SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A+' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF INFORMATION TECHNOLOGY

16IT AUGMENTED REALITY AND VIRTUAL REALITY

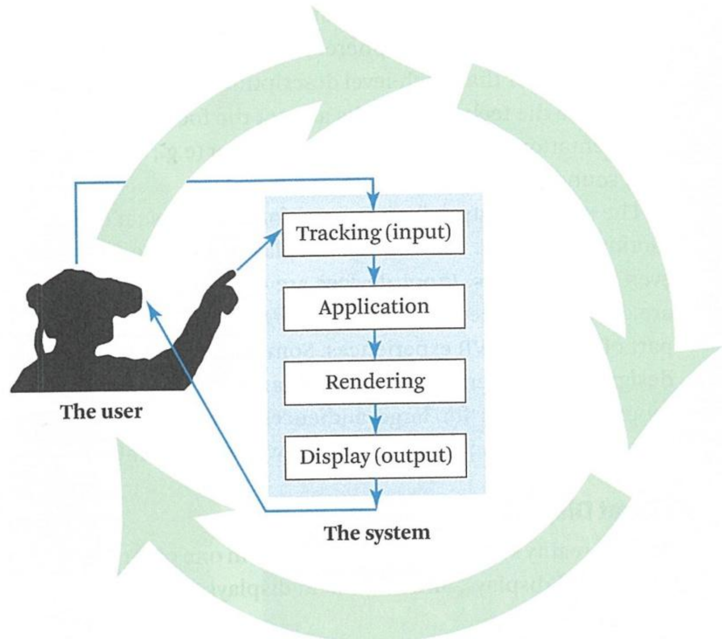
III YEAR – V SEM

UNIT 4 – INTERACTIVE TECHNIQUES AND TOOLS

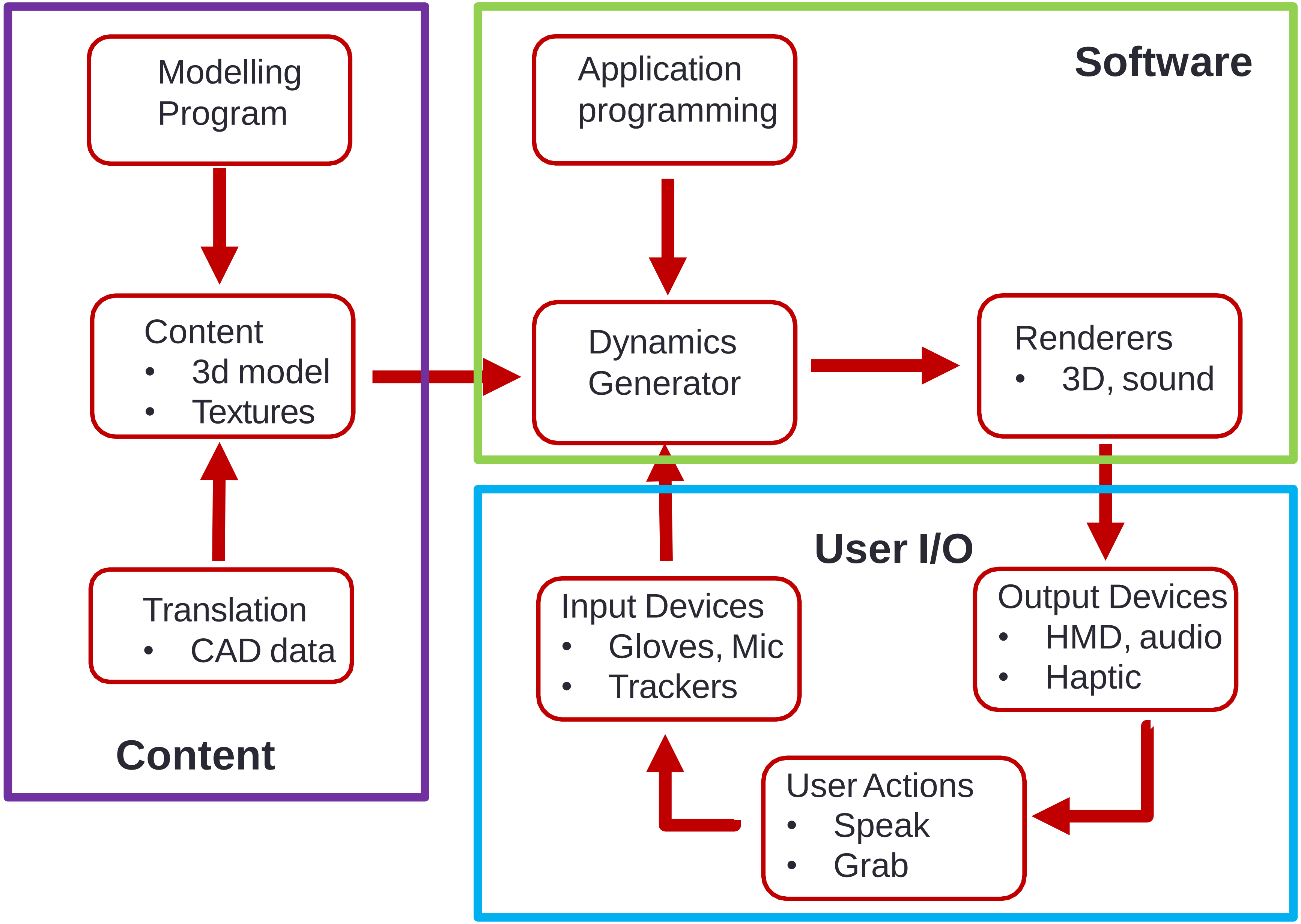
TOPIC 2 –Navigation and Manipulation Interface –Gesture Interface

