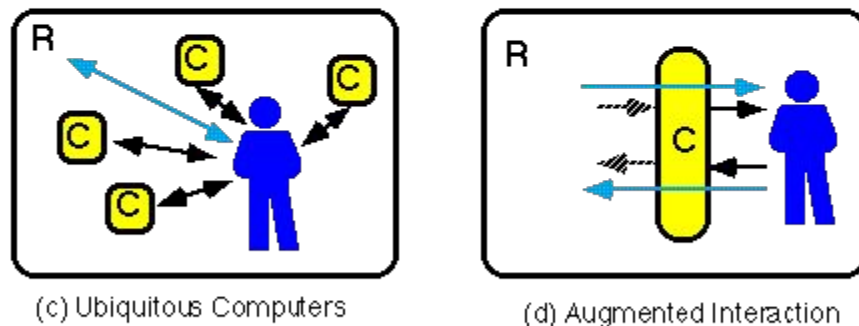
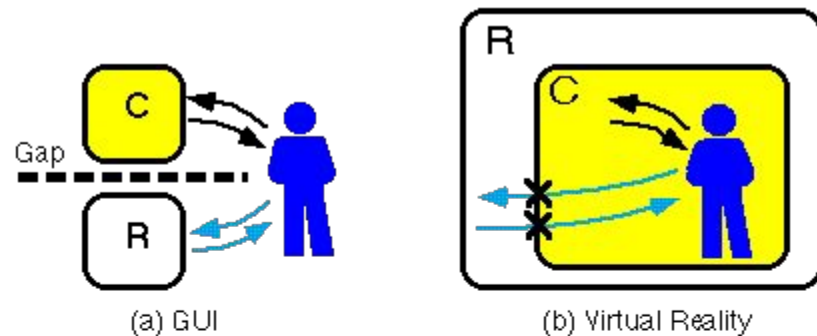


Intro to AR/VR

Alaeddin NASSANI | University of Aizu

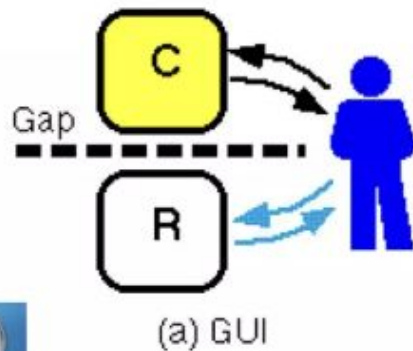
HSD-Japan | Summer School 2026



 Computer World
 Real World

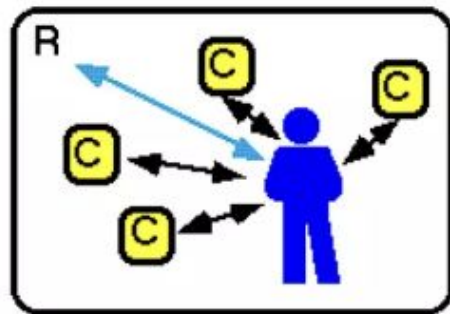
 Human - Computer Interaction
 Human - Real World Interaction
 Real World - Computer Interaction

Graphical User Interfaces



- Separation between real and digital worlds
 - WIMP (Windows, Icons, Menus, Pointer) metaphor

Internet of Things (IoT)..

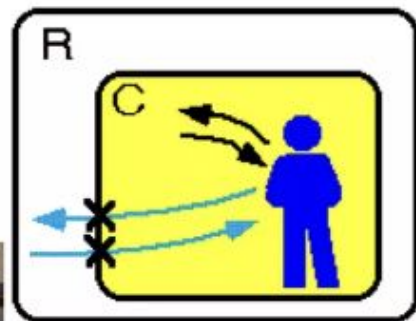


(c) Internet of Things



- Embed computing and sensing in real world
 - Smart objects, sensors, etc..

Virtual Reality (VR)

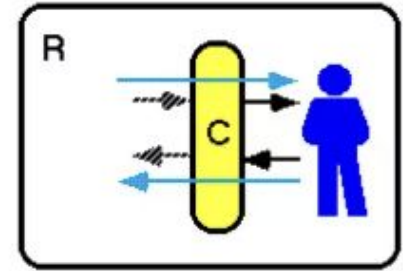


(b) Virtual Reality

- Users immersed in Computer Generated environment
 - HMD, gloves, 3D graphics, body tracking



Augmented Reality (AR)

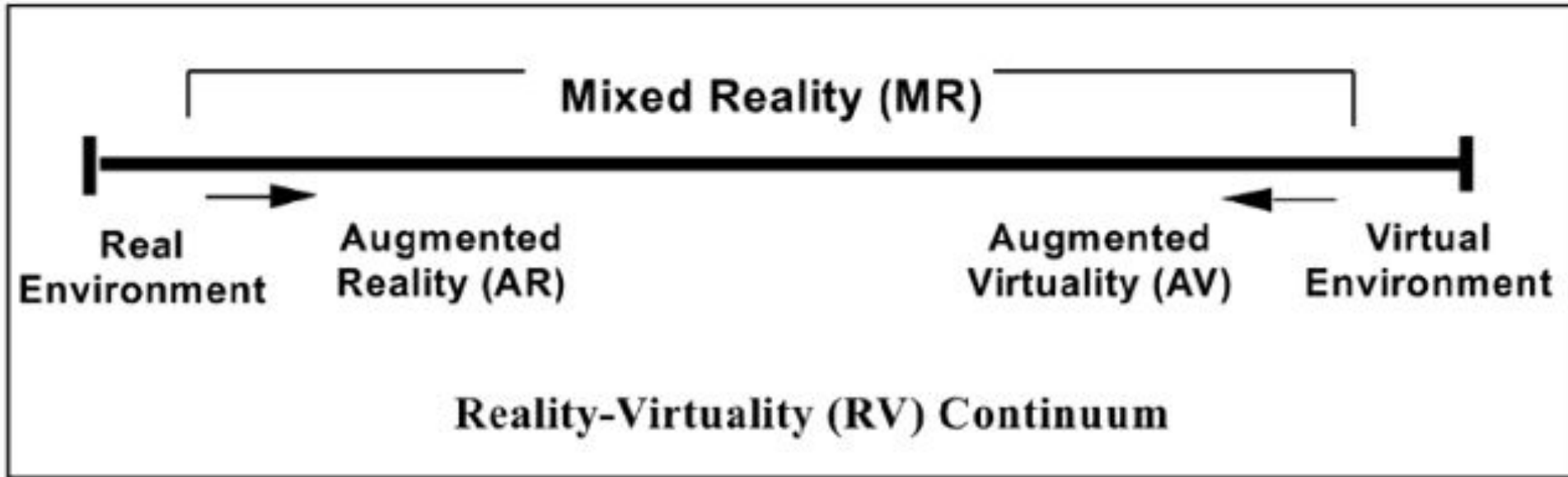


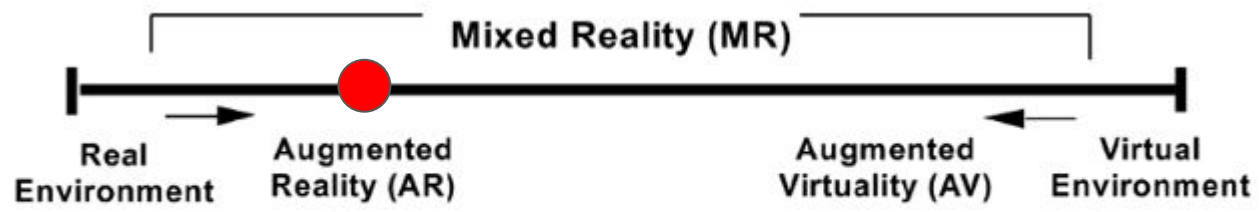
(d) Augmented Interaction

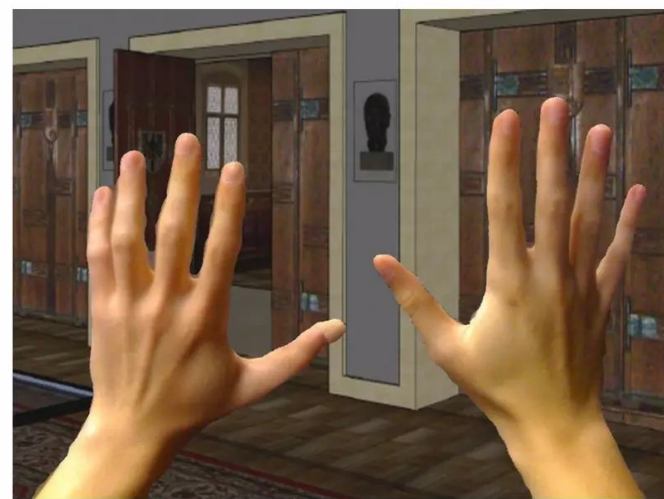
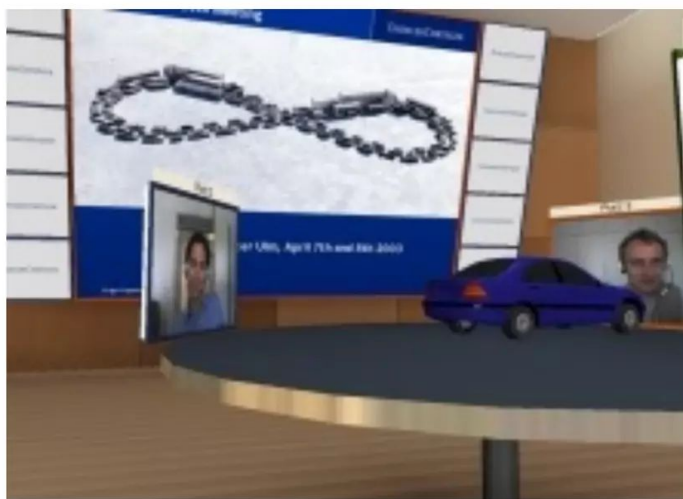
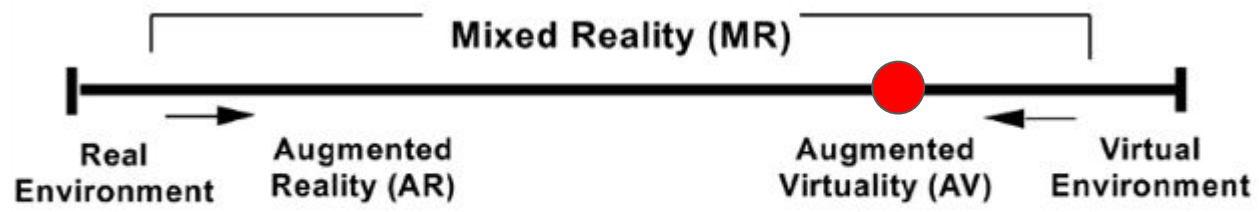
- Virtual Images blended with the real world
 - See-through HMD, handheld display, viewpoint tracking, etc..



Reality-Virtuality Continuum







Brief History

The Ultimate Display

“.. it should serve as many senses as possible..”

By Ivan Sutherland

The Ultimate Display

Ivan E. Sutherland

Information Processing Techniques
Office, ARPA, OSD

We live in a physical world whose properties we have come to know well through long familiarity. We sense an involvement with this physical world which gives us the ability to predict its properties well. For example, we can predict where objects will fall, how well-known shapes look from other angles, and how much force is required to push objects against friction. We lack corresponding familiarity with the forces on charged particles, forces in non-uniform fields, the effects of nonprojective geometric transformations, and high-inertia, low friction motion. A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland.

Computer displays today cover a variety of capabilities. Some have only the fundamental ability to plot dots. Displays being sold now generally have built in line-drawing capability. An ability to draw simple curves would be useful. Some available displays are able to plot very short line segments in arbitrary directions, to form characters or more complex curves. Each of these abilities has a history and a known utility.

It is equally possible for a computer to construct a picture made up of colored areas. Knowlton's movie language, BEFLIX [1], is an excellent example of how computers can produce area-filling pictures. No display available commercially today has the ability to present such area-filling pictures for direct human use. It is likely that new display equipment will have area-filling capability. We have much to learn about how to make good use of this new ability.

The most common direct computer input today is the typewriter keyboard. Typewriters are inexpensive, reliable, and produce easily transmitted signals. As more and more on-line systems are used, it is likely that many more typewriter consoles will come into use. Tomorrow's computer user will interact with a computer through a typewriter. He ought to know how to touch type.

A variety of other manual-input devices are possible. The light pen or RAND Tablet stylus serve a very useful function in pointing to displayed items and in drawing or printing for input to the computer. The possibilities for very smooth interaction with the computer through these devices is only just beginning to be exploited. RAND Corporation has in operation today a debugging tool which recognizes printed changes of register contents, and simple pointing and moving motions for format relocation. Using RAND's techniques you can change a digit printed on the screen by merely writing what you want on top of it. If you want to move the contents of one displayed register into another, merely point to the first and "drag" it over to the second. The facility with which such an interaction system lets its user interact with the computer is remarkable.

Knobs and joysticks of various kinds serve a useful function in adjusting parameters of some computation going on. For example, adjustment of the viewing angle of a perspective view is conveniently handled through a three-rotation joystick. Push buttons with lights are often useful. Syllable voice input should not be ignored.

In many cases the computer program needs to know which part of a picture the man is pointing at. The two-dimensional nature of pictures makes it impossible to order the parts of a picture by neighborhood. Converting from display coordinates to find the object pointed at is, therefore, a time-consuming process. A light pen can interrupt at the time that the display circuits transfer the item being pointed at, thus automatically indicating its address and coordinates. Special circuits on the RAND Tablet or other position input device can make it serve the same function.

What the program actually needs to know is where in memory is the structure which the man is pointing to. In a display with its own memory, a light pen return tells where in the display file the thing pointed to is, but not necessarily where in main memory. Worse yet, the program really needs to know which sub part of which part the man is pointing to. No existing display equipment computes the depths of recursions that are needed. New displays with analog memories may well lose the pointing ability altogether.

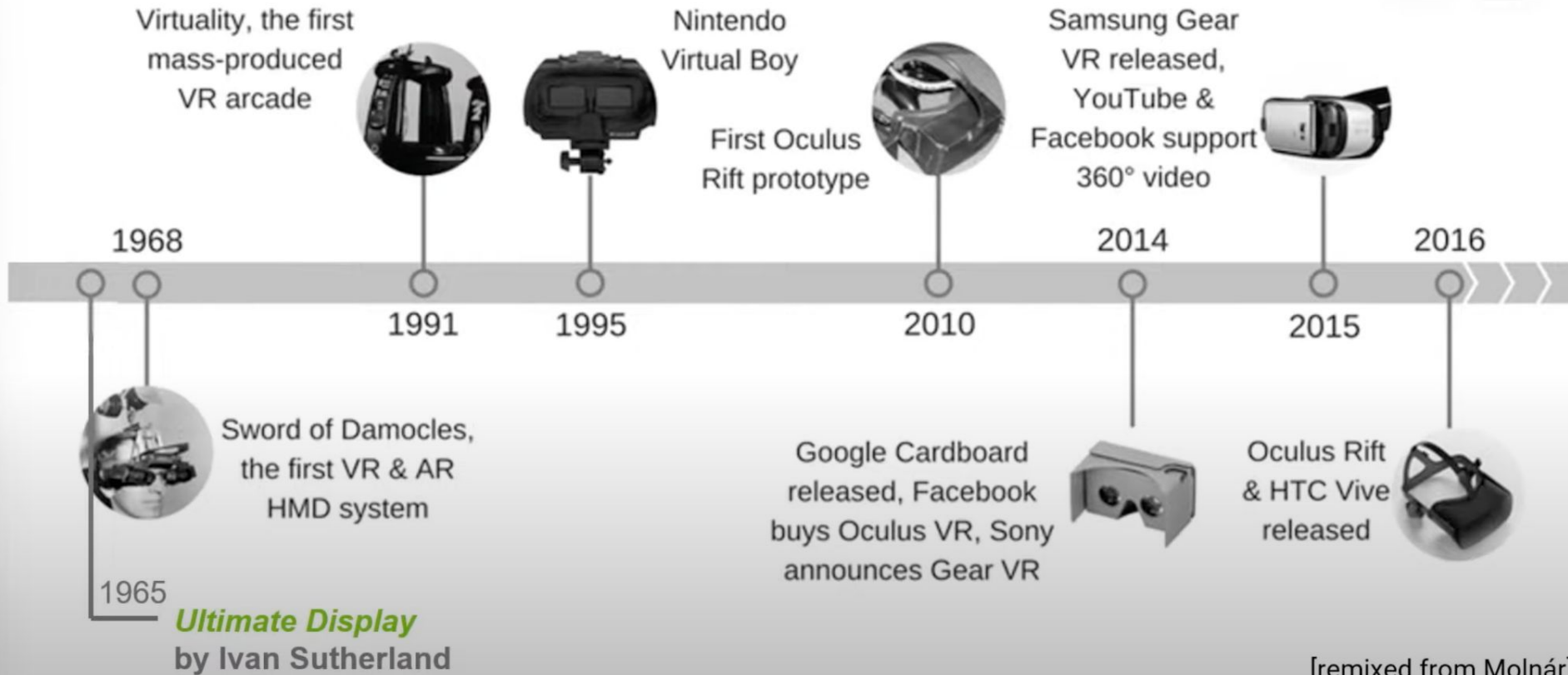
Other Types of Display

If the task of the display is to serve as a looking-glass into the mathematical wonderland constructed in computer memory, it should serve as many senses as possible. So far as I know, no one seriously proposes computer displays of smell, or taste. Excellent audio displays exist, but unfortunately we have little ability to have the computer produce meaningful sounds. I want to describe for you a kinesthetic display.

The force required to move a joystick could be computer controlled, just as the actuation force on the controls of a Link Trainer are changed to give the feel of a real airplane. With such a display, a computer model of particles in an electric field could combine manual control of the position, of a moving charge, replete with the sensation of forces on the charge, with visual presentation of the charge's position. Quite complicated "joysticks" with force feedback capability exist. For example, the controls on the General Electric "handyman" are nothing but joysticks with nearly as many degrees of freedom as the human arm. By use of such an input/output device, we can add a force display to our sight and sound capability.

Sword of Damocles





[remixed from Molnár]

Endo
al Boy

First Oculus
VR prototype



2010

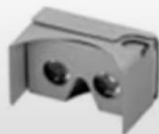
Samsung Gear
VR released,
YouTube &
Facebook support
360° video

2014



2015

Google Cardboard
released, Facebook
buys Oculus VR, Sony
announces Gear VR



Oculus Rift
& HTC Vive
released

2016



... everyone is making headsets



Meta Orion



Apple Vision



Meta Quest 3



Microsoft HoloLens

Job Simulator

- Interaction is king
- First VR game to make \$3M in 1 year
- Top downloaded game in PSVR for 3 years



Beat Saber

- \$2M in 1 month
- Developed by a team of 3 in Czech Republic
- Hand mapped levels with smart movement design

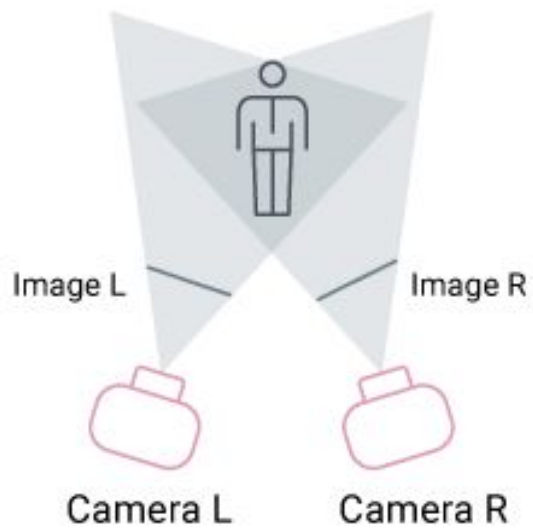


HALF-LIFE: ALYX

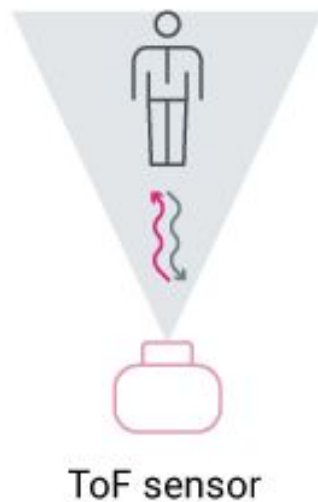
- First true AAA VR game
- Less is more
- Environment design



