.g., menu projected on a surface

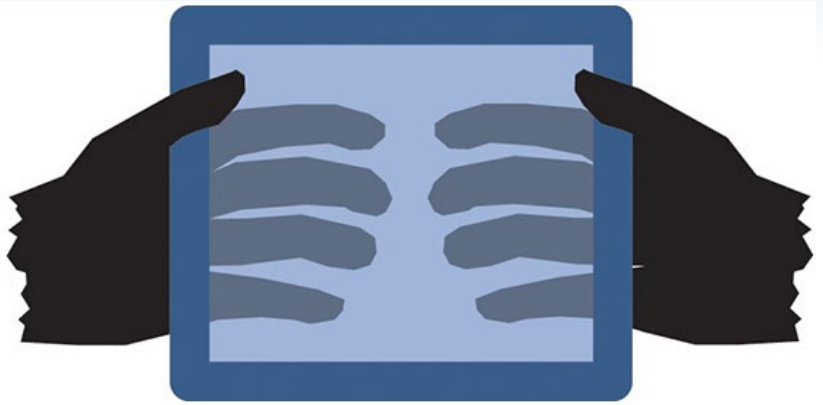
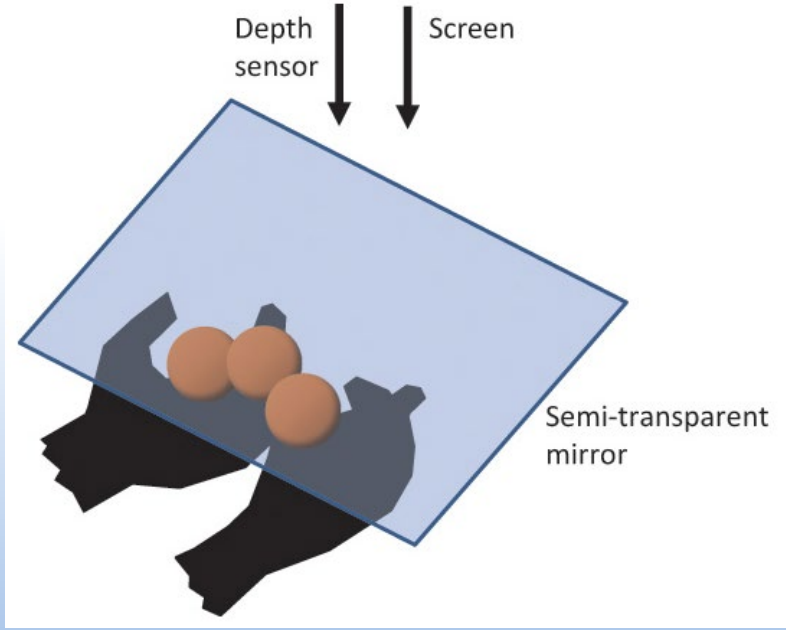


Image: Claudio Pinhanez (© IBM 2001)

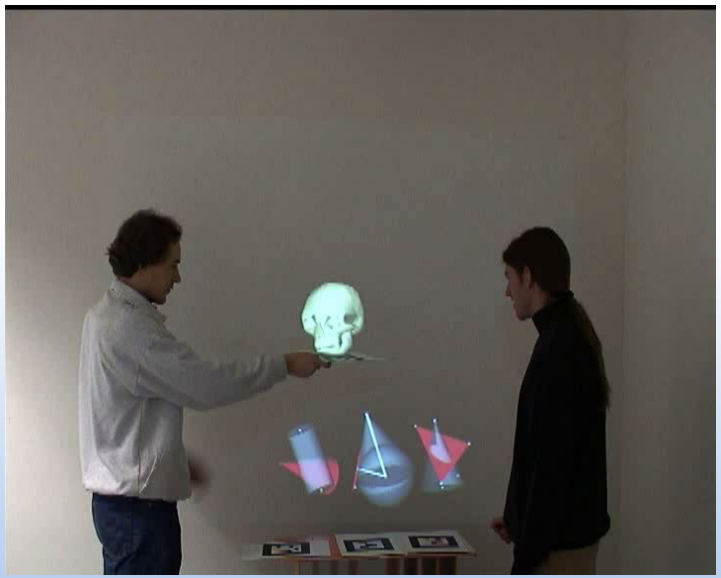
Interaction

- Physical based
  - ➢ HoloDesk
    - Combination of
      - Stationary optical see-through display
      - Depth sensor to simulate physical interaction of the user's hands with virtual objects