Lecture 4: Recap

- VR Input Devices
  - Body, Feet, Handheld, Gestures, Gaze
  - Separate device from Interaction Technique
- VR Systems
  - Multiple components
    - Content, Software, User I/O modules
  - VR Simulation Loop
    - System delays cause sickness
  - Reduce system delay
    - Predictive tracking, faster components

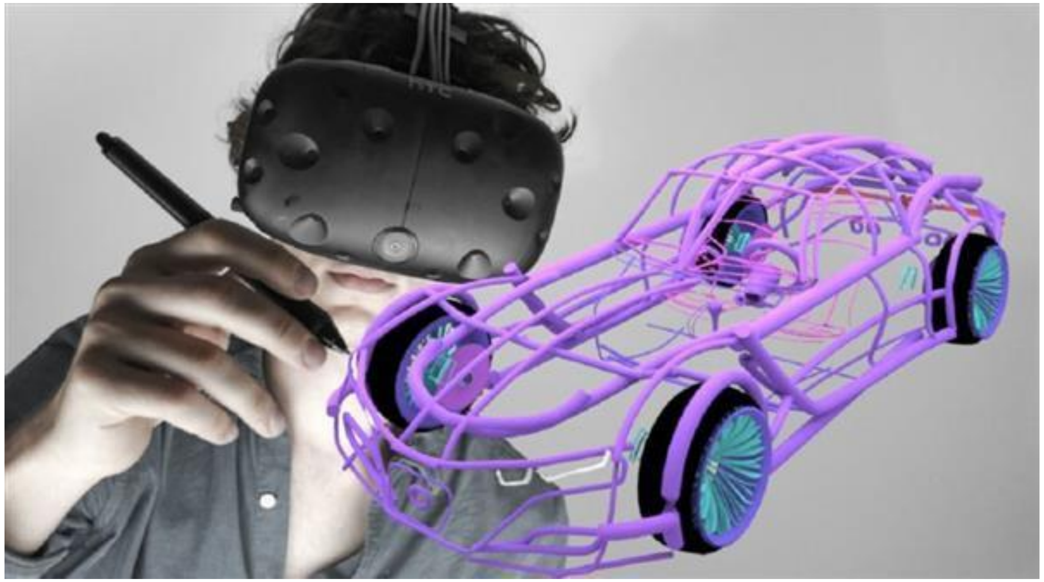


From Content to User

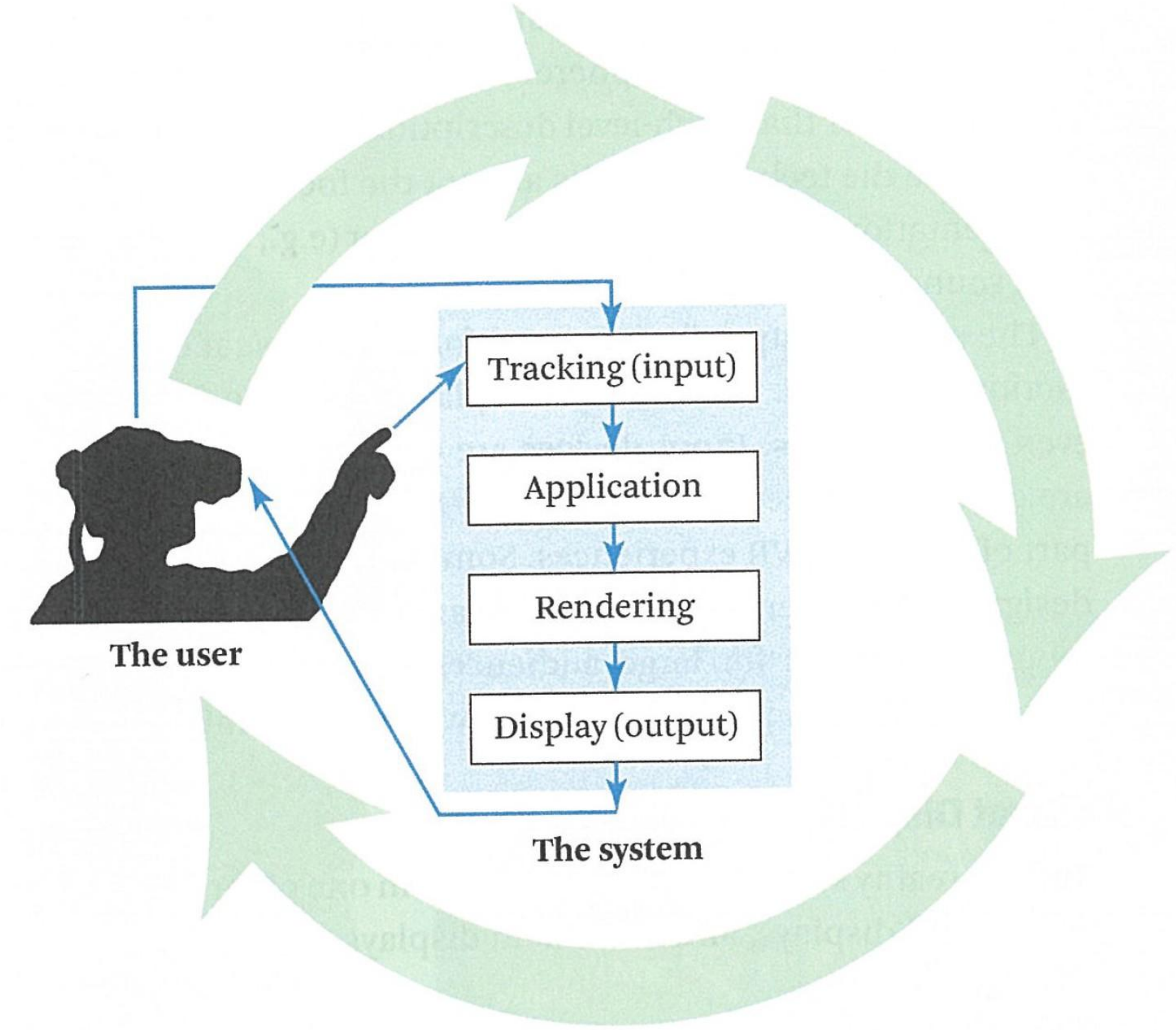


Types of VR Graphics Content

- Panoramas
  - 360 images/video
- Captured 3D content
  - Scanned objects/spaces
- Modelled Content
  - Hand created 3D models
  - Existing 3D assets