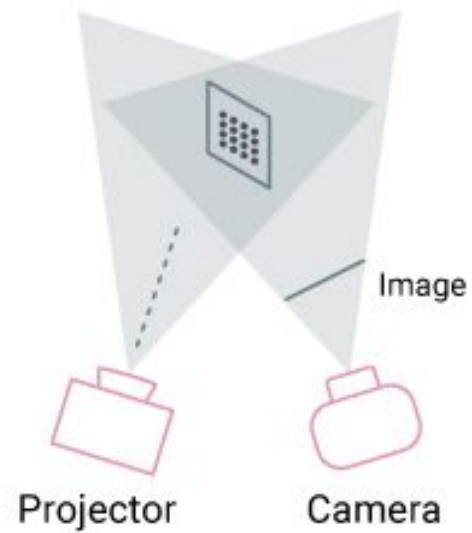
Keywords



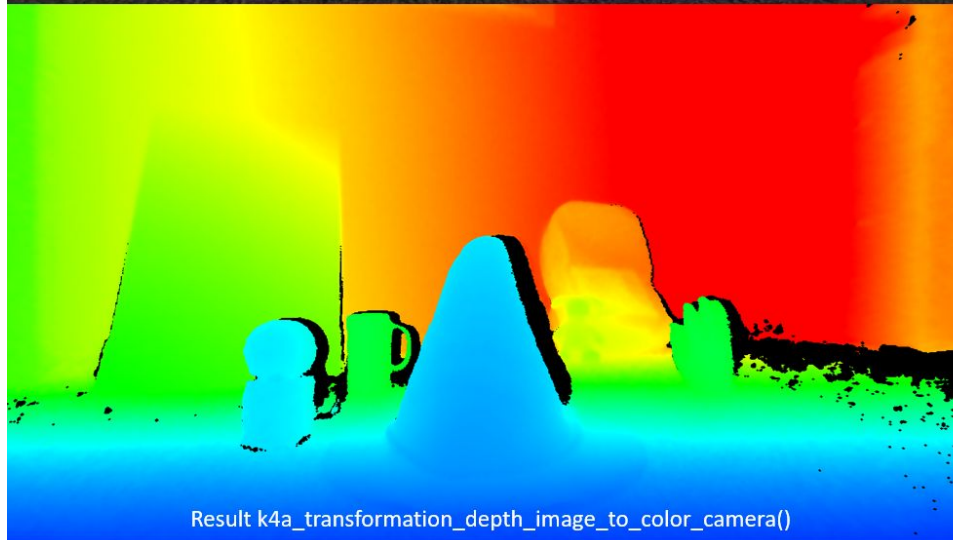
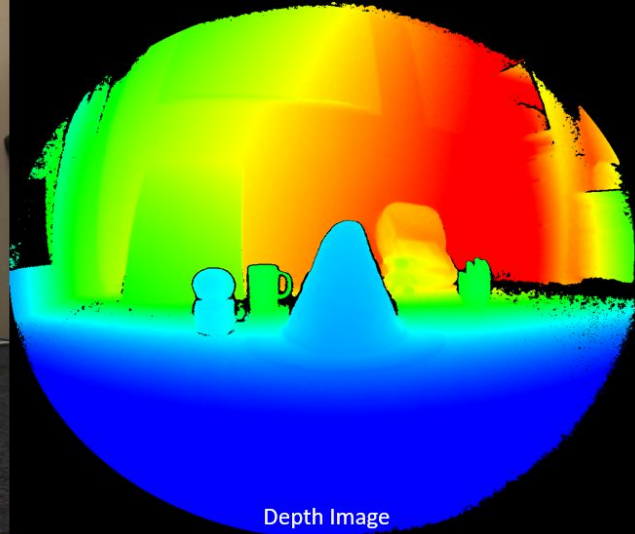
Stereo vision



Time of Flight



Structured light sensor

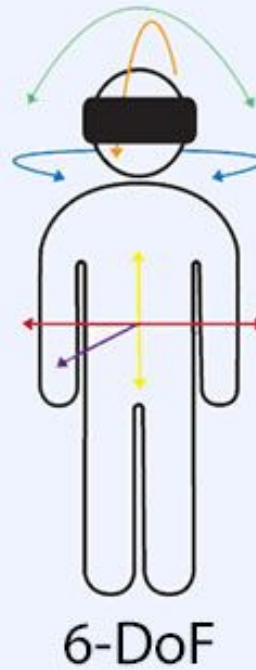
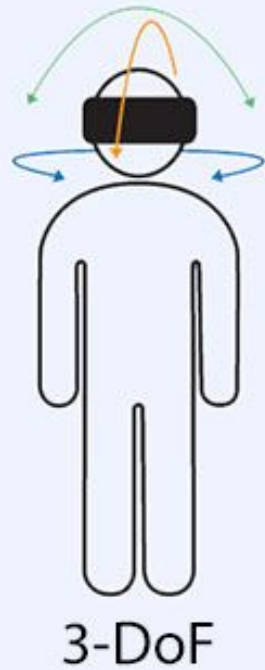


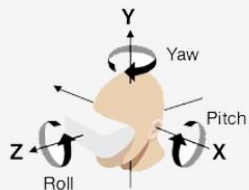


Not real time?



Degrees of Freedom (DoF)





oculus
Rift



acer DELL Lenovo hp
MR Systems



SAMSUNG
Odyssey



htc
Vive



htc
Vive Pro



6 DOF (3 DOF + X - T - Z)
Head orientation + **Walk around**
Full VR
Object-based audio

OS VR OSVR HDK 2



PlayStation.VR



Microsoft
HoloLens



htc
Vive Focus



oculus
Santa Cruz



Pico
Neo



oculus
Go



Pico
Goblin



SAMSUNG
Gear VR



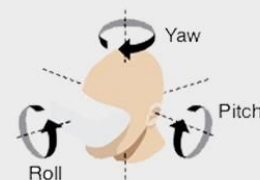
LG
LG 360 VR



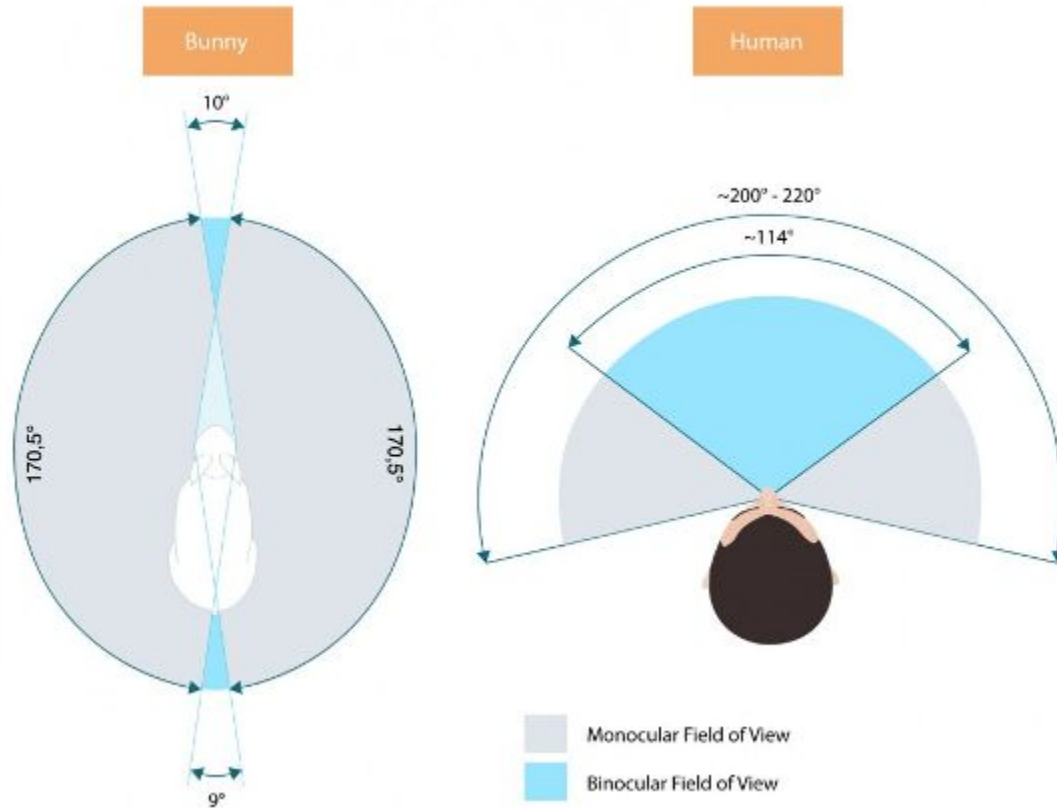
Pimax
Pimax 4K



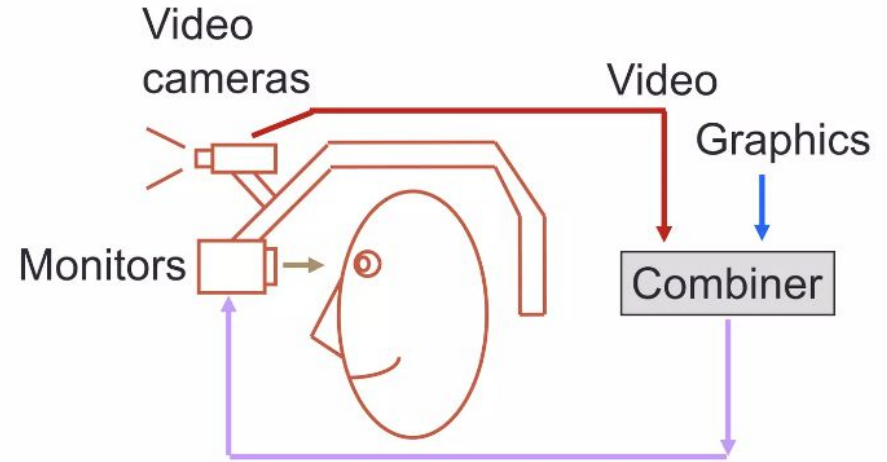
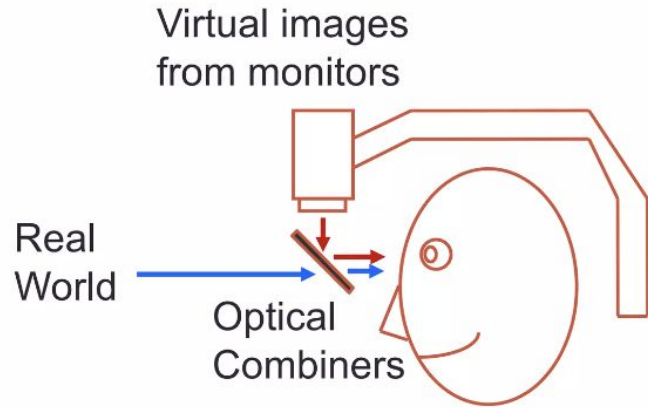
3 DOF (Yaw - Pitch - Roll)
Head orientation only
360 Video
Ambisonics



Field of View (FOV)



Optical vs Video see-through



Optical see-through



Hololens 2



Magic Leap 2



EPSON BT-200

Video see-through



Meta Quest 3

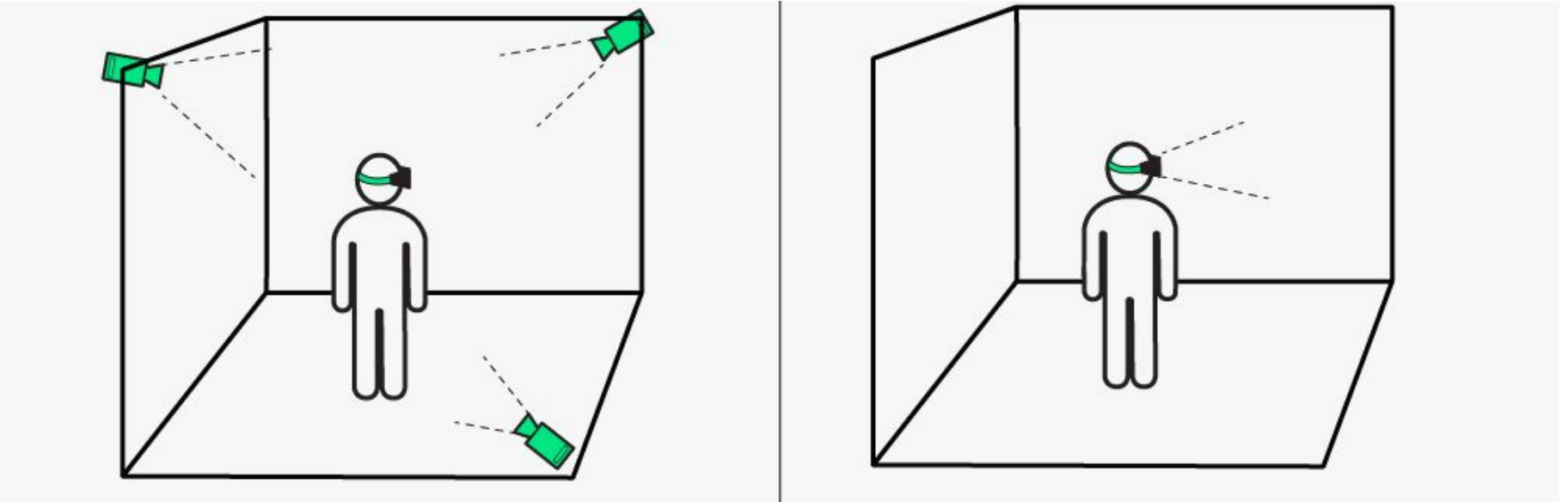


Varjo XR-4



Apple VisionPro

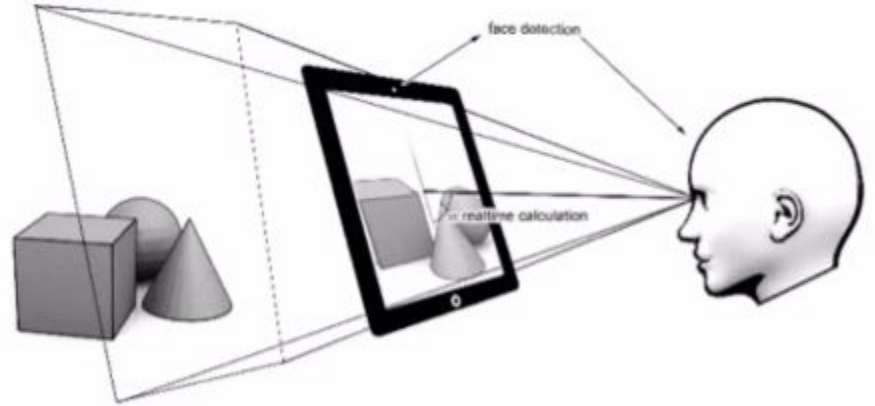
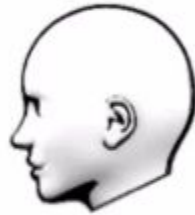
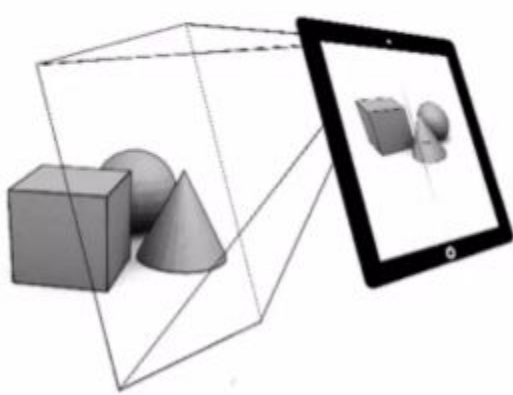
Outside-in vs Inside-out Tracking



Handheld AR



Device vs User Perspective Rendering

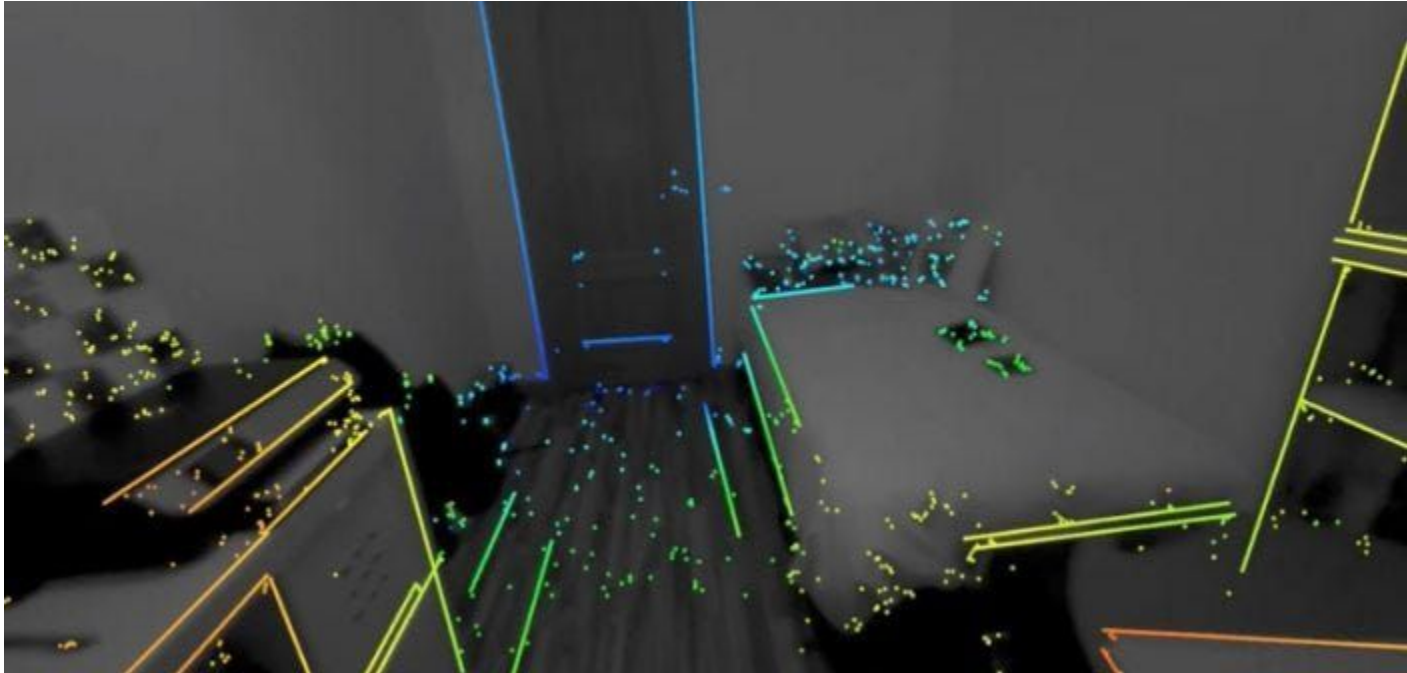


Mirror AR



Vision-based Tracking

SLAM – Simultaneous Localization and Mapping



Diminished reality: blurring virtual and physical objects



Kari, M., Schütte, R., & Sodhi, R. (2023, October). Scene Responsiveness for Visuotactile Illusions in Mixed Reality. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology* (pp. 1-15).

AR/VR Tools

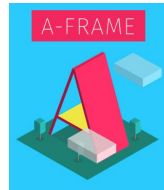
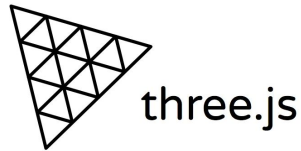
Digital & Immersive Authoring



Cross-platform Development



Web-based Development



Native Development

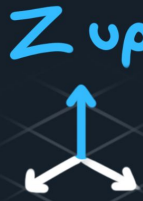


android
studio



Left vs Right

Created by
@FreyaHolmer
poor lol unreal :o



Affordance

Affordances

“... the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used...”

...Affordances provide strong clues to the operations of things.”

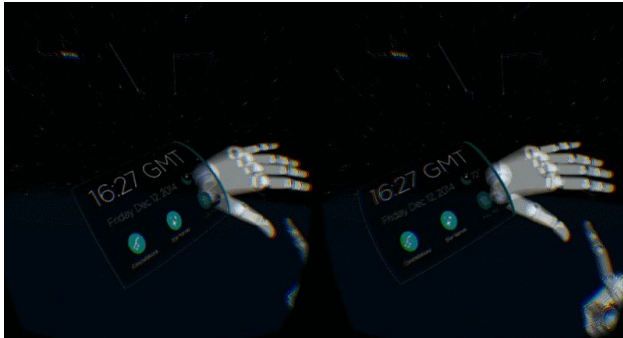
(Norman, The Psychology of Everyday Things, 1988)

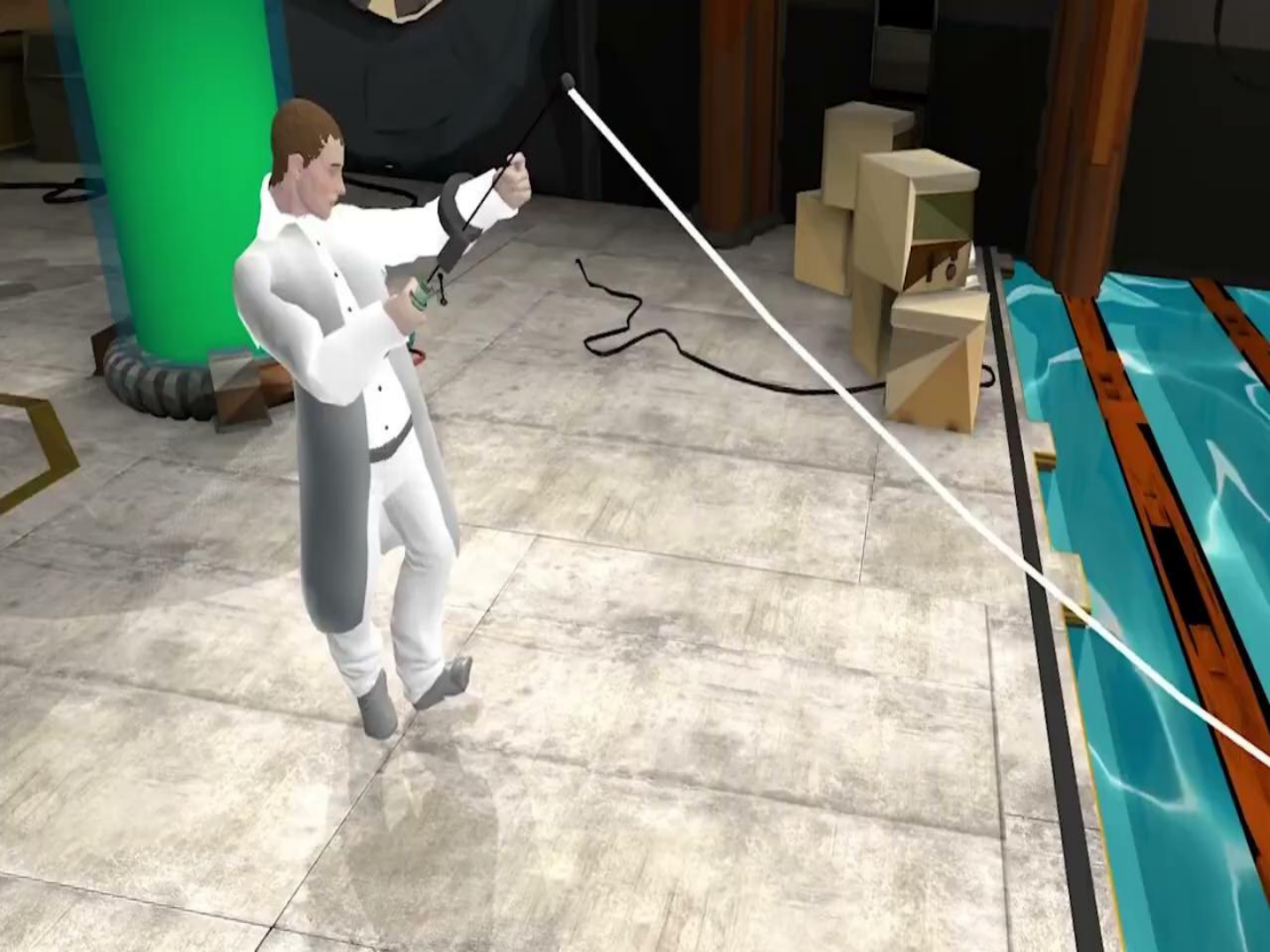


Affordances in VR

Design interface objects to show how they are used

- Use visual cues to show possible affordances
- Perceived affordances should match actual affordances
- Good cognitive model – map object behaviour to expected behaviour





Mutual Human Actuation

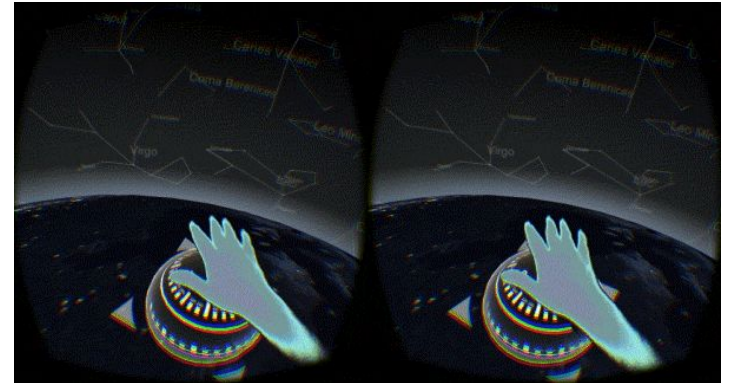
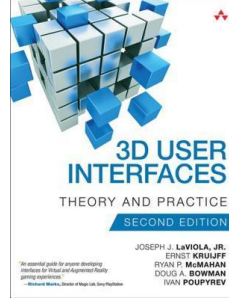
3D Interaction

3D User Interfaces

- User interfaces for VR systems
- Need good 3D UI guidelines

But 3D interaction is difficult

- Needs spatial input
- Interface layout more complex
- Lack of constraints, precision
- Lack of standards, tools
- User fatigue, perception needs
- Endless possibilities...