Interaction

- Tangibles
  - ➢ Markers used to collaboratively manipulate virtual objects
    - Example interactions
      - Picking up a tangible, arrangement of markers, distance between markers, obscuring a marker from view, tangible held in hand for gestural input



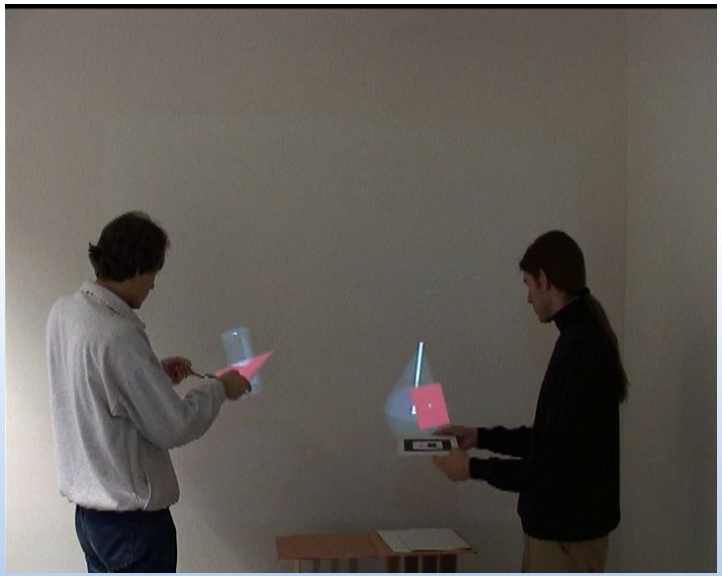


Image: Gerhard Reitmayr, Hannes Kaufmann

Interaction

- Magic lens
- Magic book and paddle
  - Physical book with tracked pages
  - Can pick up an object from the magic book with a paddle