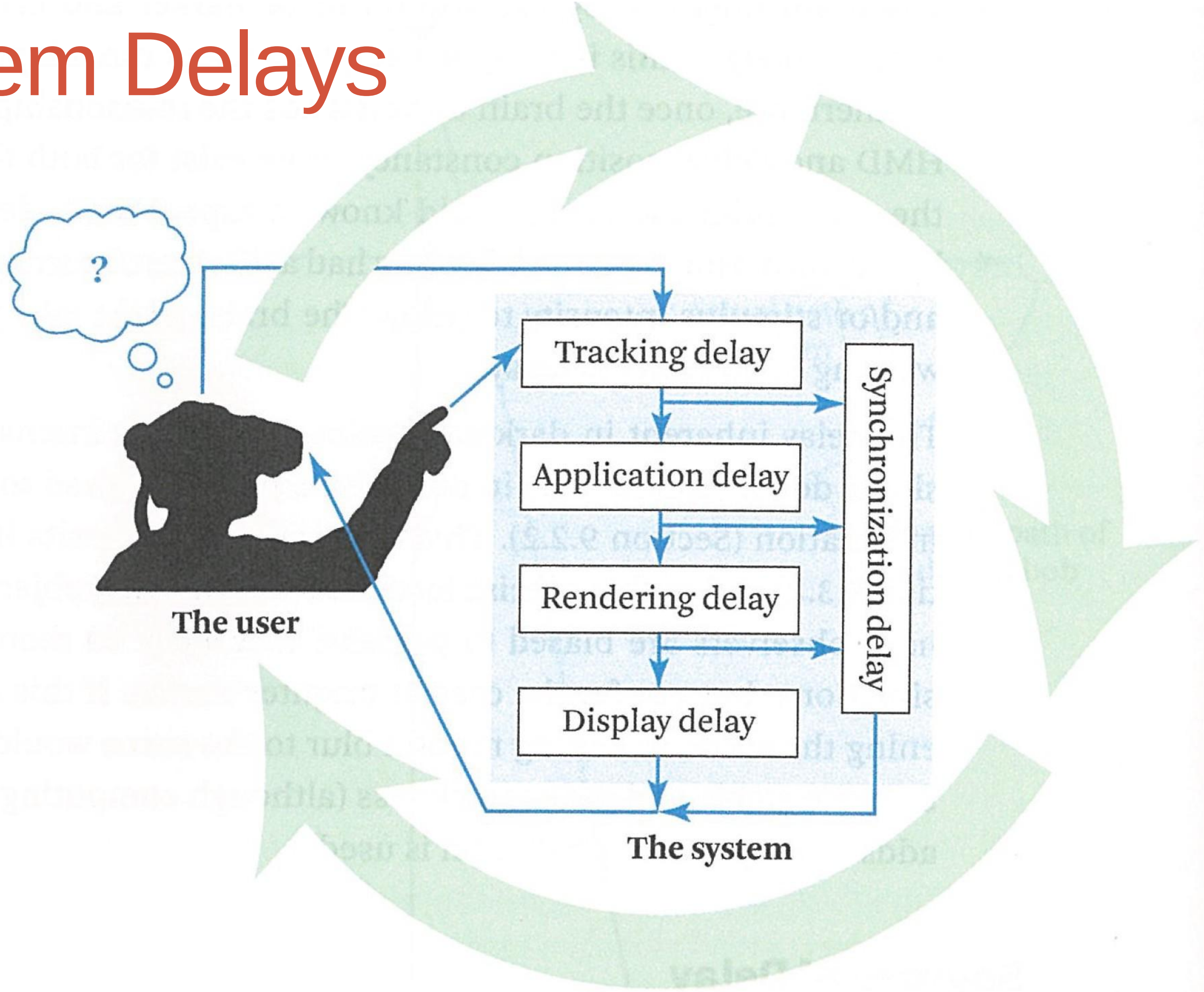


Typical VR Simulation Loop