Universal 3D Interaction Tasks in VR

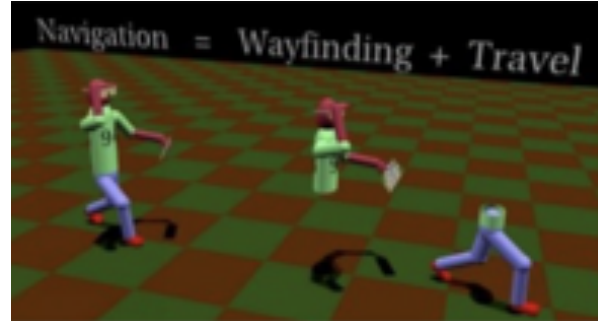
Object Interaction

- Selection: Picking object(s) from a set
- Manipulation: Modifying object properties



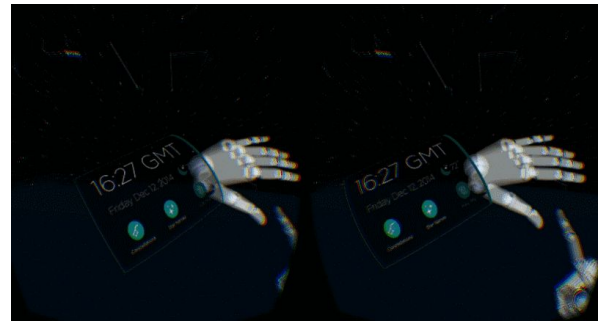
Navigation

- Travel: motor component of viewpoint motion
- Wayfinding: cognitive component; decision-making



System control

- Issuing a command to change system state or mode



Object Interaction

Selection and Manipulation

Selection

- Specifying one or more objects from a set

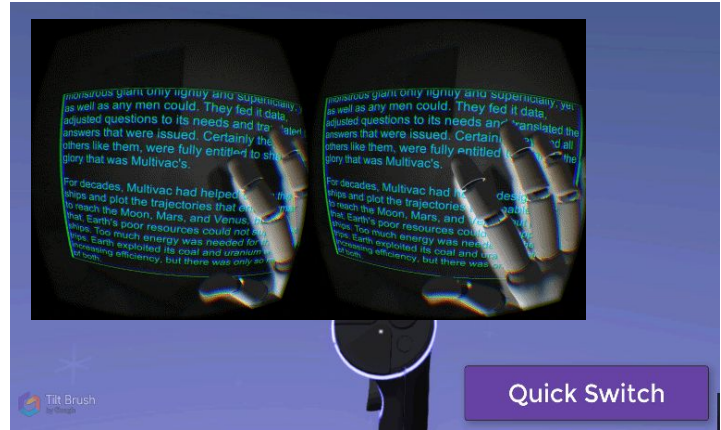
Manipulation

- Modifying object properties: position, orientation, scale, shape, color, texture, behaviour...



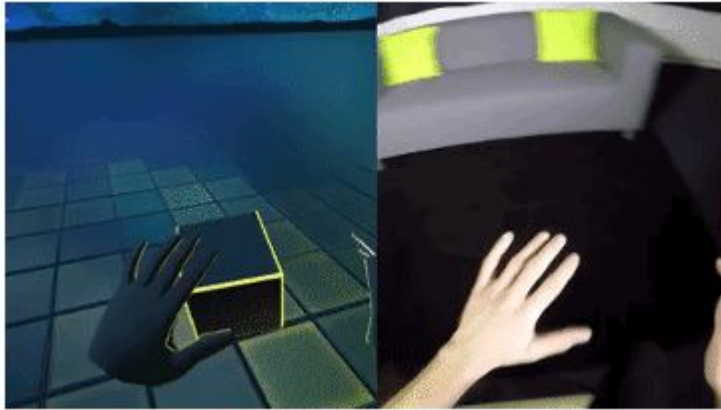
Goal of selection

- Indicate action on object
- Query object
- Make object active
- Travel to object location
- Set up manipulation



Common Selection Techniques

- Virtual hand



- Occlusion

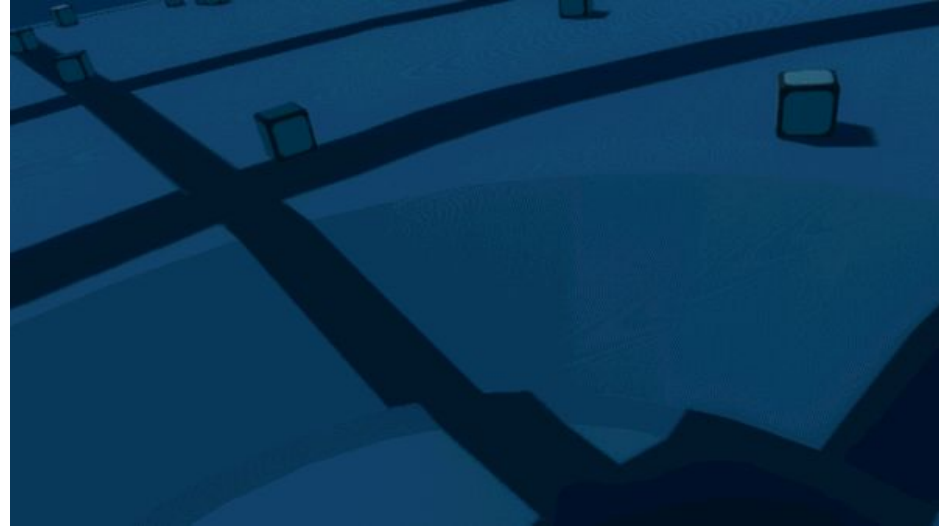


Common Selection Techniques

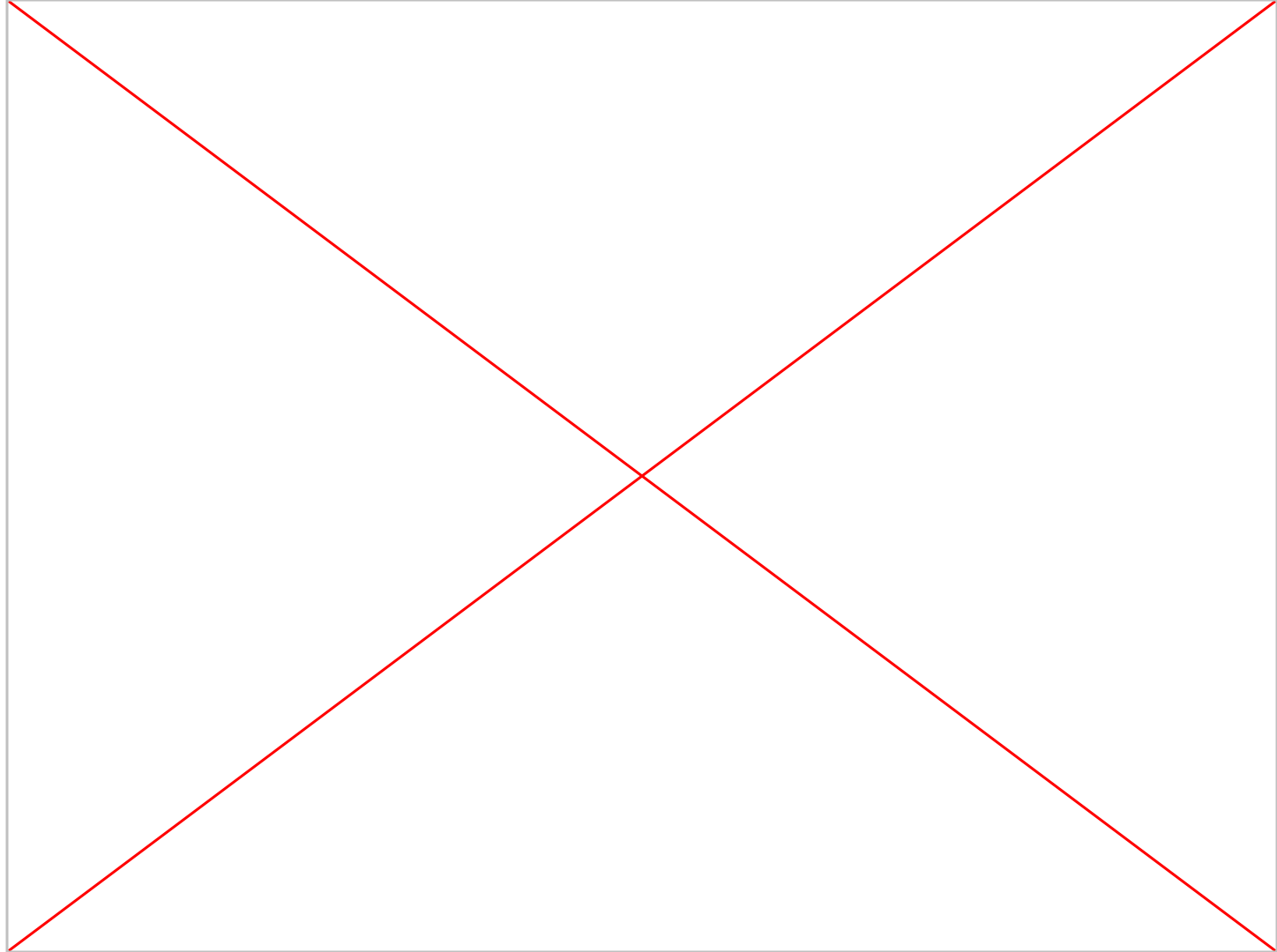
- Ray-casting



- Go-Go (arm-extension)



Go-Go



Goal of Manipulation

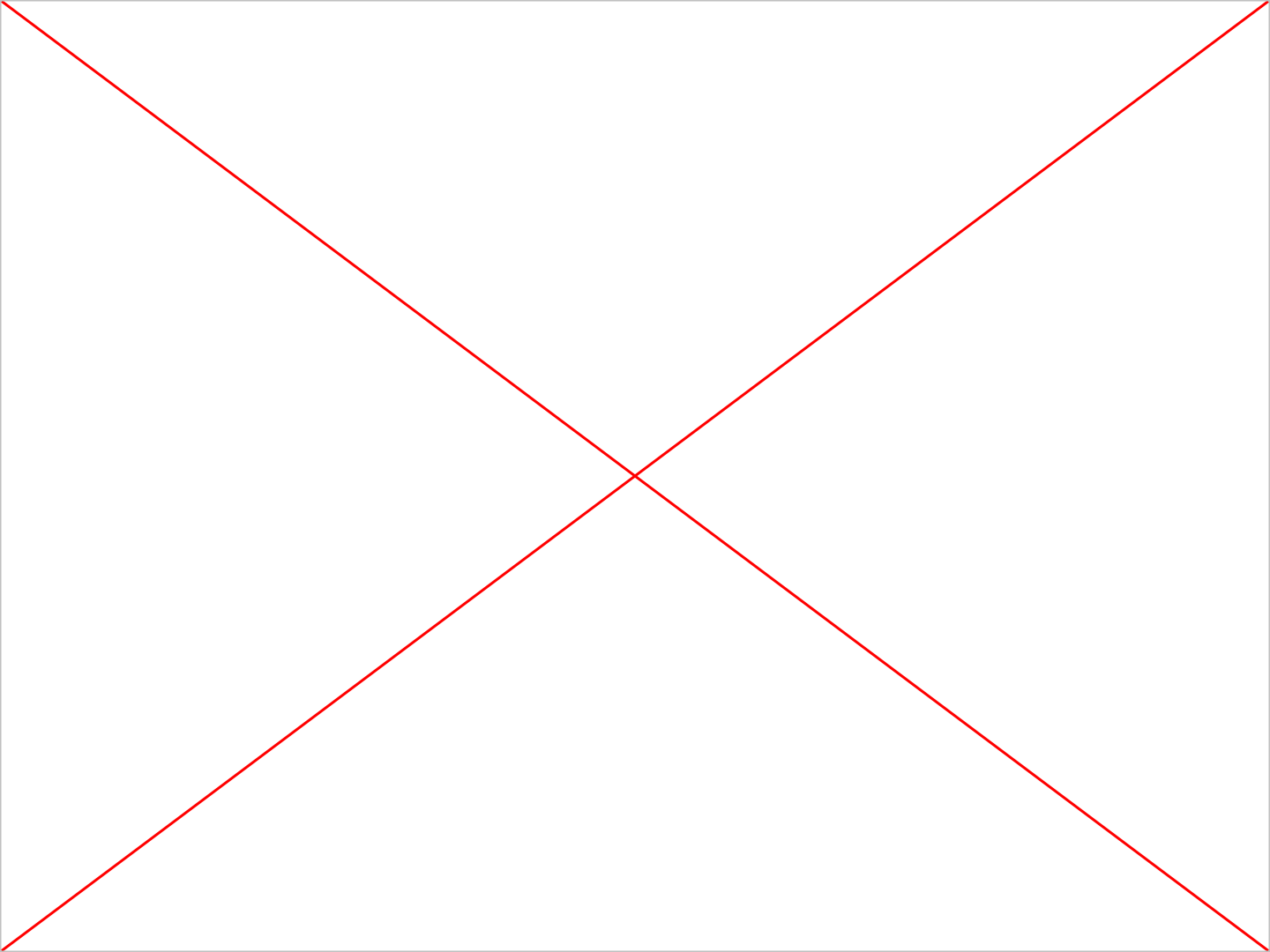
Object placement

- Design
- Layout
- Grouping

Tool usage

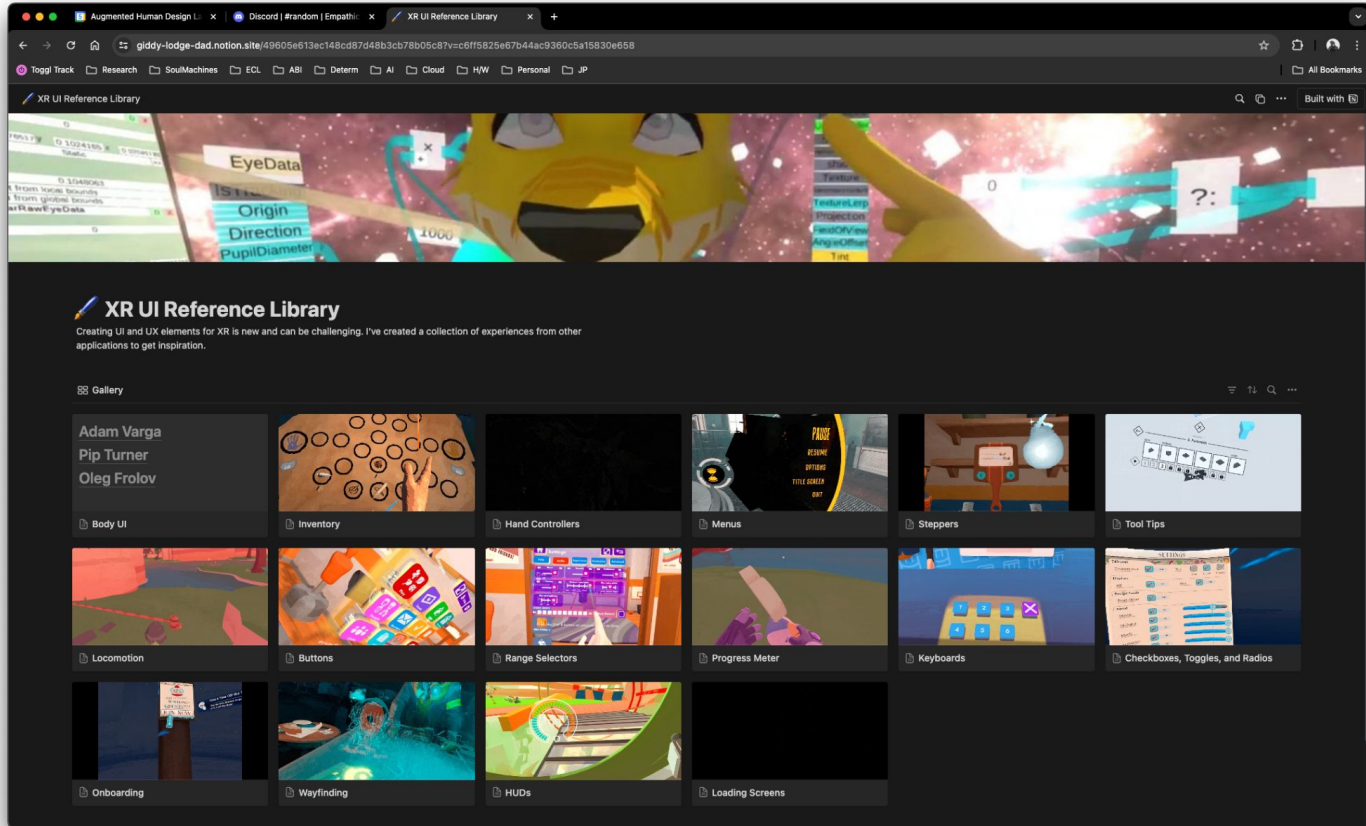
Travel





Manipulation in HolLens

XR UI Reference Library



<https://giddy-lodge-dad.notion.site/49605e613ec148cd87d48b3cb78b05c8?v=c6ff5825e67b44ac9360c5a15830e658>