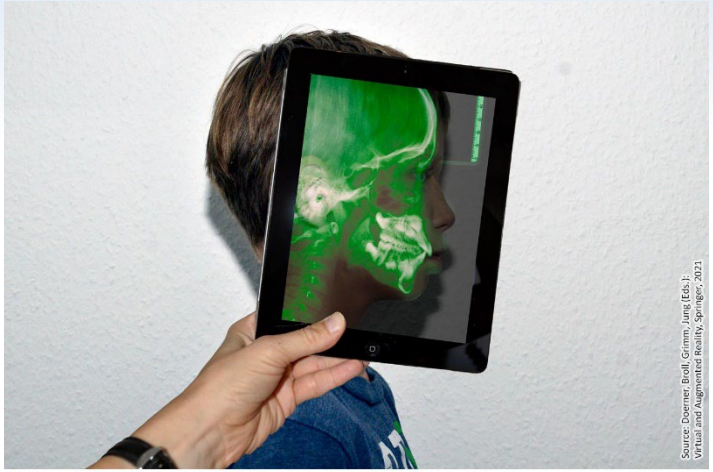
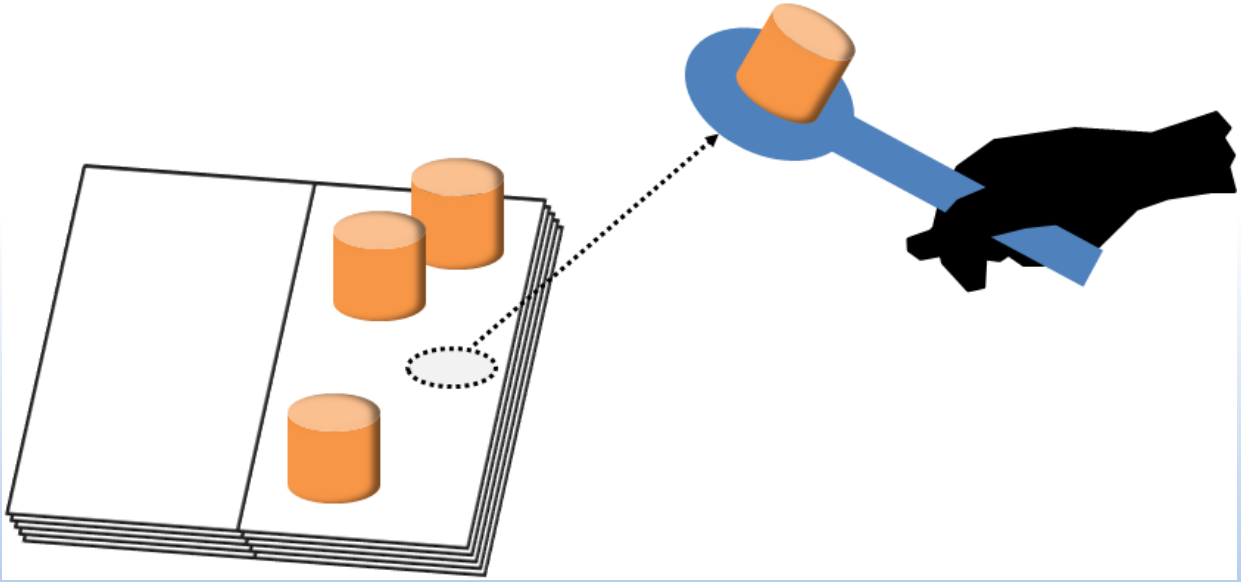
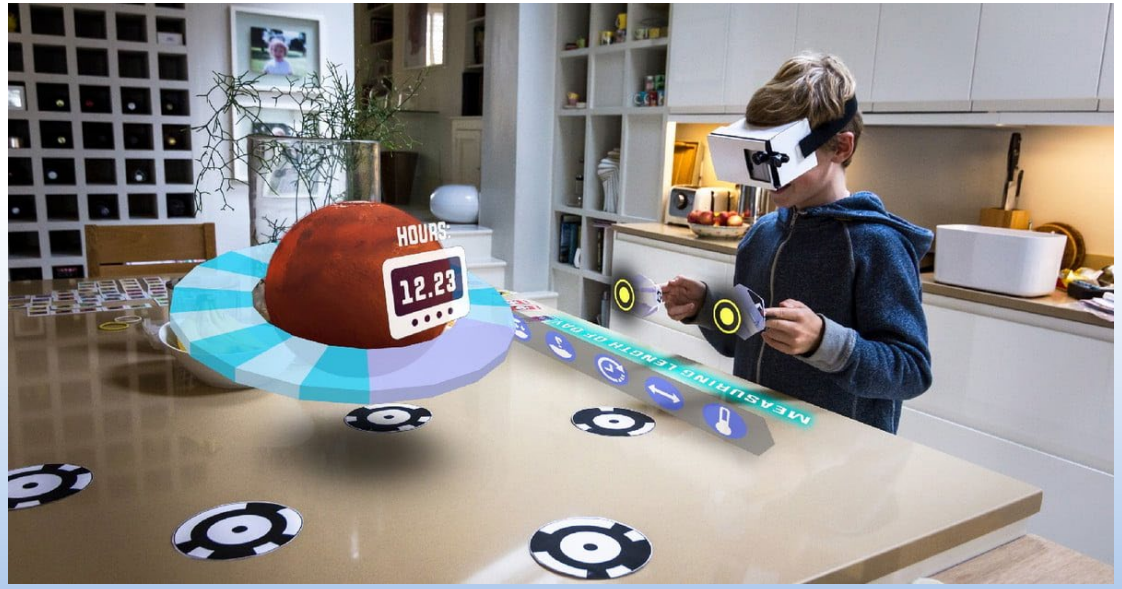


Fig. 8.5 Example of a Magic Lens effect.