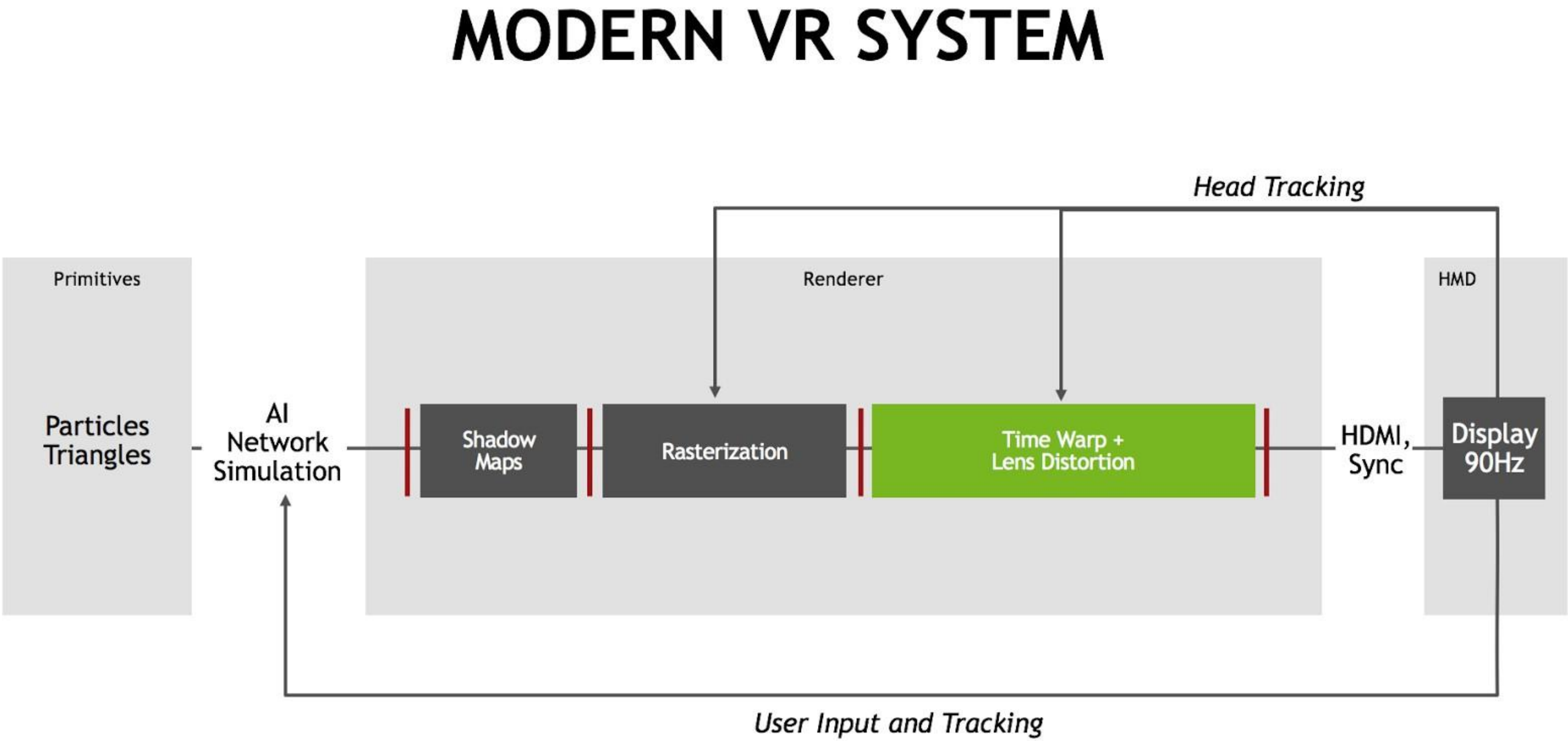
- User moves head, scene updates, displayed graphics change