Scaled-world



HOMER

Hand-Centered
Object
Manipulation
Extending
Ray-Casting

- Selection:
ray-casting
- Manipulate: directly
with virtual hand



Snow Dome

Snow Dome: A Multi-Scale Interaction in Mixed Reality Remote Collaboration

Thammathip Piumsomboon, Gun A. Lee and Mark Billingham

University of South Australia, Adelaide, Australia





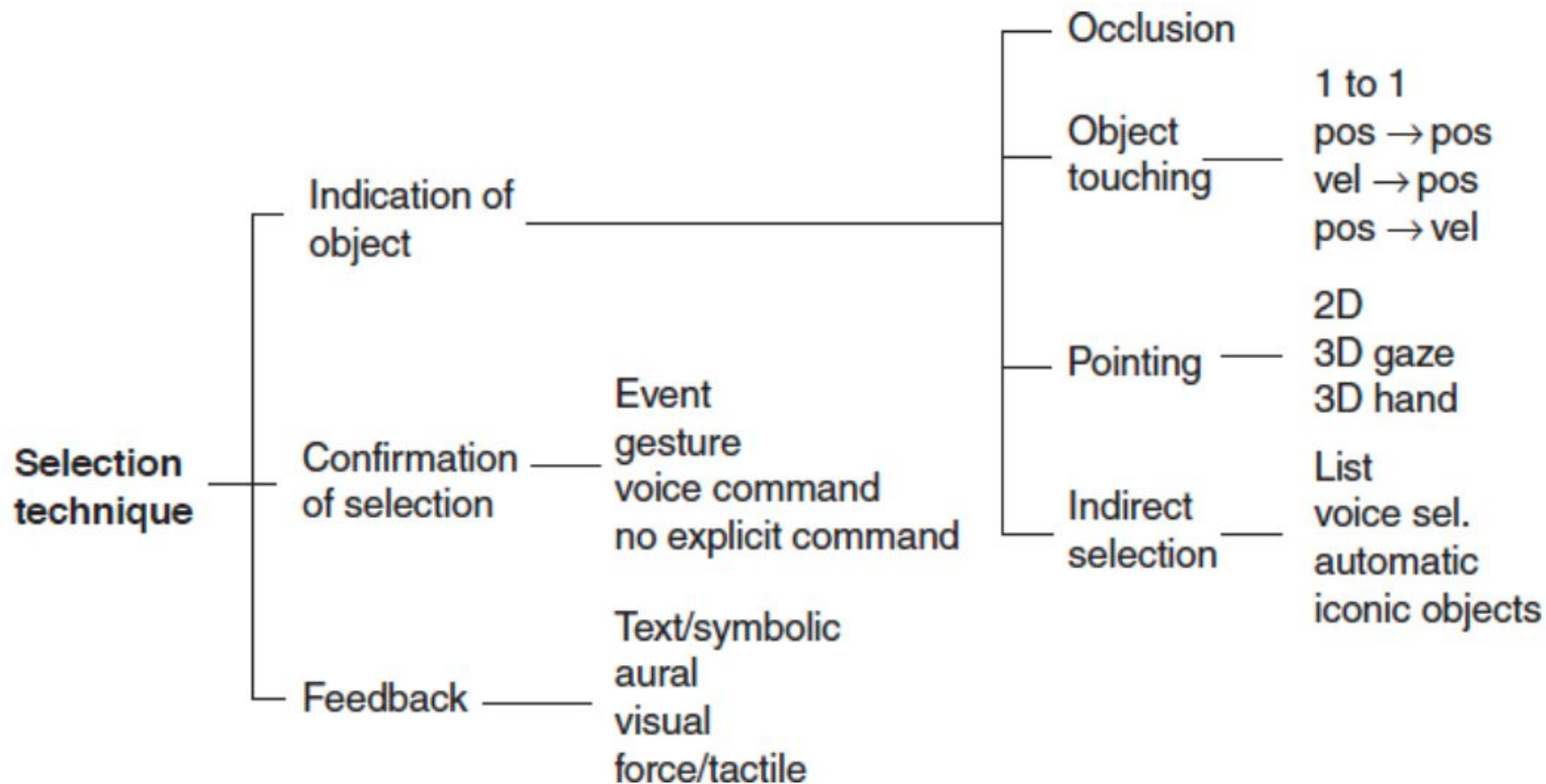
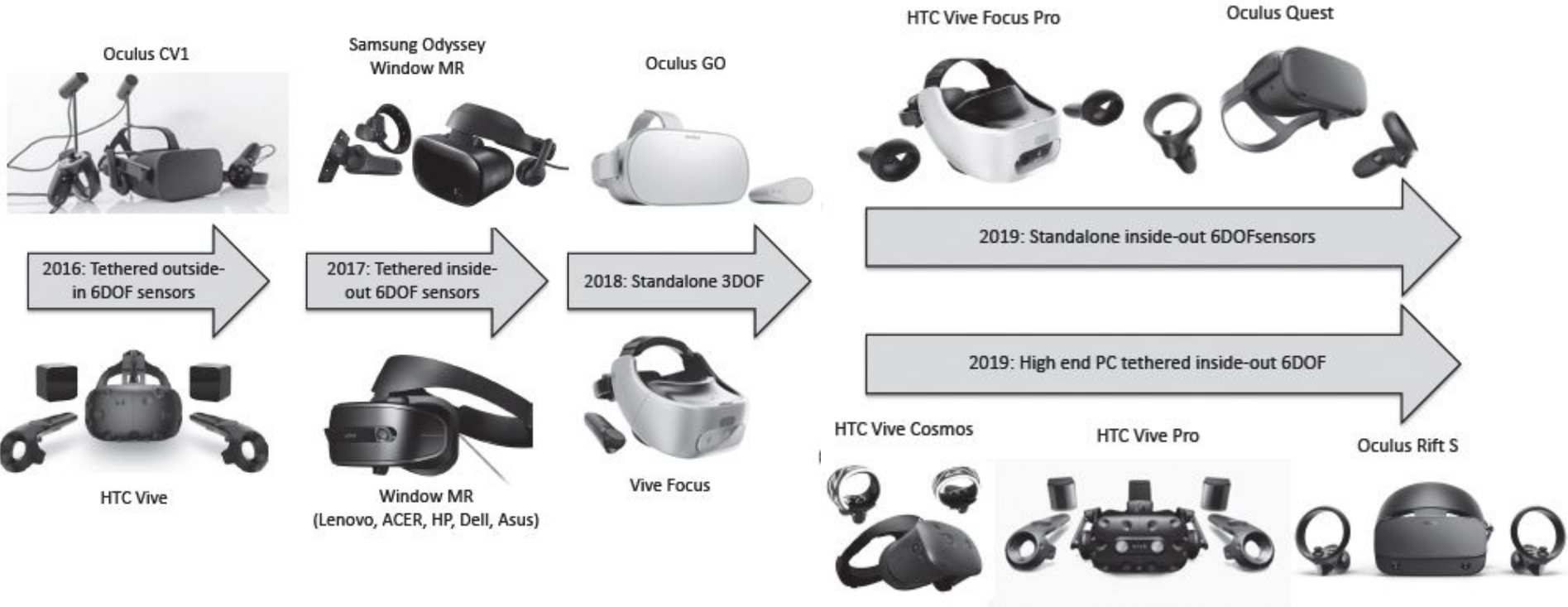


Figure 7.2 Classification of selection techniques by task decomposition.

Navigation

Tethered vs Standalone



Travel

The motor component of navigation

Movement between 2 locations, setting the position (and orientation) of the user's viewpoint

The most basic and common VE interaction technique, used in almost any large-scale VE



Types of Travel

Exploration

- No explicit goal for the movement

Search

- Moving to specific target location
 - Naïve – target position not known
 - Primed – position of target known

Manoeuvring

- Short, precise movements changing viewpoint



Locomotion

Physical locomotion metaphors

- Treadmills, cycles, etc...

Steering metaphor

Route planning metaphor

Target specification metaphor

Manual manipulation metaphor

Scaling metaphor



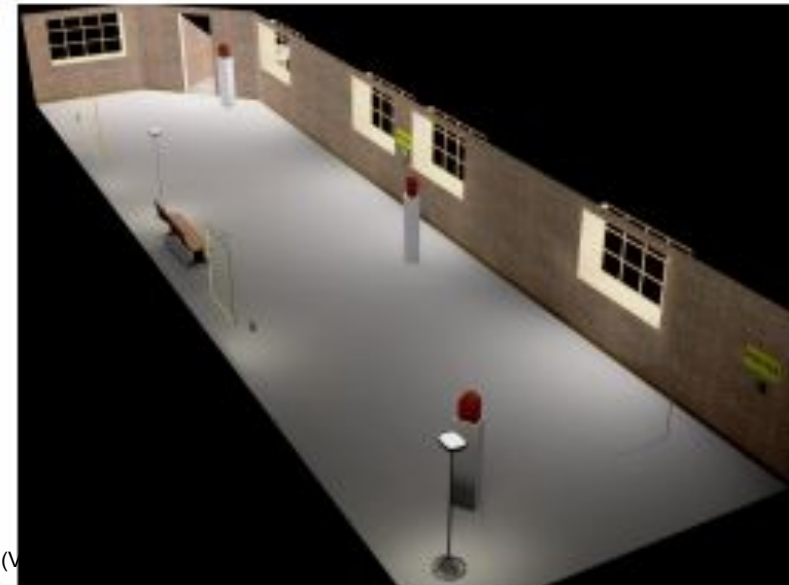
Virtuix

Bull Runner



Redirected Walking (RDW)

- RDW fundamentally manipulates human spatial perception below the conscious threshold.
- Translation and Rotation Manipulation: Scaling virtual movement non-linearly against physical movement (e.g., 5° physical = 7.5° virtual).
- Path Redirection: Subtly guiding users away from physical boundaries



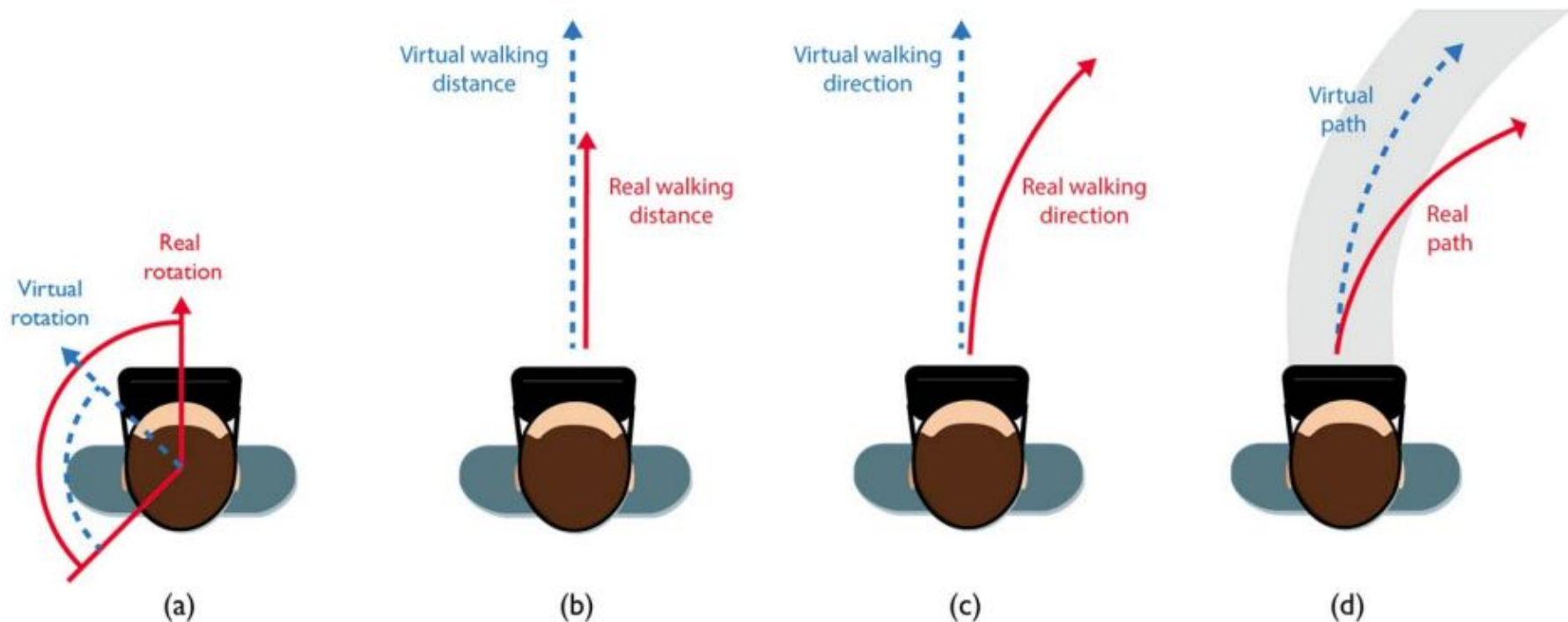
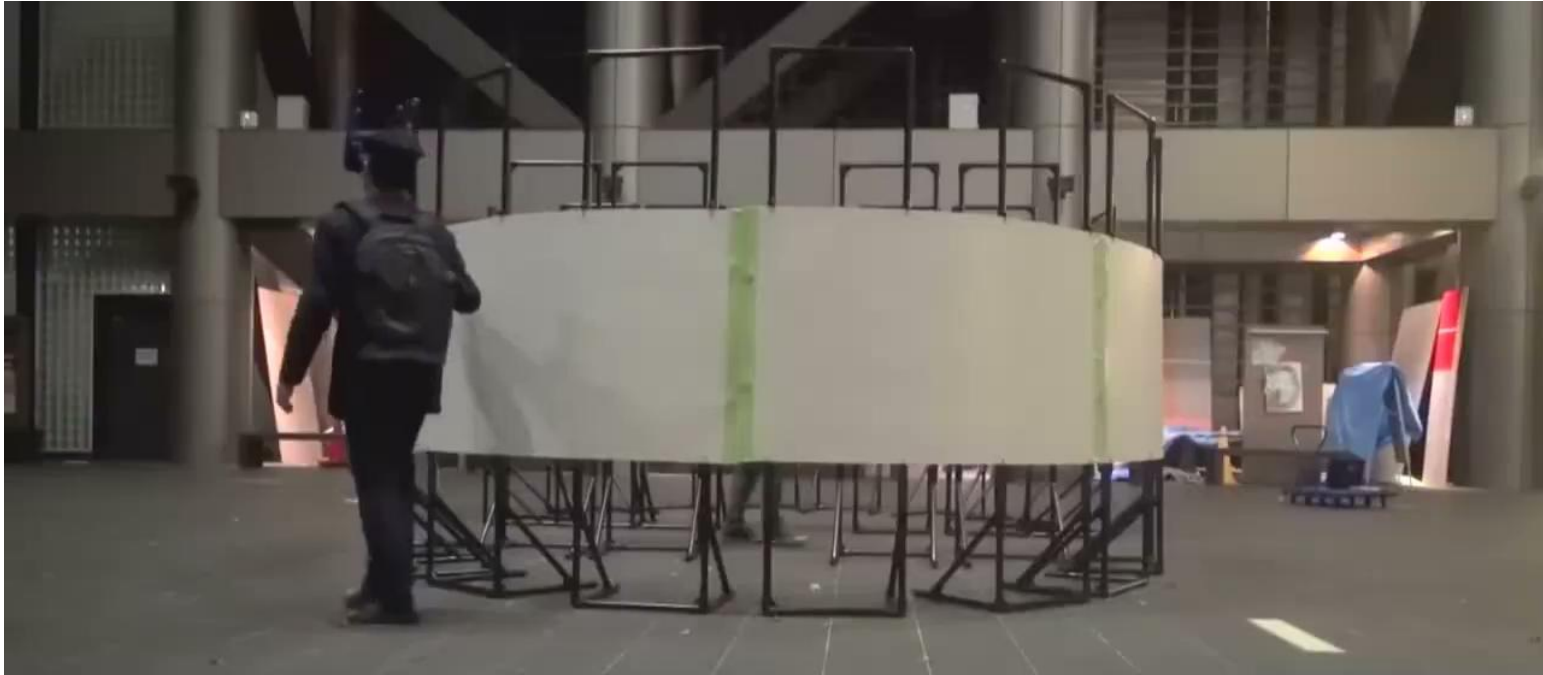


Figure 1. Illustration of four types of gains used to manipulate the mapping between the user's real and virtual movement: (a) rotation gains (user stationary), (b) translation gains (user moving forward), (c) curvature gains (user moving forward), and (d) bending gains (user moving on a curve).

Redirected Walking with Walls



A Japanese firm has found a way to enable you to
walk long distances in Virtual reality.

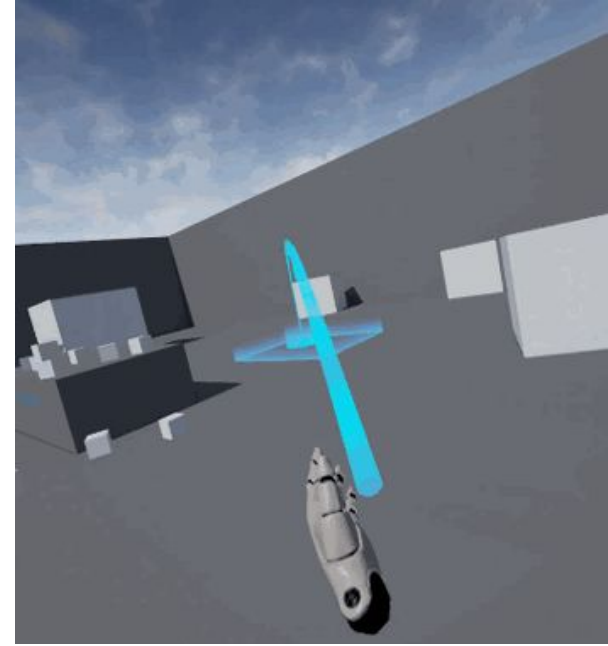
Teleportation

Use controller to select end point

- Usable with 3-DOF controller

Jump to a fixed point in VR

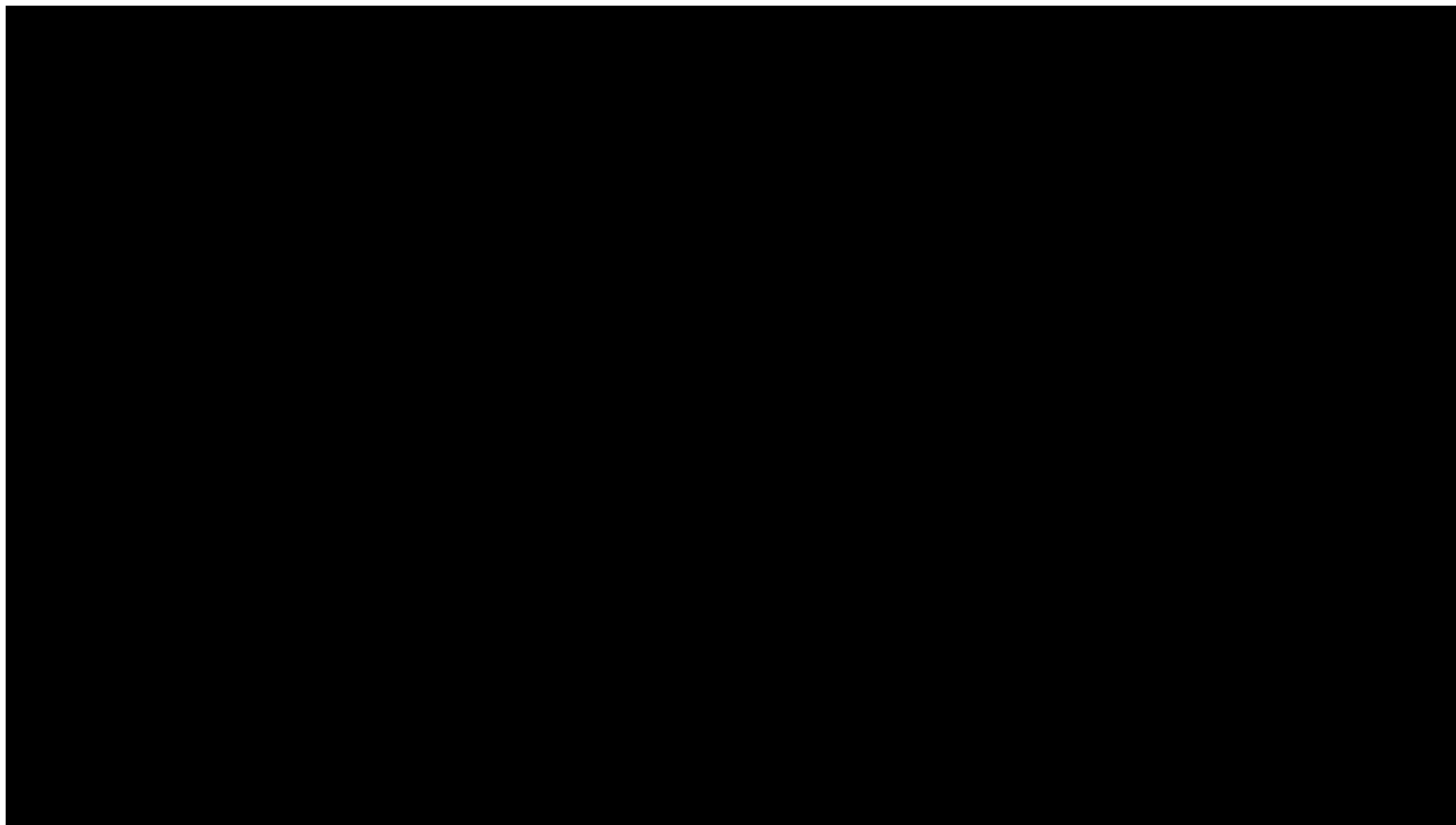
Discrete motion can be confusing/cause sickness