Interaction

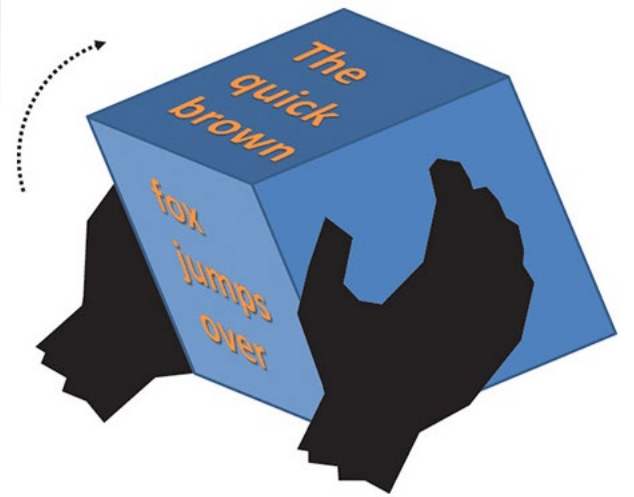
- Zappar ZapBox
  - Room-scale tracking
    - Vision-based
  - Handheld controllers
    - Customisable
  - Mobile AR HMD
  - Tangible AR



https://www.zappar.com/zapbox/

Interaction

- CoCube
  - A tangible object
  - Can show either virtual 3D objects inside the cube or 2D information, such as text, on its surfaces



- Merge Cube

https://mergevr.com/cube

Interaction

- Real surfaces
  - ➢ Digital desk
    - Often using projection
    - Paper and electronic documents treated as the same

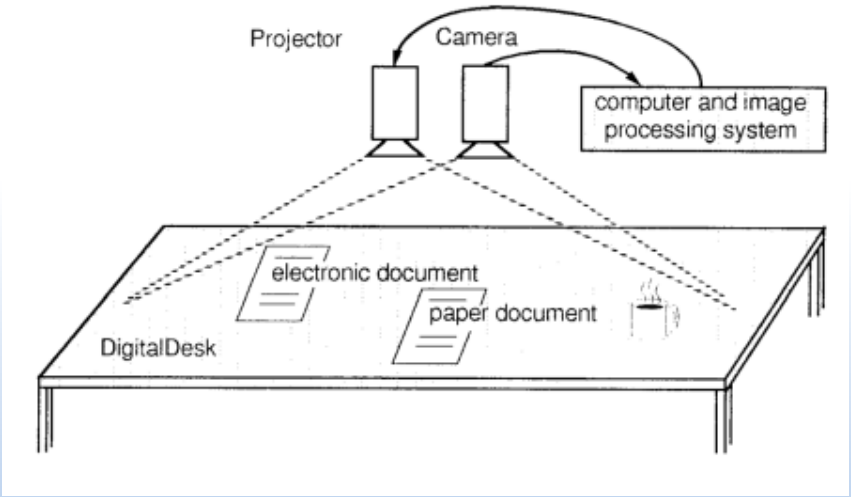
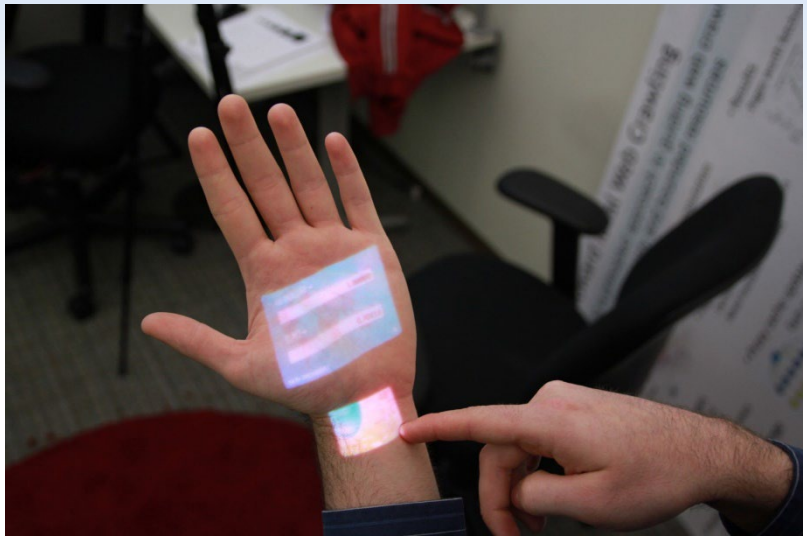


Image: Paul Wellner

Interaction

- OmniTouch
  - Uses a projector and depth camera to turn the user's own hand into a touchscreen
- Augmented paper
  - Paper is an important everyday artifact
  - Augmented maps
    - Conventional paper map with projected interactive content