System Delays



- Need to synchronize system to reduce delays

VR System Pipeline

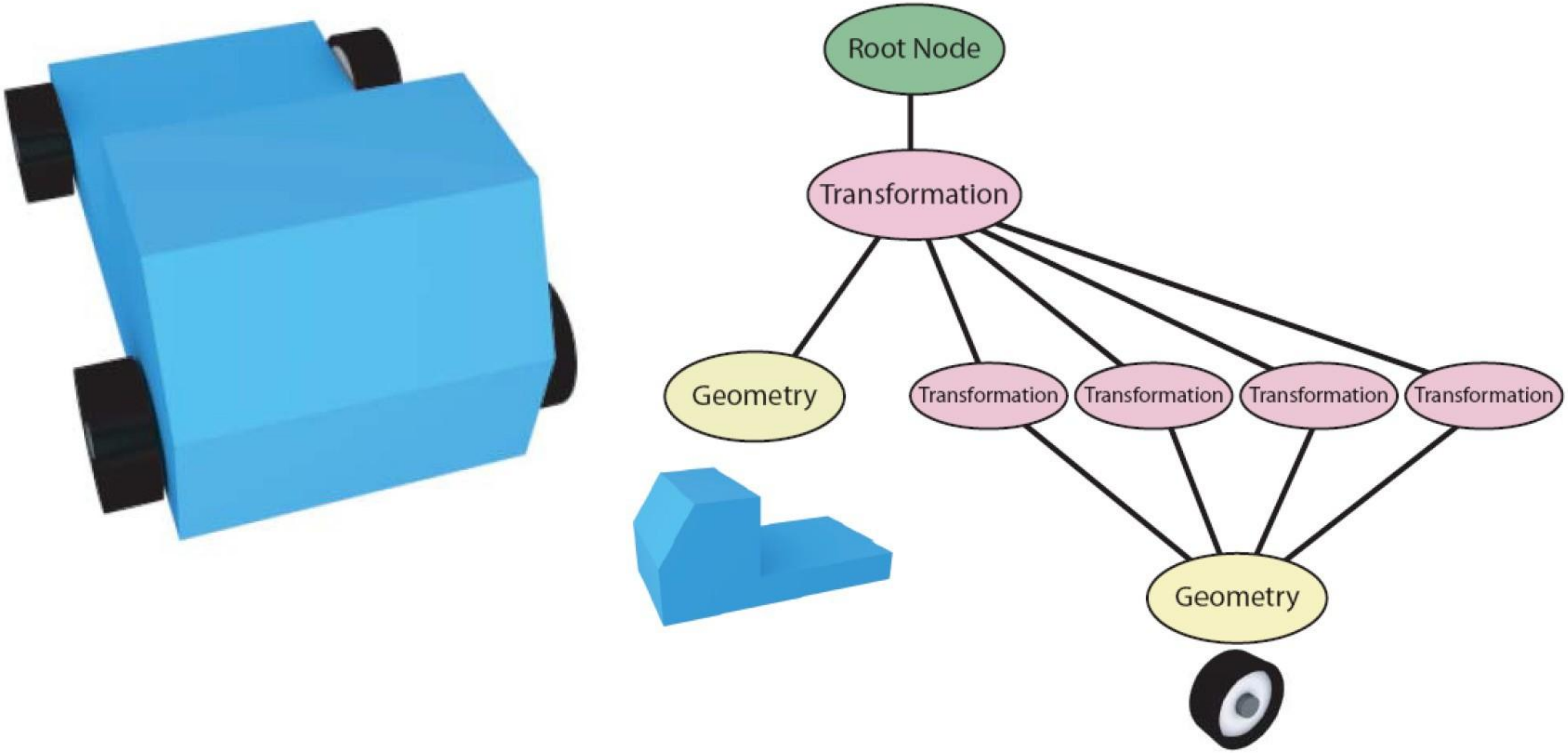


- Using time warping and lens distortion

Scene Graphs

- Tree-like structure for organising VR graphics
  - e.g. VRML, OSG, X3D
- Hierarchy of nodes that define:
  - Groups (and Switches, Sequences etc…)
  - Transformations
  - Projections
  - Geometry
  - …
- And states and attributes that define:
  - Materials and textures
  - Lighting and blending
  - …

Example Scene Graph



- Car model with four wheels
  - Only need one wheel geometry object in scene graph

INTERACTING IN VR

Typical Virtual Reality System

How can we Interact in VR?

- How can VR devices create a natural user experience?

Background: Human-computer interaction

- HCI studies *communication*
  - Users and computers communicate via the interface
- Traditional UI design issues:
  - Input device
  - Interaction style
  - Feedback to the user
  - Gulf of execution / gulf of evaluation
- All these are relevant for 3D/VR User Interfaces

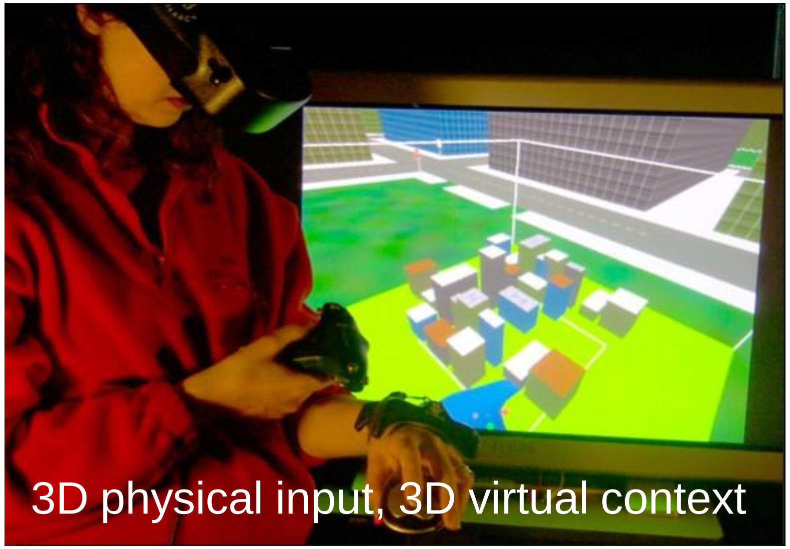
Why 3D Interaction?