Locomotion: techniques



Half-Life: Alyx - Locomotion

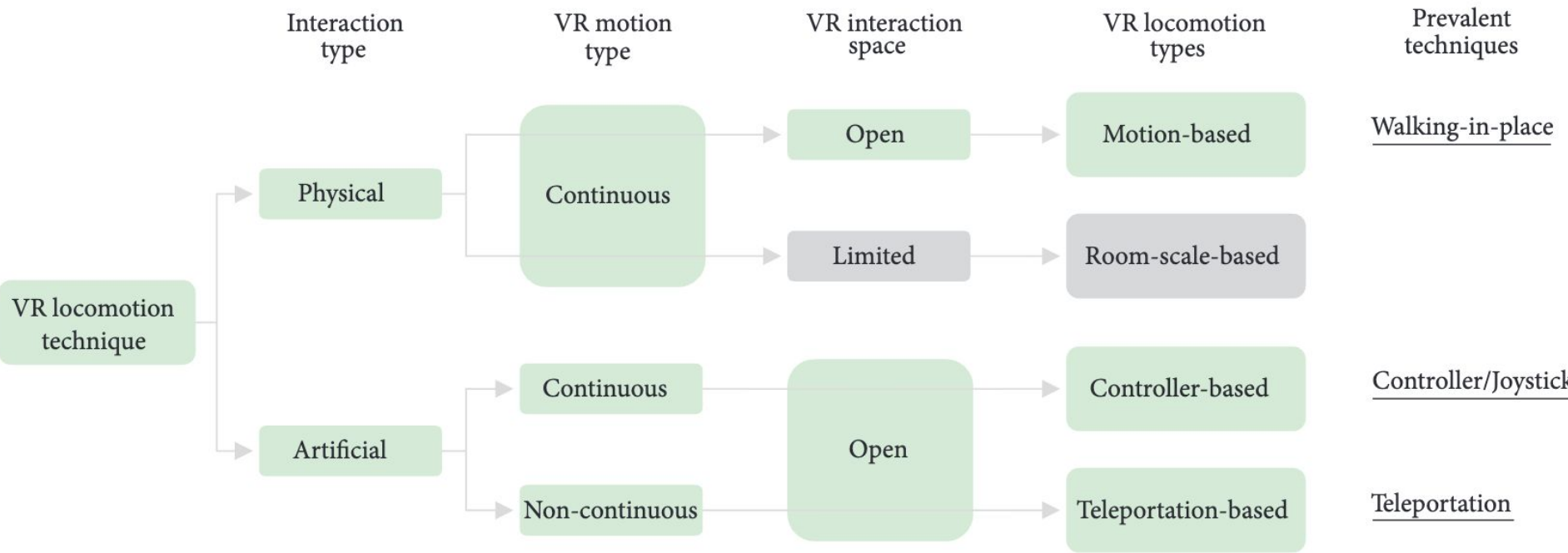


The Climb

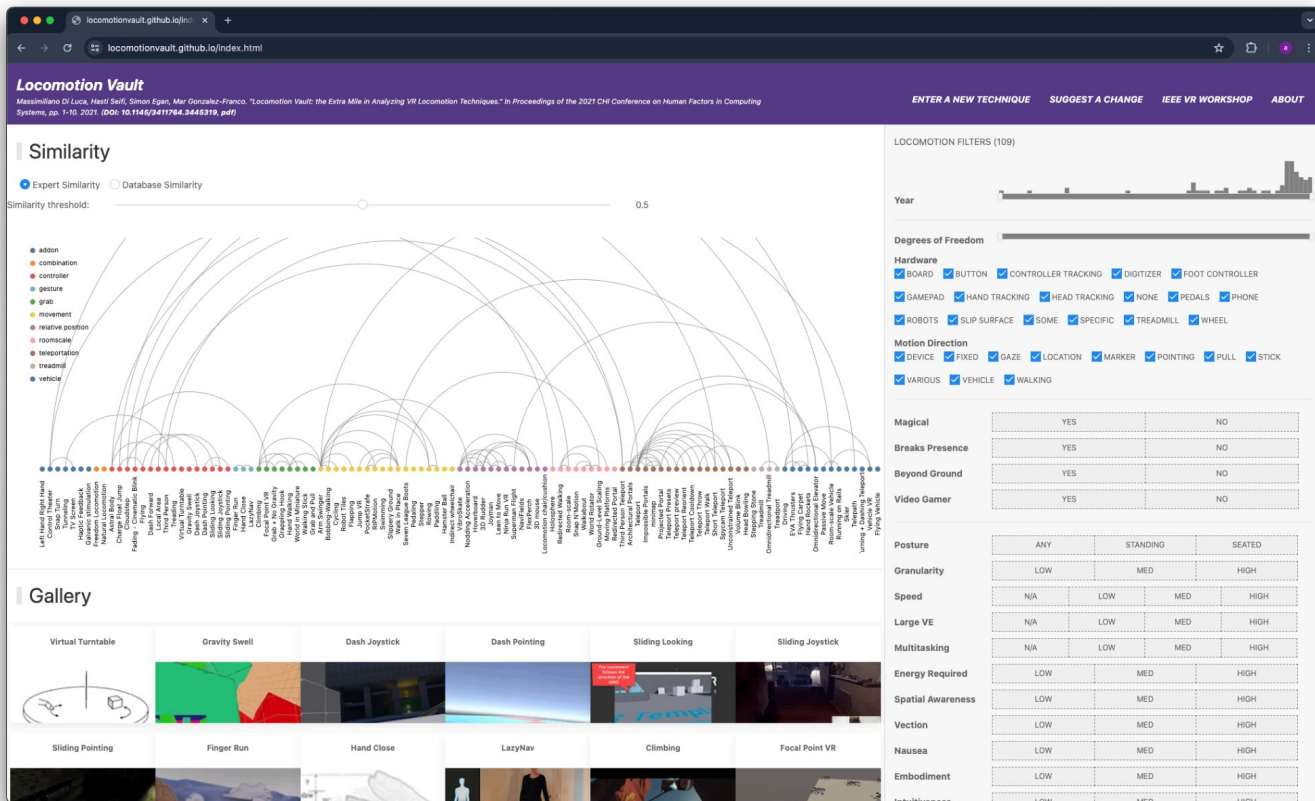


Eight360





<https://locomotionvault.github.io/index.html>



System Control

System Control

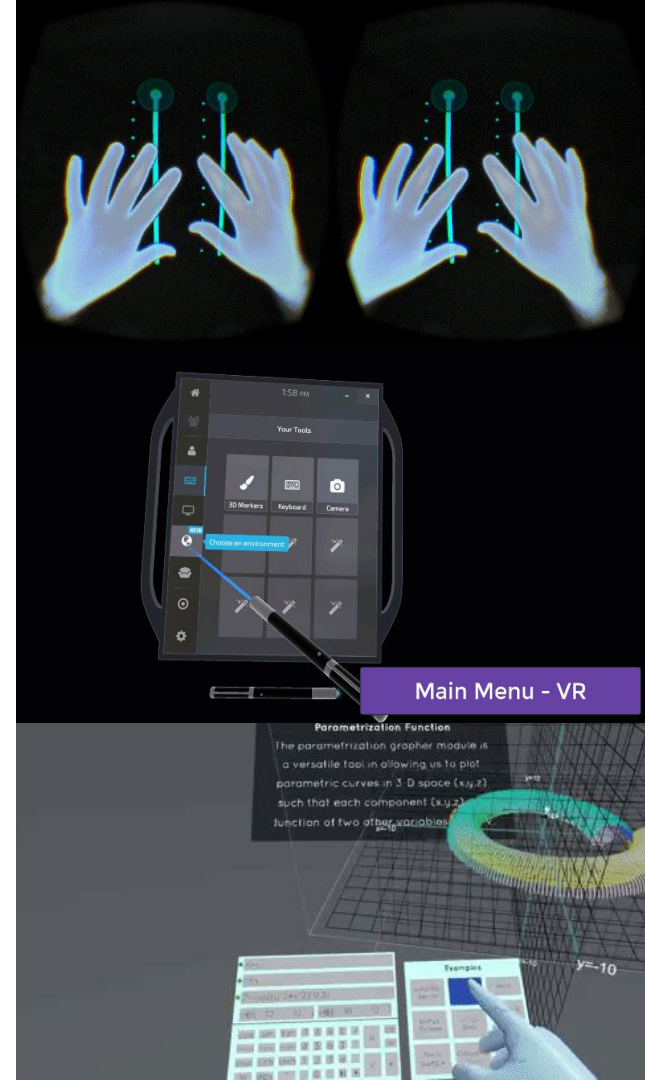
Issuing a command to change system state or mode.

E.g.

- Launching application
- Changing system settings
- Opening a file

Key points

- Make commands visible to user
- Support easy selection



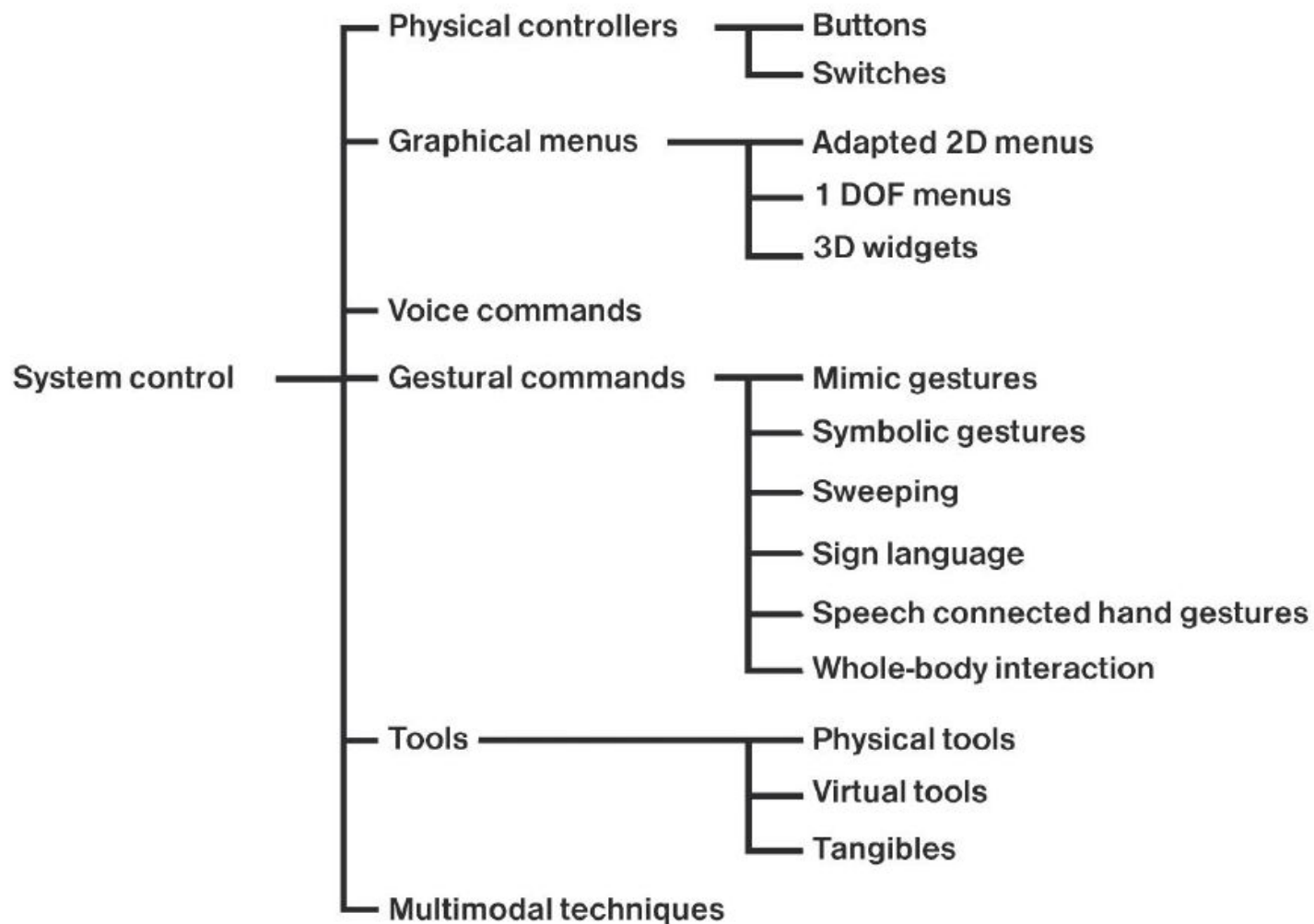


Figure 9.1 Classification of system control techniques.

Physical Control



Figure 9.2 A Thrustmaster flight joystick deploying numerous switches and buttons. (© Guillemot Corporation S.A. All rights reserved. Thrustmaster® is a registered trademark of Guillemot Corporation S.A.)

Graphical Menus

adapted 2D menus

1-DOF menus

3D widgets

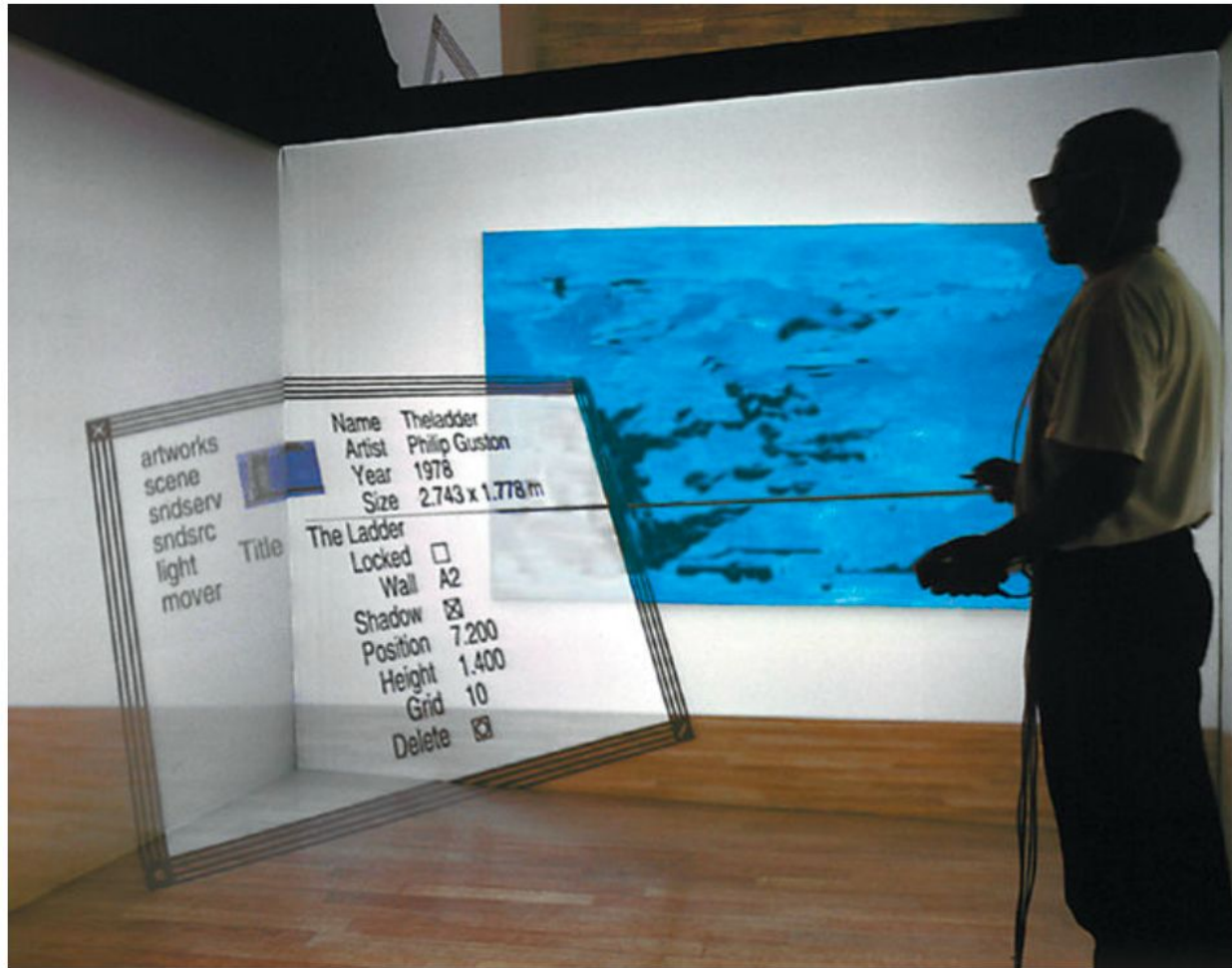
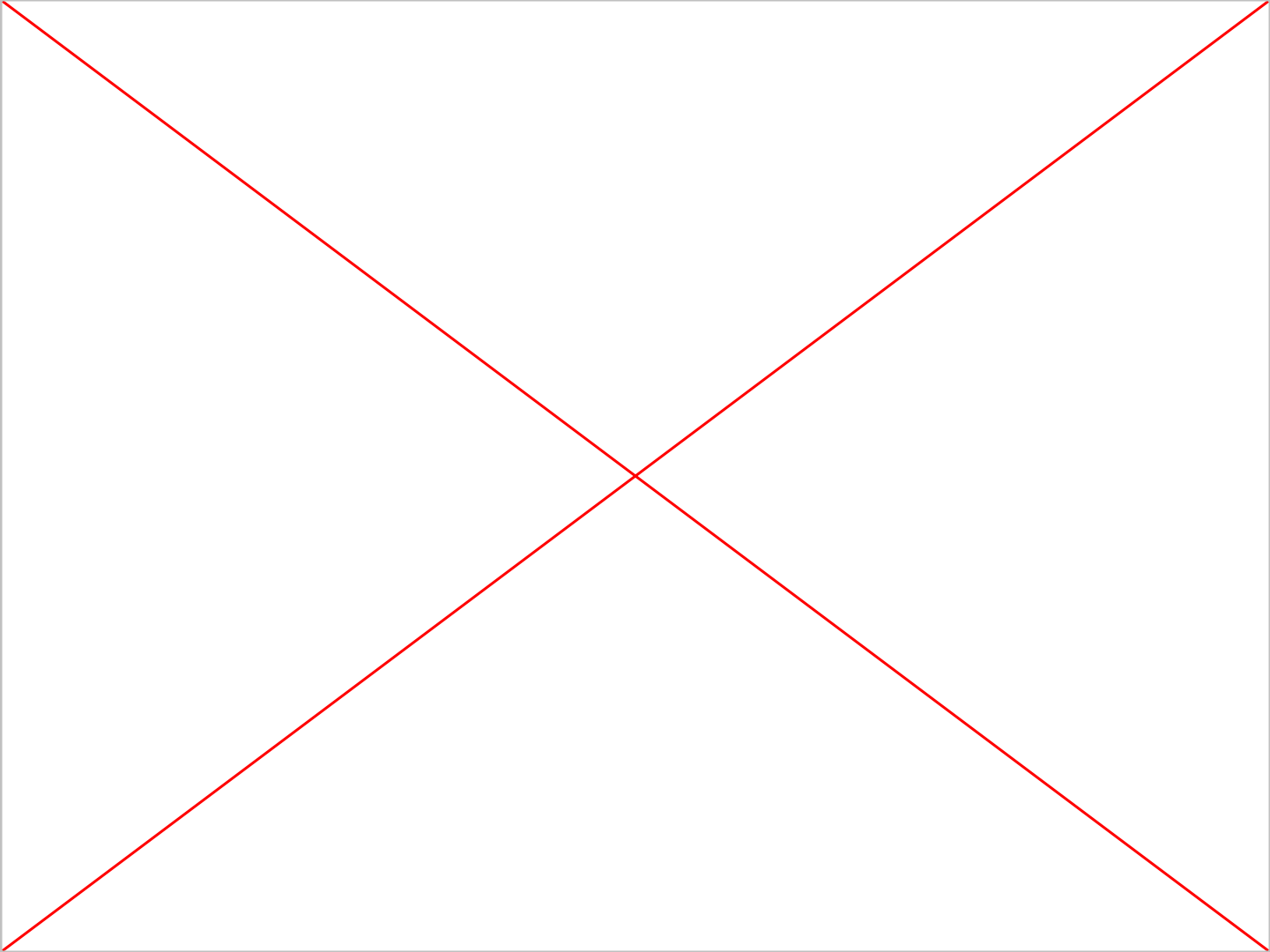


Figure 9.3 A floating menu in the Virtual Museum application.
(Photograph courtesy of Gerhard Eckel, Fraunhofer IMK)



Figure 9.4 Pie menu in immersive virtual environment.
(Photograph courtesy of Thorsten Kuhlen, Virtual Reality & Immersive Visualization Group, RWTH Aachen)

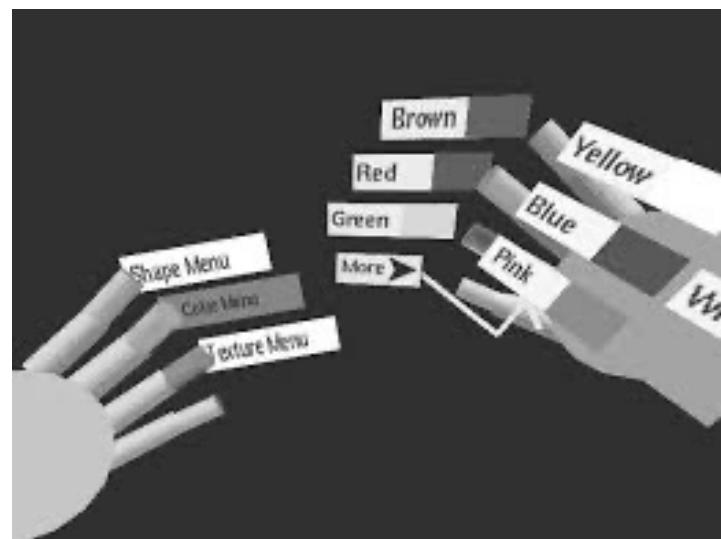
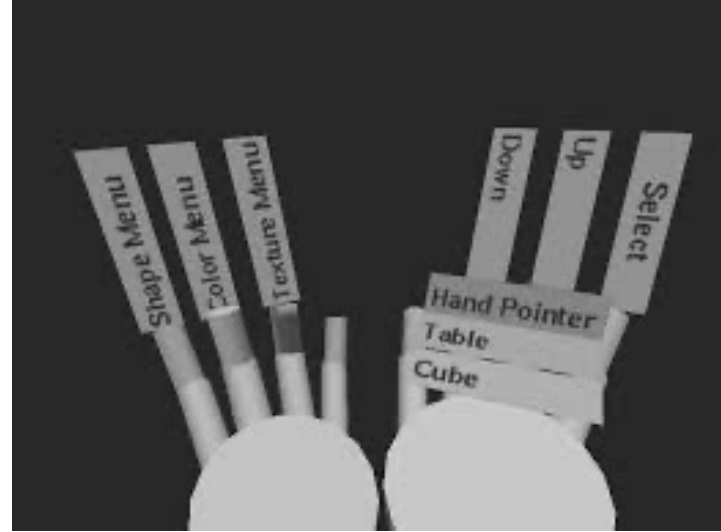