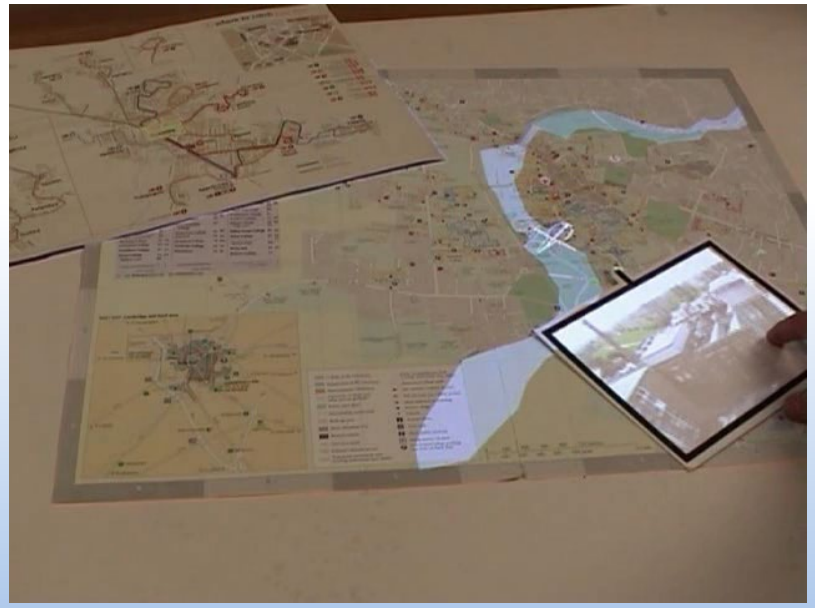
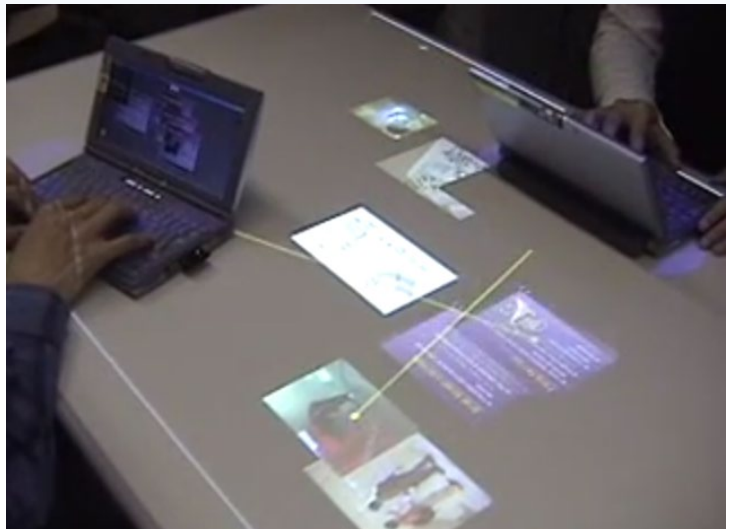


Image: Microsoft Research
Image: Gerhard Reitmayr, Ethan Eade, and Tom Drummond

Interaction

- Multi-view interfaces
  - ➢ Augmented surfaces
    - Combining laptops and projection surfaces into a continuous display space
  - ➢ MultiFi
    - Combination of HMD and smartwatch or smartphone



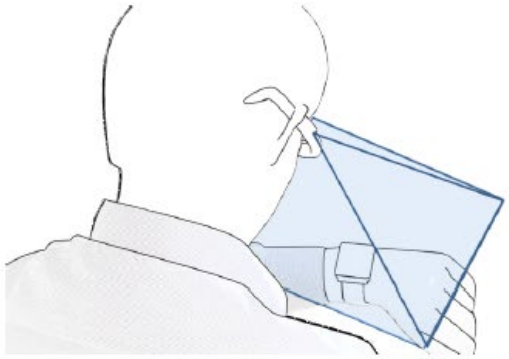


Image: Jun Rekimoto, Sony CSL
Image: Jens Grubert

Ring menu

Virtual folding screen

References

- Among others, material sourced from
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