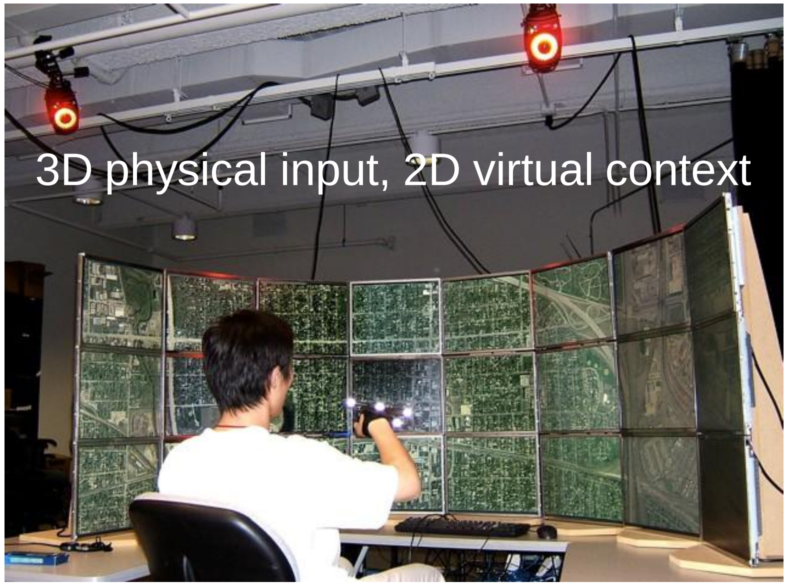
- 3D / VR application should be useful
  - Support immersion
  - Use natural skills
  - Provide immediacy of visualization
- But many current VR apps either
  - Support only simple interaction
  - Or, have serious usability problems
- We need good 3D user interface guidelines

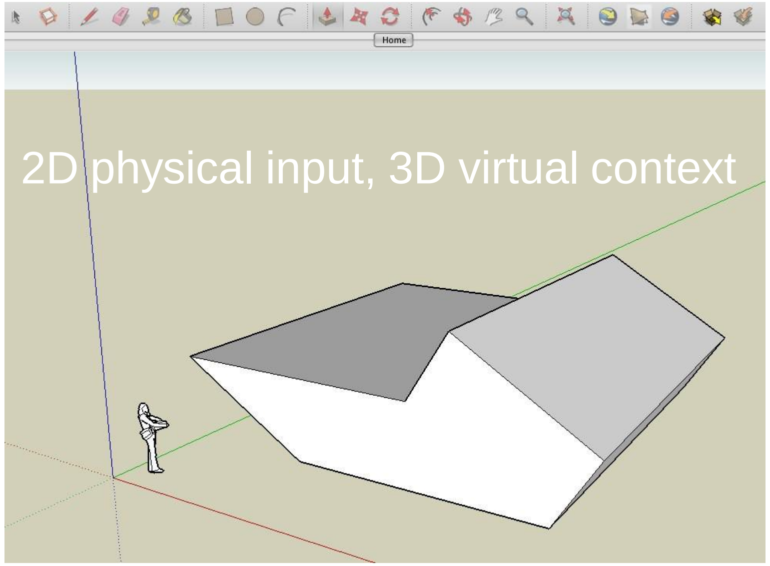
Some Definitions

- 3D Interaction:
  - Human-computer interaction in which the user's tasks are carried out in a 3D spatial context
    - 3D input devices, 2D input devices mapping into 3D
- 3D user interface (3D UI):
  - A UI that involves 3D interaction
- 3D interaction technique:
  - A method (hardware and software) allowing a user to accomplish a task in a 3D UI