TULIP Menu

Menu items attached to virtual fingertips

Ideal for pinch glove interaction

Use one finger to select menu option from another



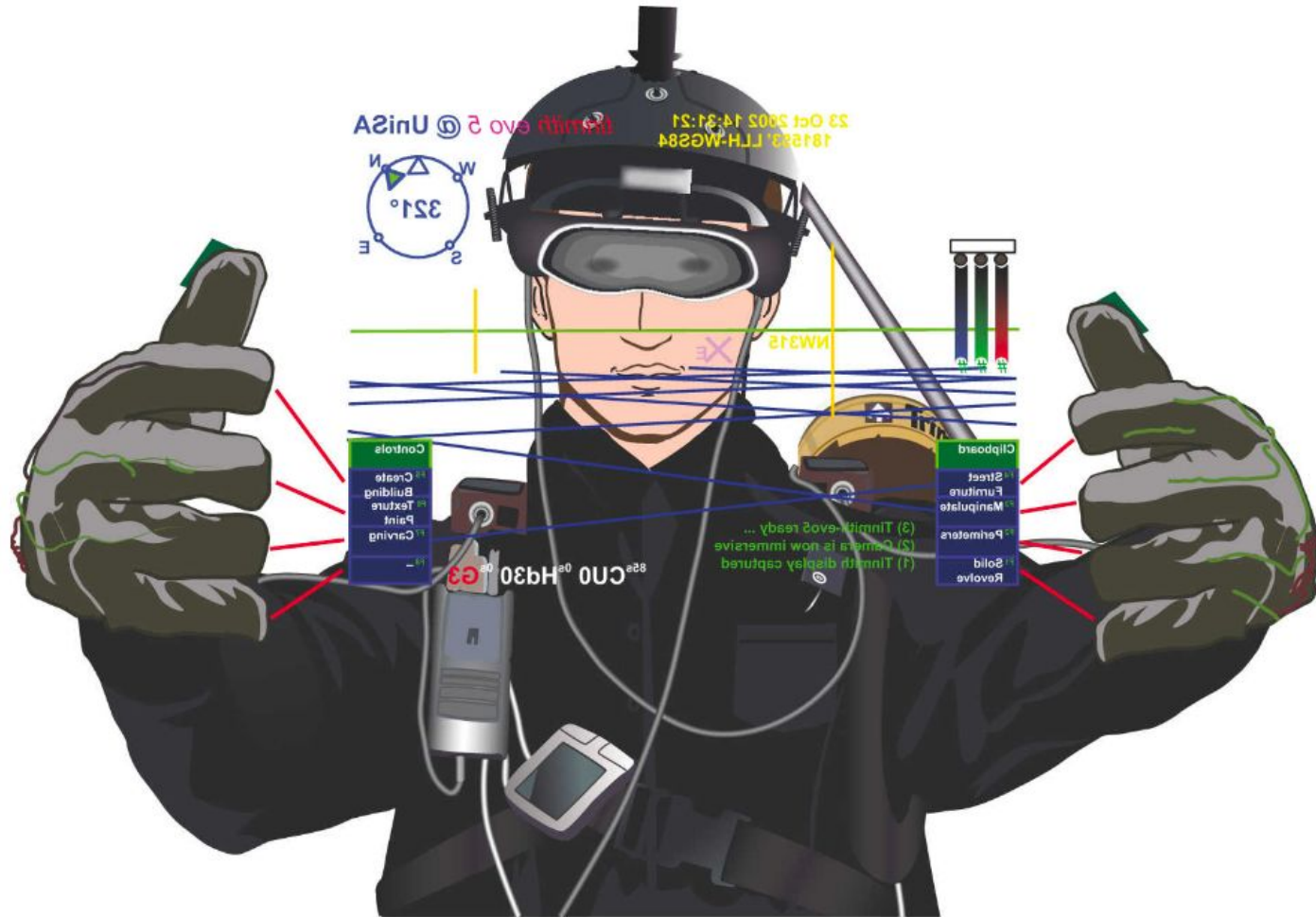


Figure 9.5 TINMITH menu using Pinch Gloves. (Adapted from Piekarski and Thomas 2003)

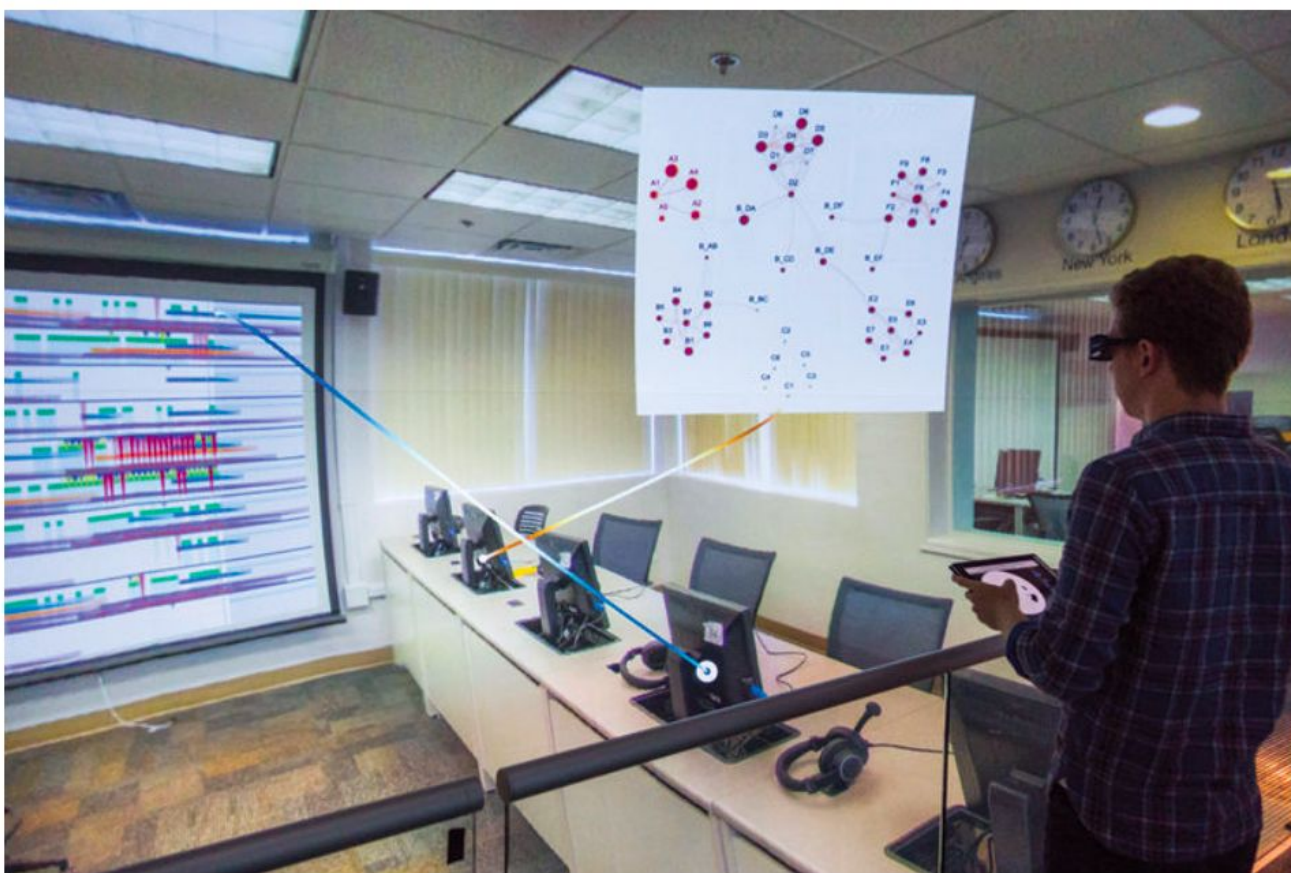


Figure 9.6 Tablet control of interactive visualizations layered on top of surround-view imagery in the UCSB Allosphere. Photograph shows left-eye view of stereo content viewed and controlled by the user. (Image courtesy of Donghao Ren and Tobias Höllerer)

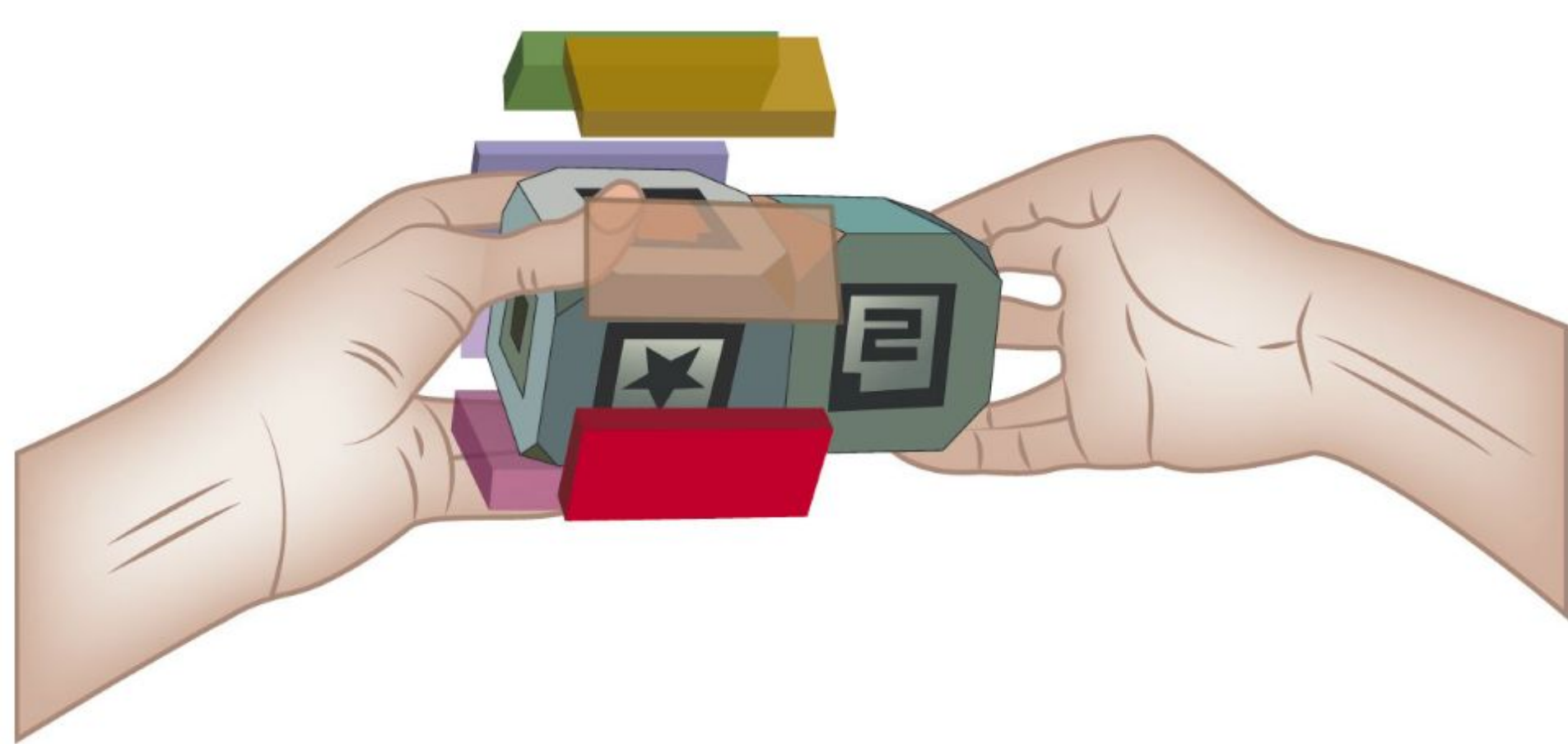


Figure 9.7 Ring menu implemented with tangible skin cubes.
(Adapted from Lee and Woo 2010)

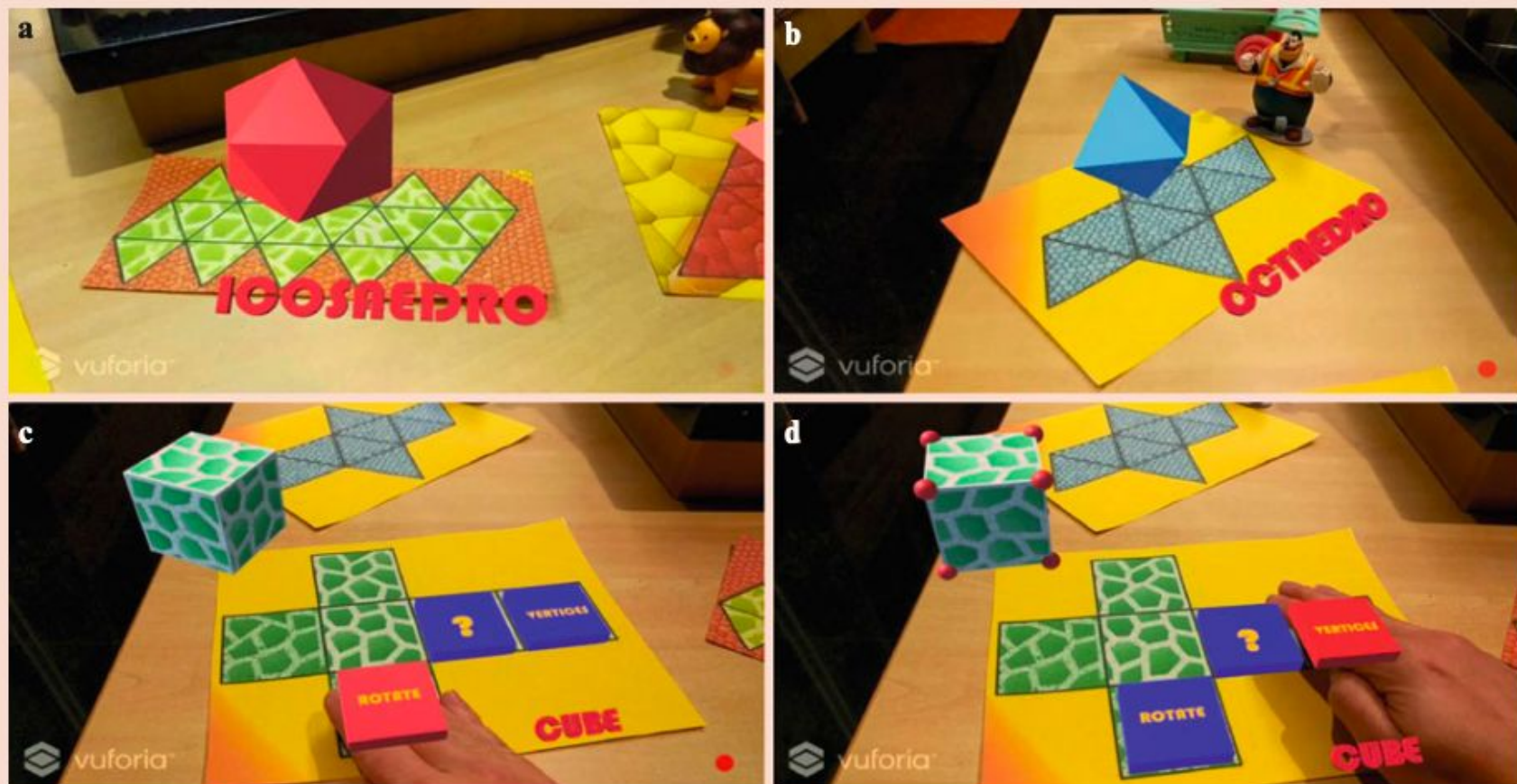


Fig. 15.4 The platonic solids Icosaedro (a) and Octaedro (b) with respective markers; representations with the virtual buttons for rotating (c) and for displaying the vertices (d) printed bottom (red) active mode.

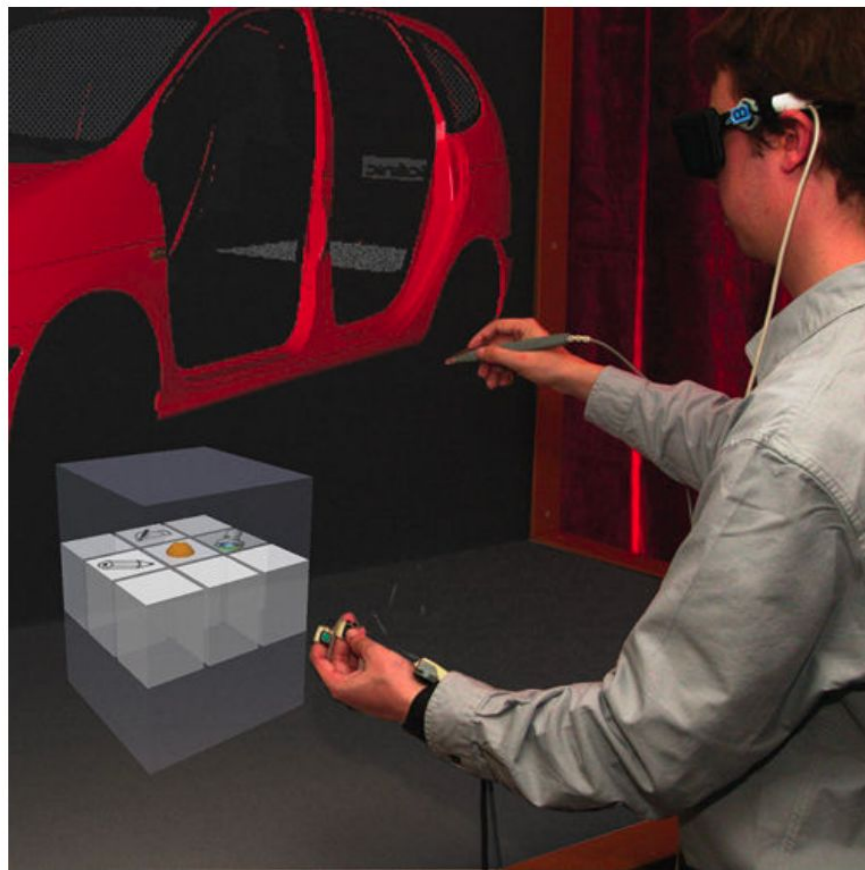


Figure 9.9 The command and control cube. (i3D-INRIA. Data © Renault. Photograph courtesy of Jerome Grosjean)



Figure 9.10 Legibility with different backgrounds in augmented reality. This mockup image shows several frequently occurring issues: the leader line of label 1 (right) is difficult to see due to the light background, whereas label 2 (left) can be overlooked due to the low color contrast with the blue sign behind and above it. Label 3 can barely be read, as the label does not have a background color. While this reduces occlusion, in this case legibility is low due to the low contrast and pattern interferences of the background.

(Image courtesy of Ernst Kruijff)



Figure 26.2 Information and a visual representation of a non-tracked hand-held controller in the torso reference frame. (Courtesy of NextGen Interactions)



Figure 26.3 A simple transparent texture in the hand can convey the physical interface. (Courtesy of NextGen Interactions)

FIGURE 11-5:
thyssenkrupp's
take on a field
technician's
use of AR.





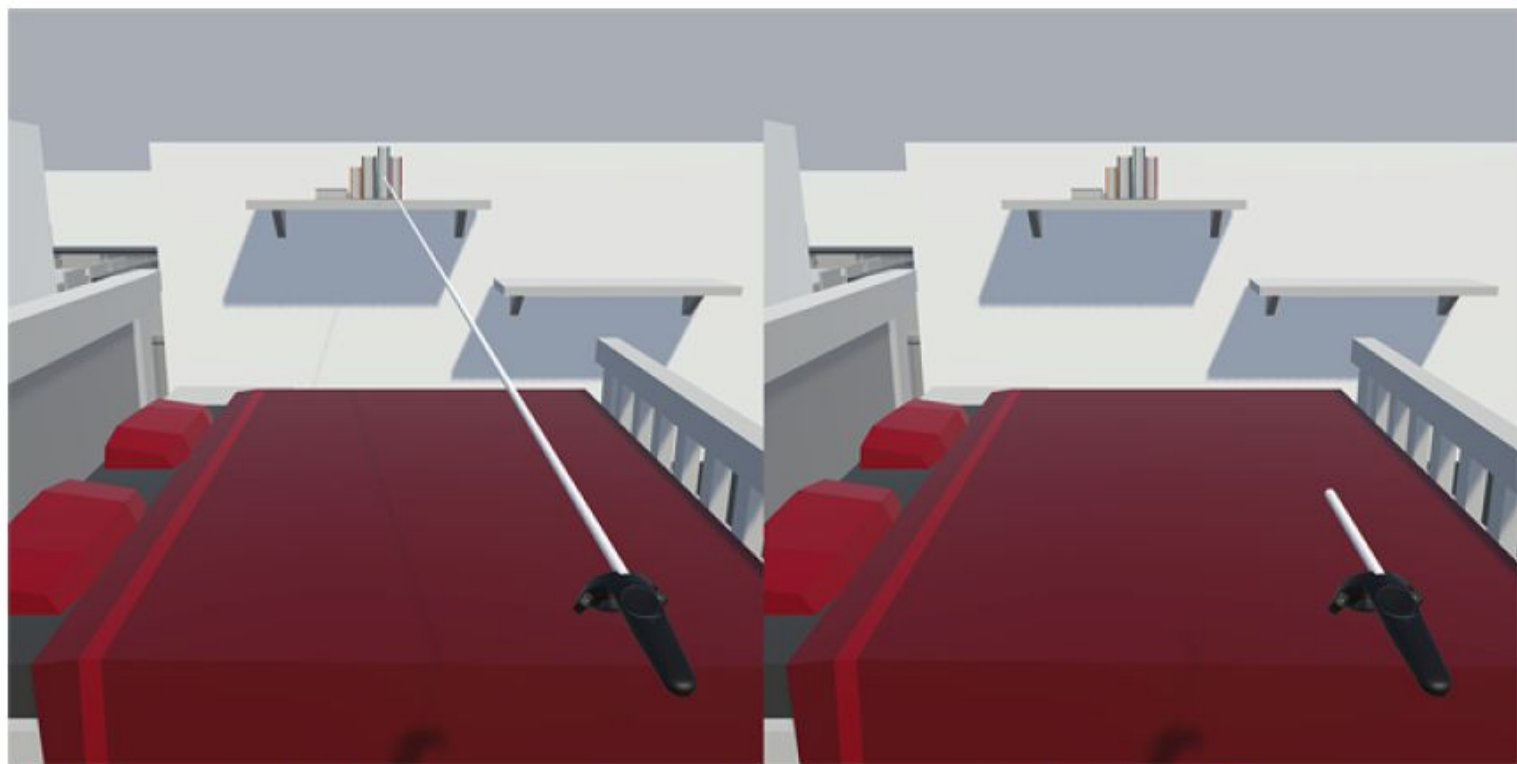
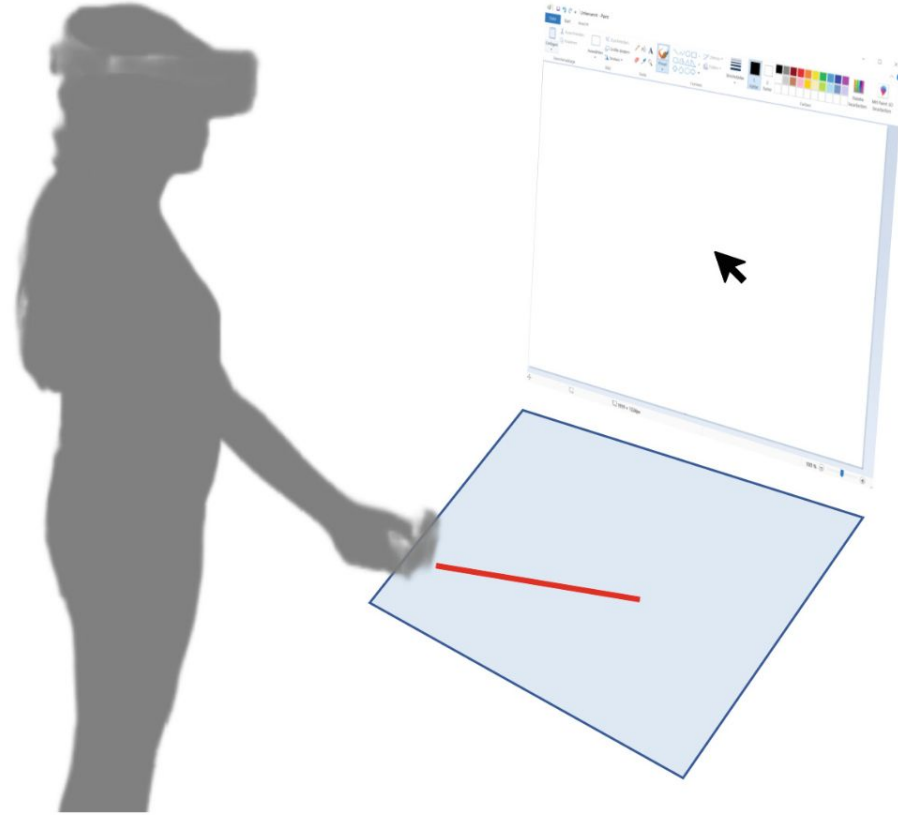
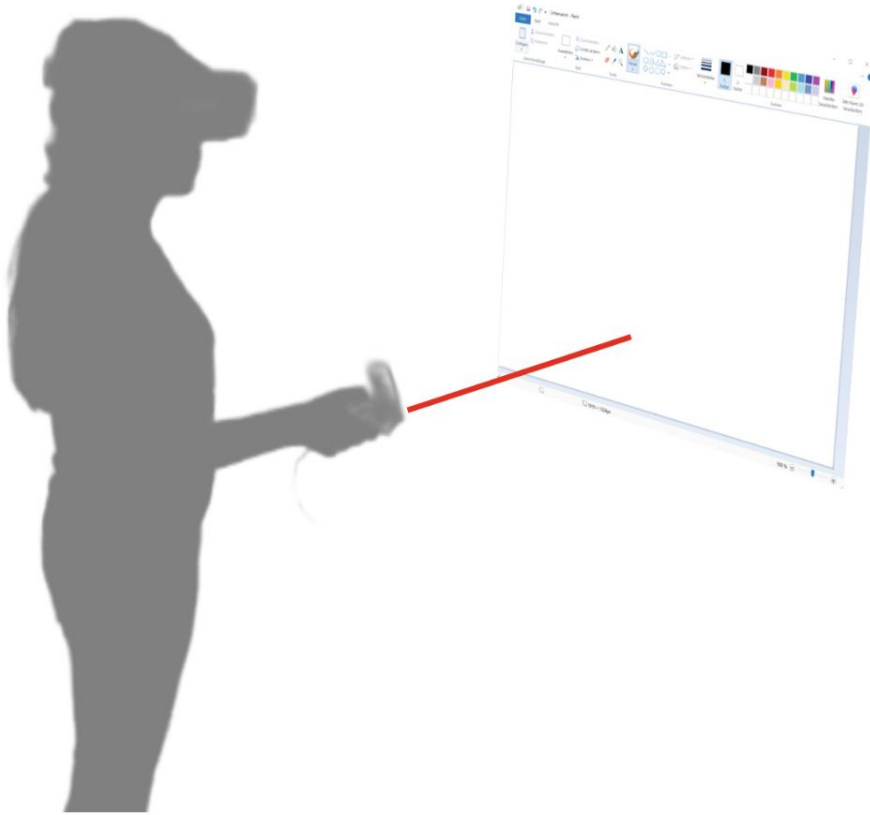


Figure 4.13 The ray-casting technique on the left provides better informative feedback than the ray-casting technique on the right.
(Image courtesy of Ryan P. McMahan)



I heard it was at 5?
I heard it was at 5?_



a

Reclass both please.
REclass both _



b

See you next week.
See y_



c

Thursday works better for me.
Thursday worj_



d





Voice Command

Implementation

- Wide range of speech recognition engines available
- E.g. Unity speech recognition plug-in, IBM VR speech sandbox

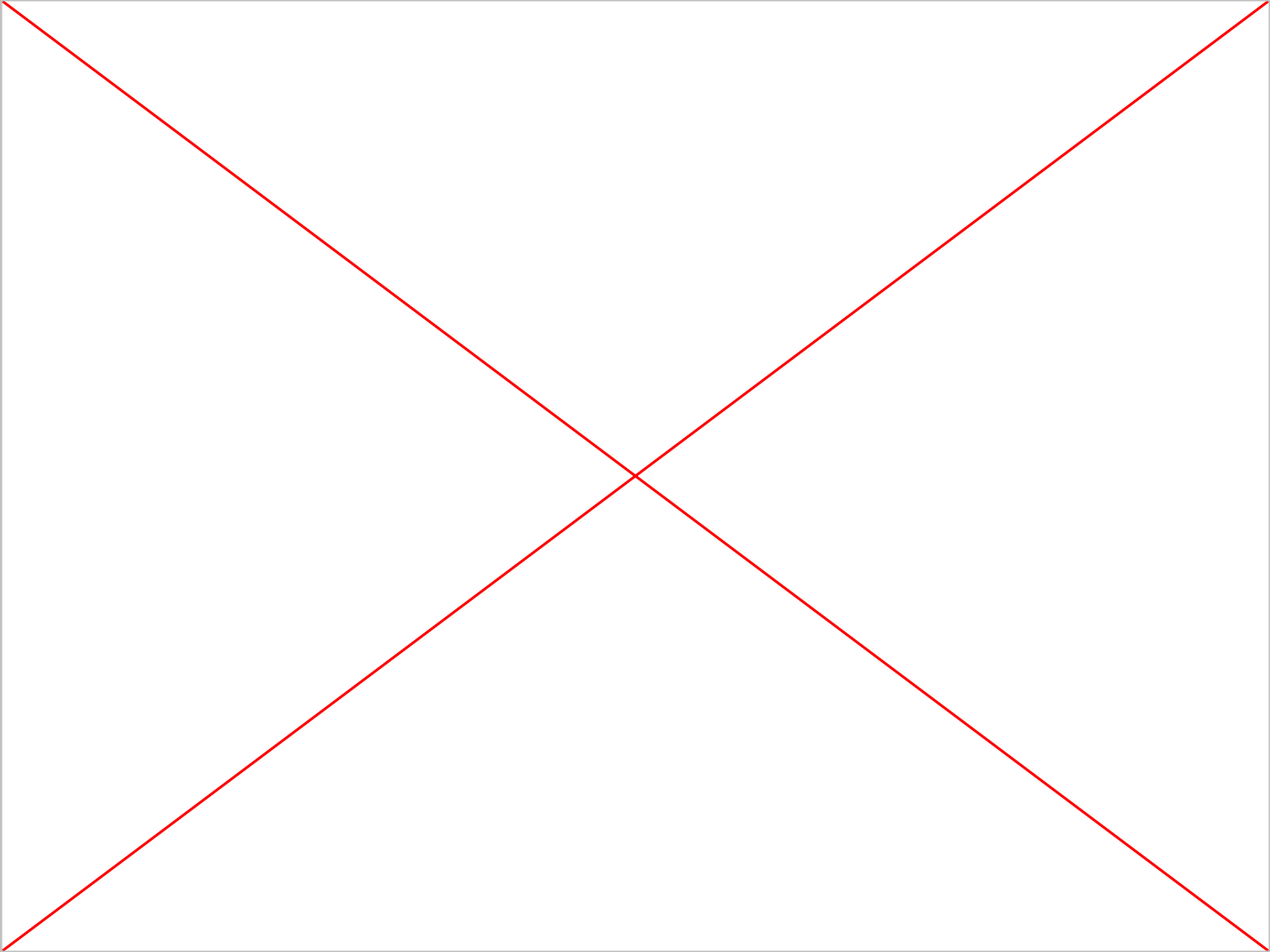
Factors to consider

- Recognition rate, background noise, speaker dependent/independent

Design Issues

- Voice interface invisible to user
- no UI affordances, overview of functions available
- Need to disambiguate system commands from user conversation
- Use push to talk or keywords
- Limited commands – use speech recognition
- Complex application – use conversational/dialogue system

Utterance	Action
“Take me to block twelve”	section teleport
“Show me the view from row F”	seat preview
“Where are the toilets?”	semantic query + beacon
“Quieter” / “louder”	crowd volume
“Compare”	open compare widget



Tools

Use tools for system commands

- Tangible user interfaces (real tools)
- Virtual tools (3D objects)

Design issues

- Support eyes-off use
- Use of physical affordances
- Base on familiar objects
- Provide tactile feedback
- Map real tool to virtual operation



Figure 9.19 Visualization artifacts—physical tools for mediating interaction with 3D UIs. (Image courtesy of Brygg Ullmer and Stefan Zachow, Zuse Institute Berlin)

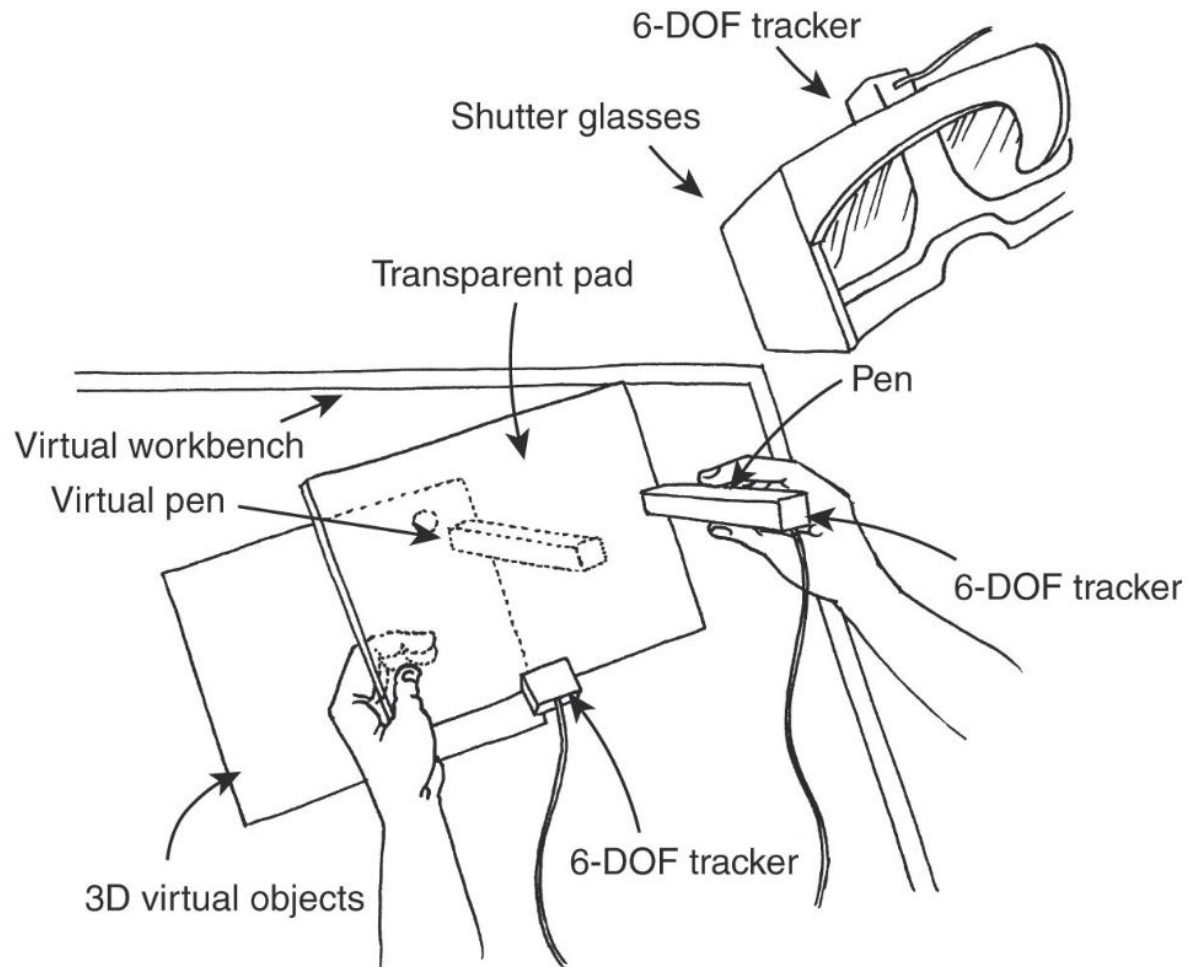
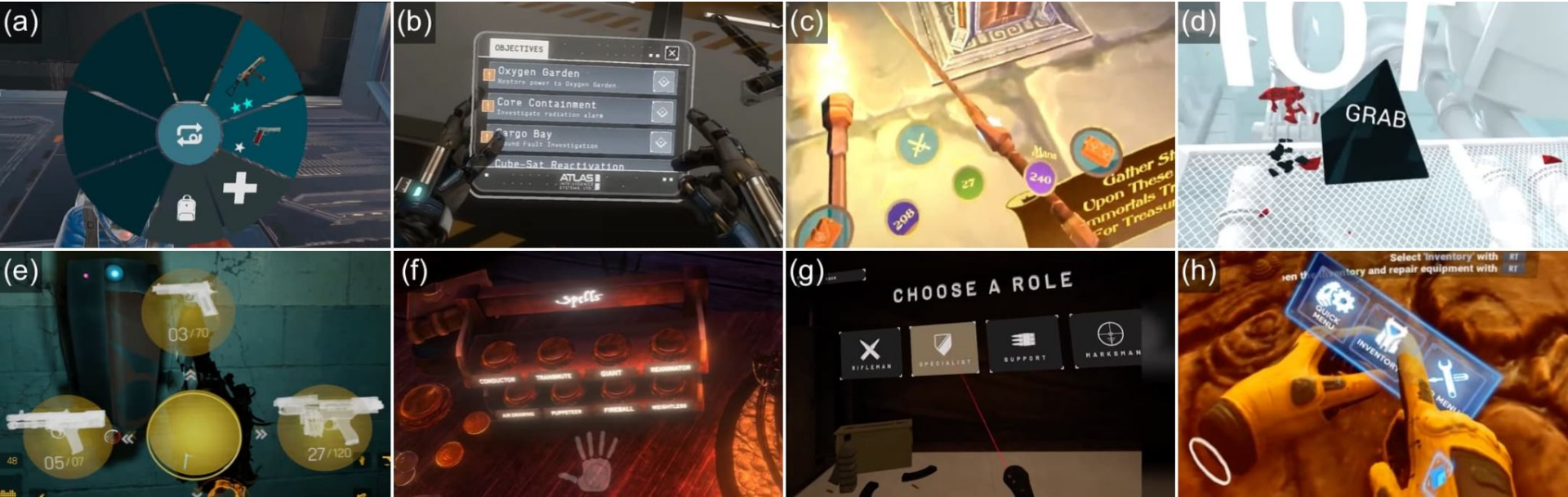


Figure 9.20 Personal Interaction Panel—combining virtual and augmented reality. (Adapted from Schmalstieg et al. 1999)

Design Guidelines

- Avoid disturbing the flow of action of an interaction task.
- Prevent unnecessary focus switching and context switching
- Design for discoverability.
- Avoid mode errors.
- Use an appropriate spatial reference frame.
- Structure the functions in an application and guide the user
- Consider using multimodal input.
- 3D is not always the best solution - consider hybrid interfaces

Research Trends



Tools & Unity

Frameworks

		 Virtual Reality Toolkit	 Windows Mixed Reality Toolkit	 Mixed Reality Toolkit	 XR Interaction Toolkit	 Oculus Interaction SDK
Multiple XR Target devices/ platforms	Oculus Steam VR HP Reverb Windows MR Pico Varjo Vive	Oculus Steam VR AR Core AR Kit Magic Leap Hololens Windows MR	Oculus Steam VR AR Core AR Kit Magic Leap Hololens Windows MR	Oculus Steam VR AR Core AR Kit Magic Leap Hololens Windows MR	Oculus Steam VR HP Reverb Pico AR Core AR Kit Magic Leap Varjo Vive	Oculus
Target XR Environment	VR	VR AR	VR AR	VR AR	VR AR	VR
Game Engine	 				 	

Which framework?

Meta XR All-in-One SDK	XR Interaction Toolkit (Unity)
For Meta Quest devices only - Hardware focused	Cross-platform (Quest, OpenXR, Windows MR, etc)
Build for Windows and Mac	Build for Windows and Mac
Simulator run on Windows	Simulator run on Windows and Mac

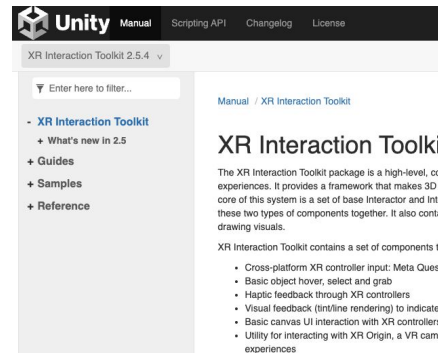
Meta XR All-in-One SDK (UPM)

Published: 21 Dec 2023



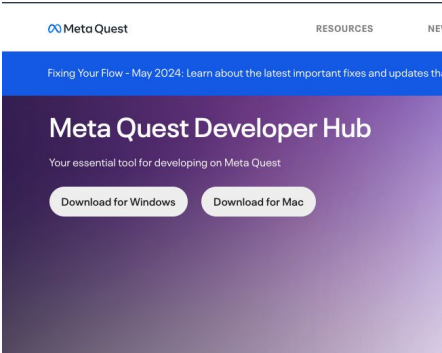
The Meta XR All-in-One SDK, [com.meta.xr.sdk.all](https://github.com/facebook/meta-xr-sdk), bundles several Meta SDKs together, which includes many features that offer advanced rendering, social and community building, and provides capabilities to build immersive experiences in both virtual reality and mixed reality.

Looking for samples? The Meta XR All-in-One SDK itself does not contain samples, but some of the packages it pulls in as dependencies may contain samples. You can browse these installed dependencies and their samples via the Unity package Manager window (Window -> Package Manager), then switching the "Packages" dropdown in the top bar of the window to "My Assets". Additionally, larger samples previously found in the legacy Oculus Integrations package have been moved to Github, under the [StarterSamples repository](#).



Which Application

Meta Quest Developer Hub	Quest Link
Run on Windows and Mac	Run on Windows
Comprehensive portal for managing device and installing app	Good for live debugging



XRI Toolkit

Interactor components

The interactor components provided by the toolkit.

Topic	Description
Near-Far Interactor	Interacts with both close and distant interactables when the user either touches or points at them.
XR Direct Interactor	Interacts with nearby interactables when the user touches them.
XR Poke Interactor	Interacts with nearby interactables when the user performs a specific poking motion.
XR Ray Interactor	Interacts with interactables at a distance when the user points at them.
XR Gaze Interactor	Interacts with gaze-enabled interactables via eye tracking. (Can fallback to use head tracking for devices that don't support eye tracking.)
XR Socket Interactor	A specialized interactor that only interacts with interactables close to it.

Interactable components

The interactable components provided by the toolkit.

Topic	Description
XR Grab Interactable	An interactable that is picked up when selected.
XR Simple Interactable	An interactable that changes state when interacted with, but does not have any built-in behavior.