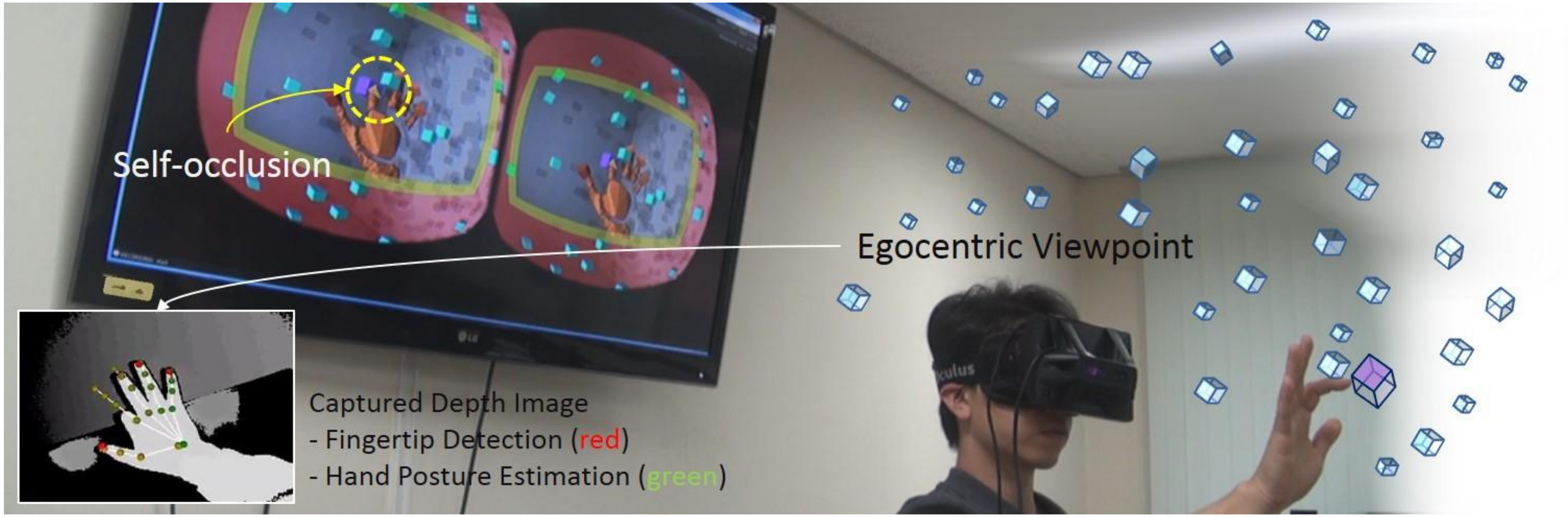
Examples of 3D UIs – VR and non-VR







What makes 3D interaction difficult?

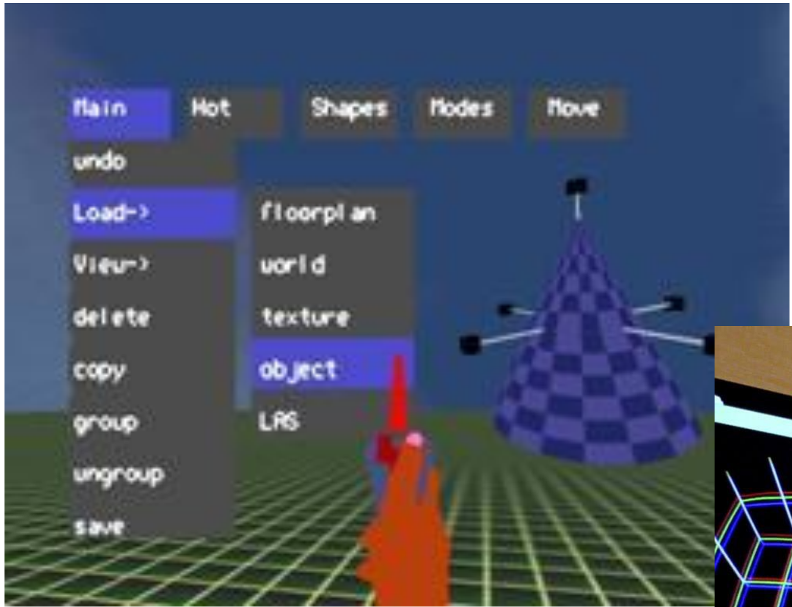


- Spatial input
- Lack of constraints
- Lack of standards
- Lack of tools
- Lack of precision
- Fatigue
- Layout more complex
- Perception