<https://docs.unity3d.com/Packages/com.unity.xr.interaction.toolkit@3.5/manual/interactor-components.html>
<https://docs.unity3d.com/Packages/com.unity.xr.interaction.toolkit@3.5/manual/interactable-components.html>

Grab Interactable Objects

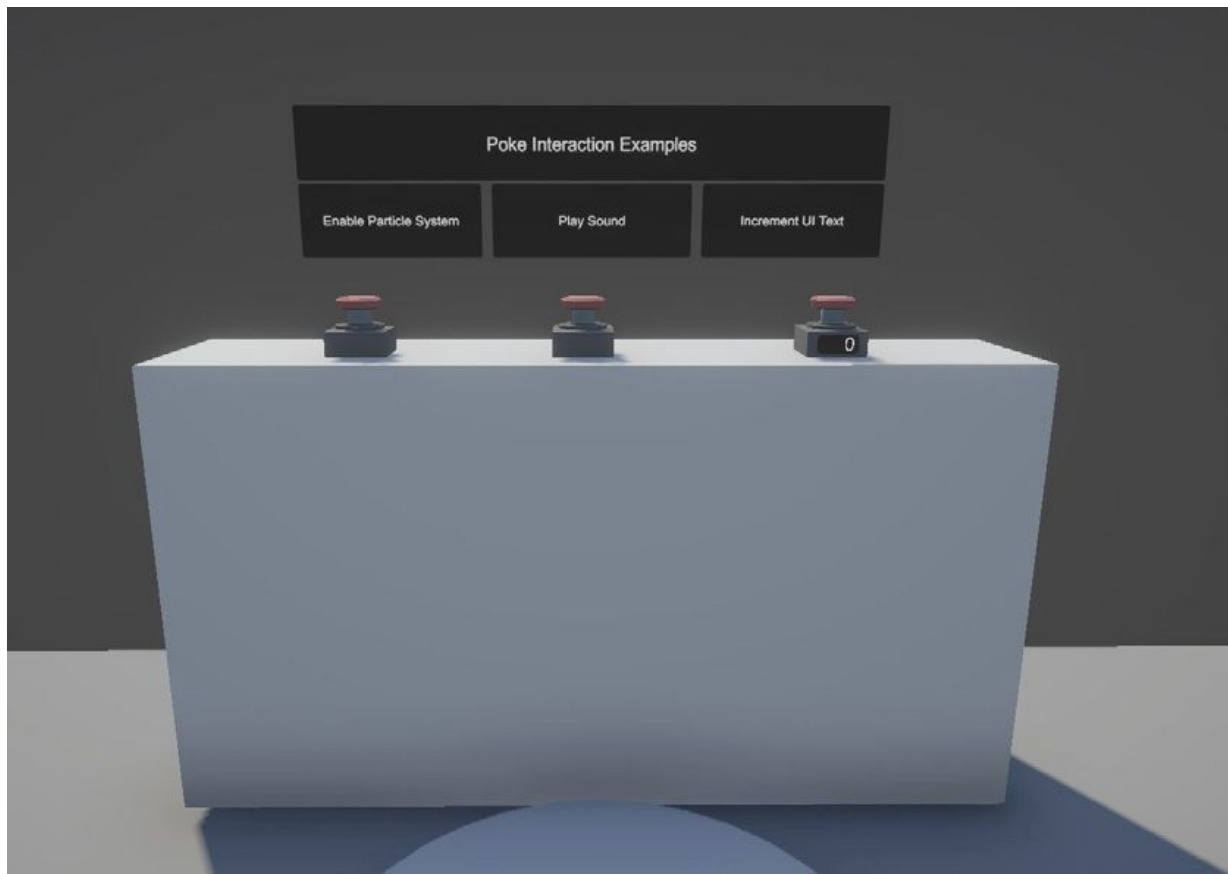
Kinematic
Movement

Instantaneous
Movement

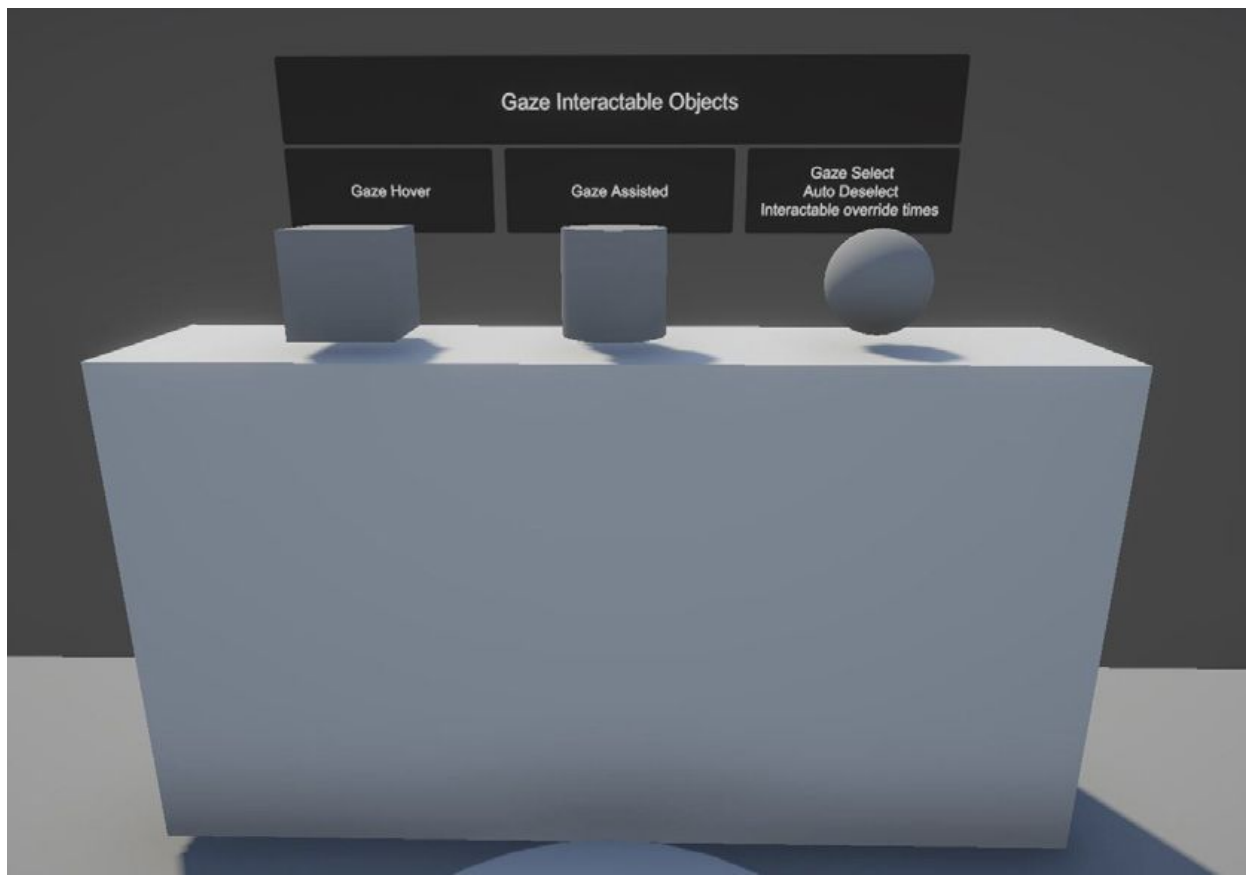
Velocity Tracked
Movement



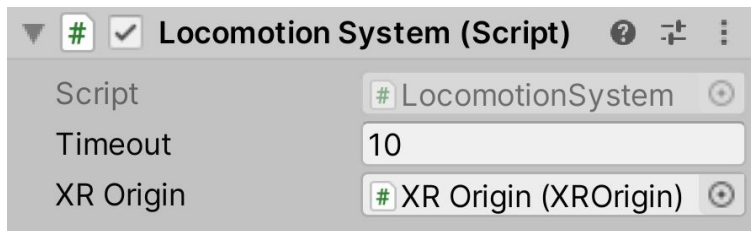
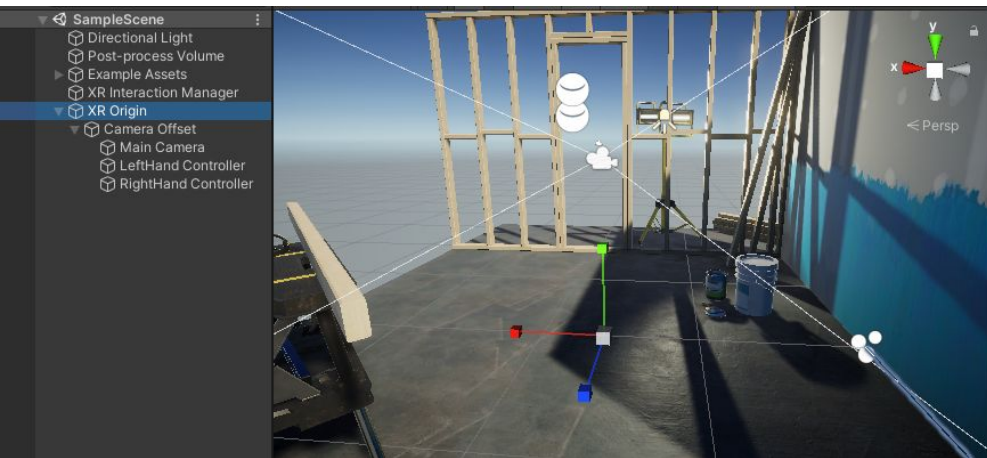
Poke Interactable



Gaze Interactable



Locomotion in Unity

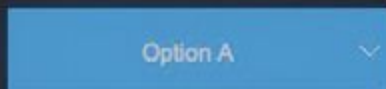


Locomotion System	Locomotion System	Holds a reference to the XR Origin which the locomotion providers use to move or rotate the player. Controls access to the XR Origin to ensure only one locomotion provider can move it at a time when locked.
Turn	Snap Turn Provider Continuous Turn Provider	Locomotion providers which handle turning (rotating) the player, either in fixed angle intervals or continuously over time, typically via thumbstick input. The Action Based Controller Manager enables or disables the input actions to control whether snap turn or smooth turn is used.
Move	Dynamic Move Provider	Locomotion provider which handles moving (translating) the player continuously over time, typically via thumbstick input.
Grab Move	Grab Move Provider Grab Move Provider Two-Handed Grab Move Provider	Locomotion providers which handle moving and/or turning the player typically via squeezing the grip of a controller and moving them as if grabbing the whole world and pulling. This GameObject is deactivated by default to disable this locomotion style.
Teleportation	Teleportation Provider	Locomotion provider which handles teleporting the player to a desired location. This component is what allows the Teleportation Anchor and Teleportation Area components to move the player when they are triggered, in this case by the Teleport Interactor.
Climb	Climb Provider	Locomotion provider which handles moving the player counter to controller movement while they are grabbing a Climb Interactable.

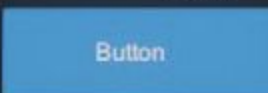
Test Modal Window

Confirm

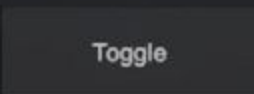
Test Controls



Buttons



Toggles

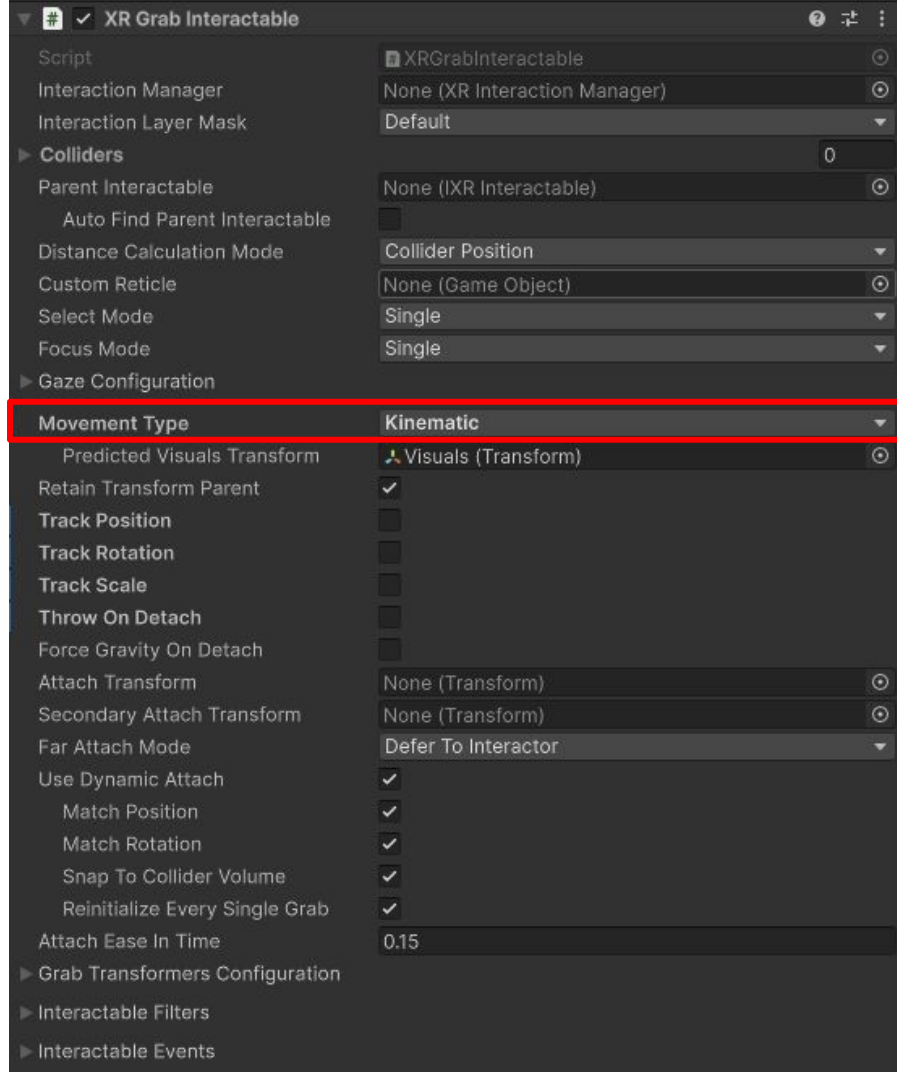


Test Scrollview

You can scroll this window using the scrollbars, or by using the thumbstick on your controller.

The controller ray must be pointed at the UI

Movement Type



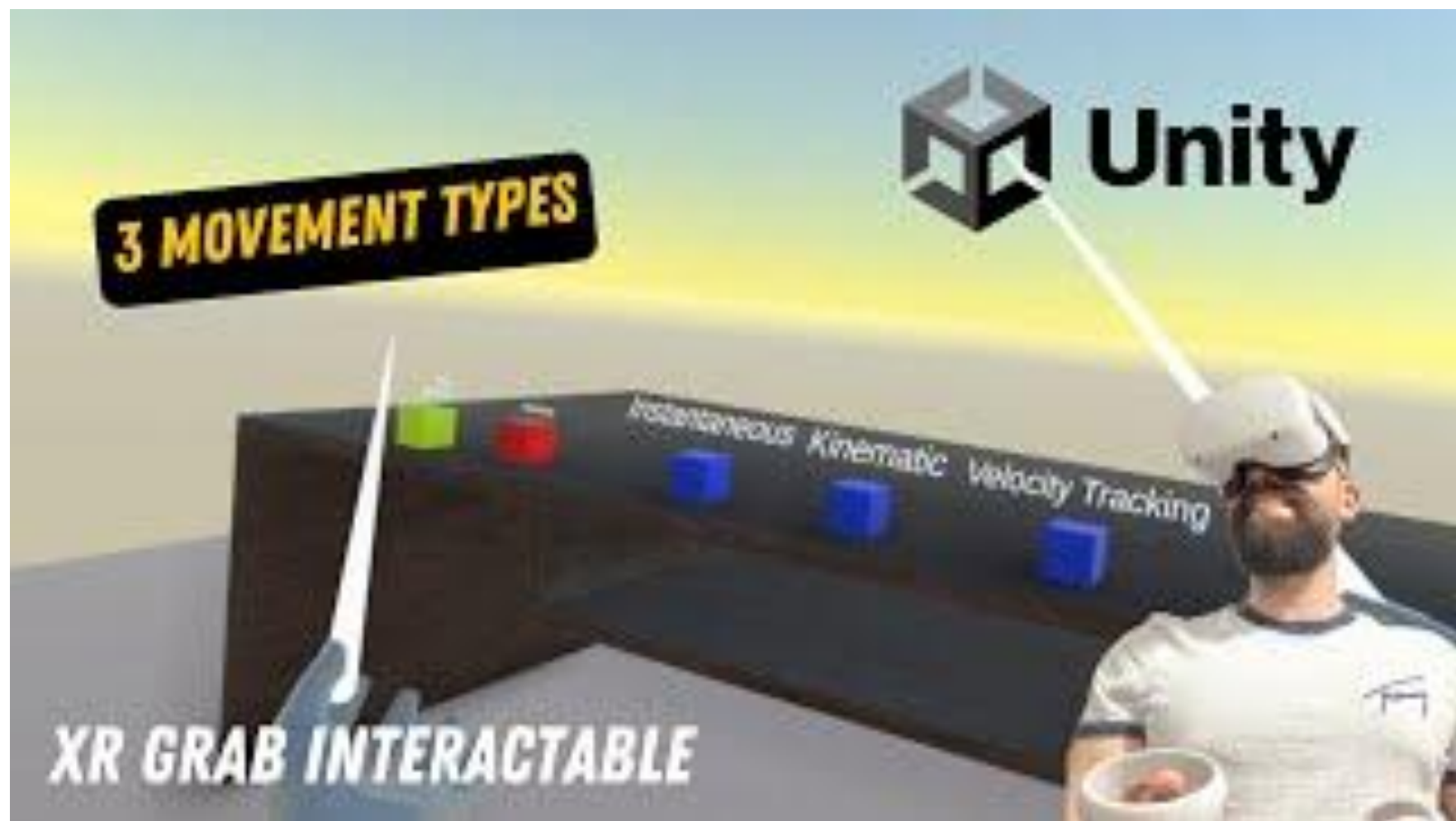
3 MOVEMENT TYPES



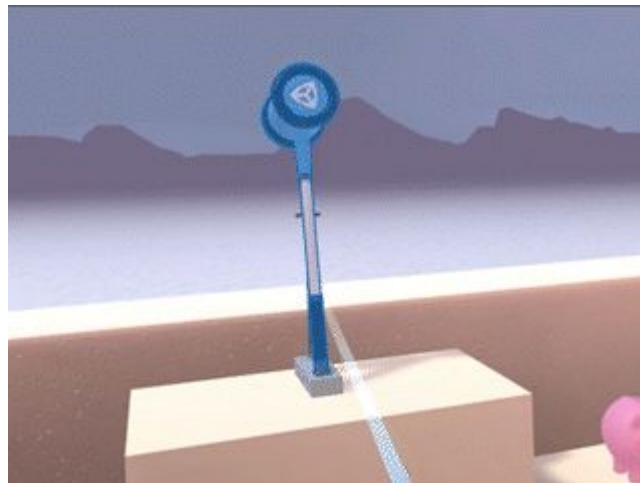
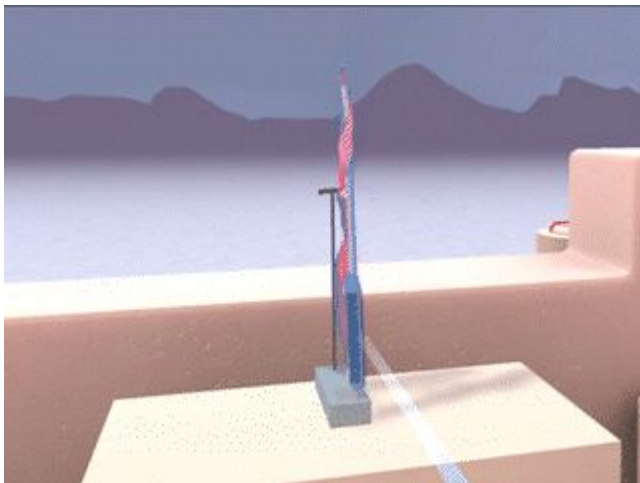
Unity

Instantaneous Kinematic Velocity Tracking

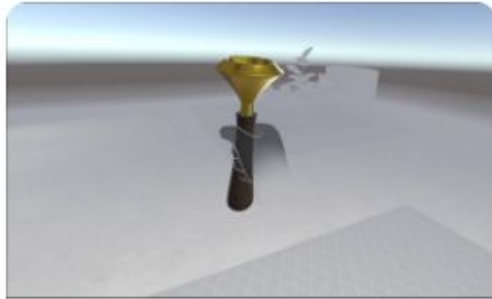
XR GRAB INTERACTABLE



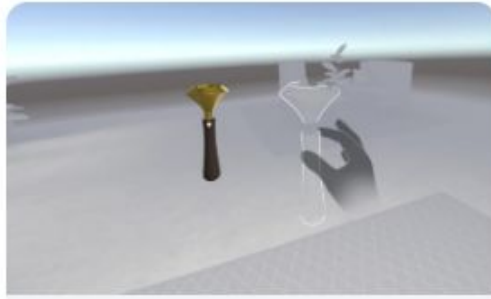
More Examples



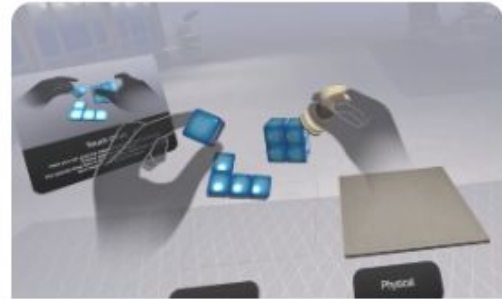
Meta XR



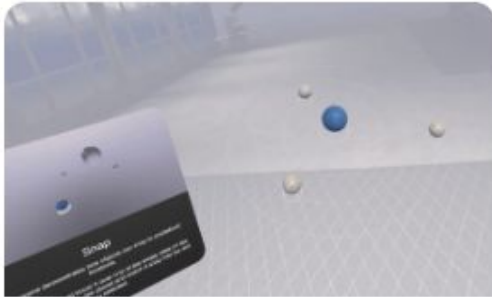
Grab



Distance Grab



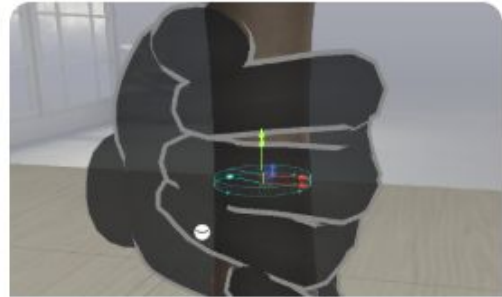
Touch Grab



Snapping Objects



Using Objects



Custom Hand Poses

Evaluation

Evaluating your prototype

Questionnaires

SSQ (Kennedy 1993): 16 symptoms, before and after each session

IPQ (Schubert 2001): 14 items on presence

SUS (Brooke 1996): 0–100; >68 is above average

NASA-TLX for workload in the wayfinding task

FMS every minute, with the stop rule

Task metrics

- Time to find the assigned seat; wrong turns; help requests
- Seat preview: agreement between the seat chosen in VR and satisfaction on site (photo comparison)
- Comfort: dropouts, SSQ delta, session length

Protocol

- Informed consent
- 10–15 min sessions, breaks, stop on discomfort
- Within-subject VR vs AR, counterbalanced order
- n = 12–20 for a pilot

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