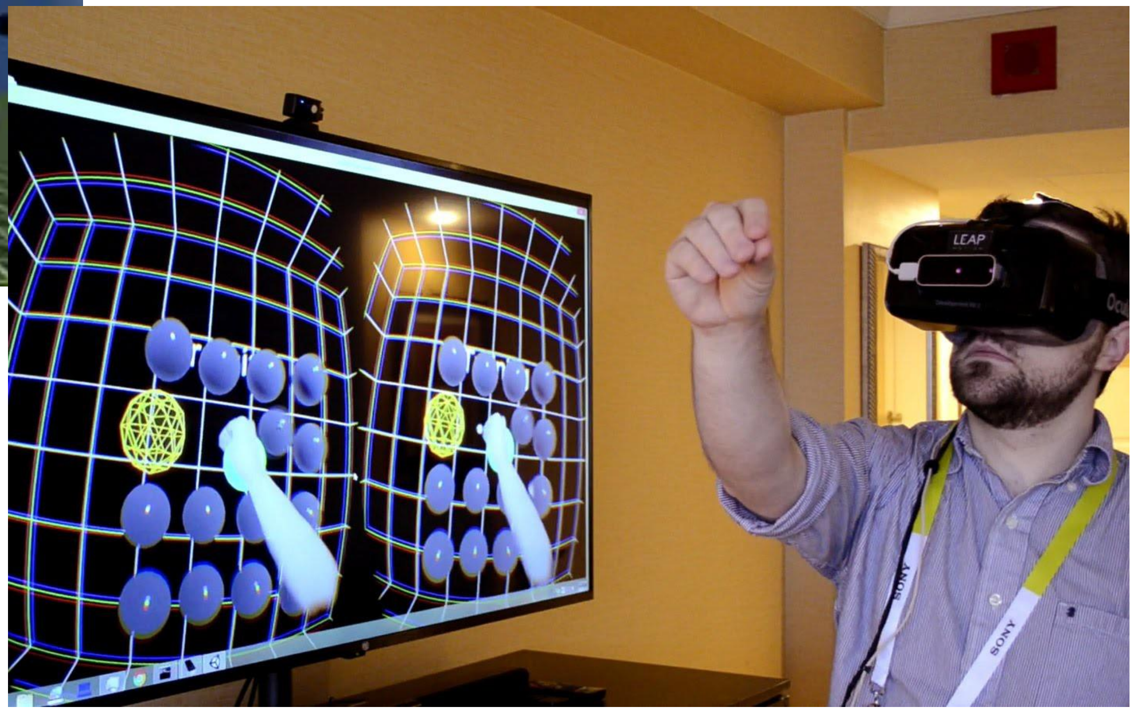
Example: Virtual-SAP

- https://www.youtube.com/watch?v=Xz_J0EK8LLs

Moving from Menus to Natural Interaction



2D UI in 3D

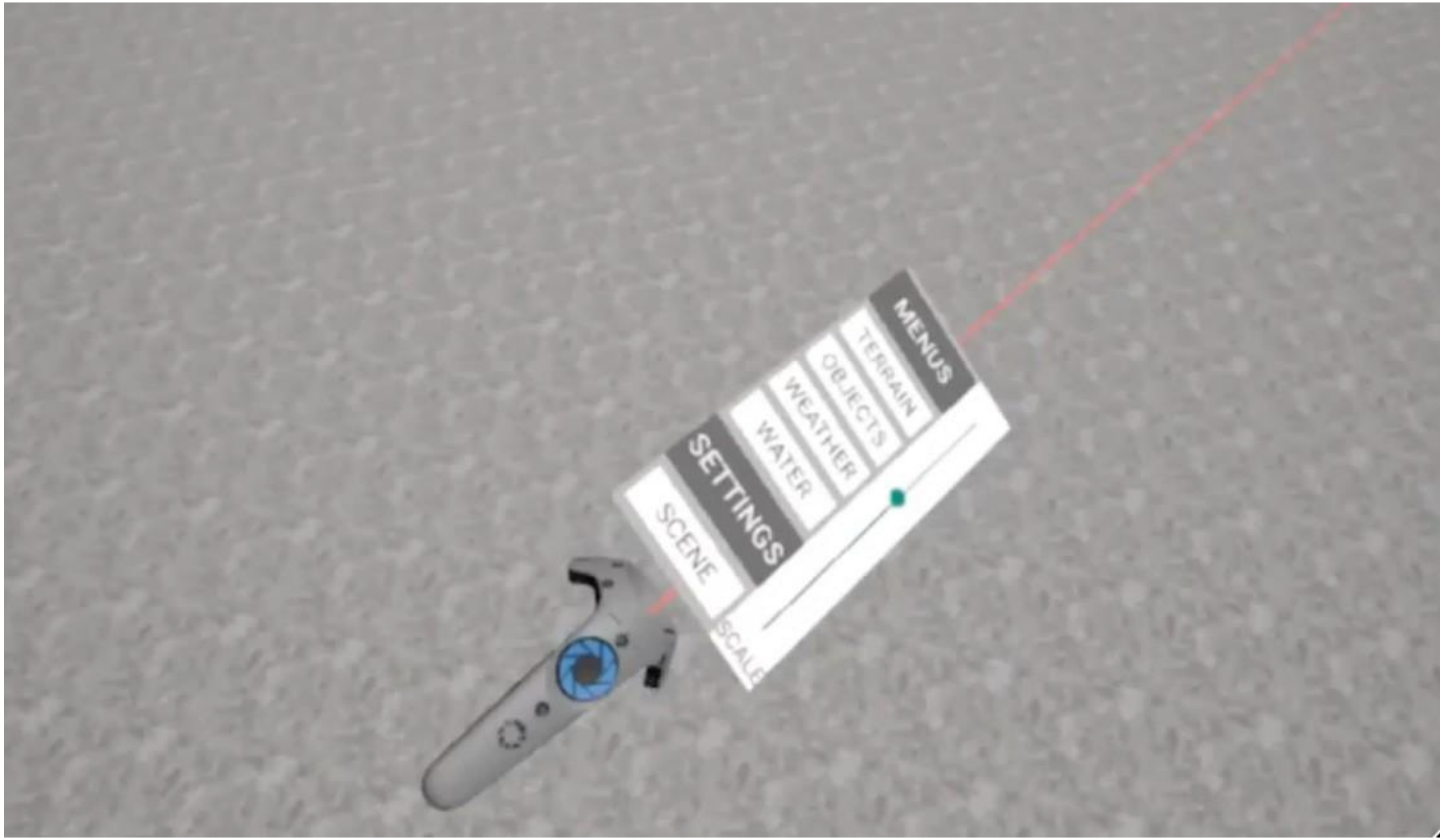


Natural 3D Interaction

Natural Interface Concept - WorldBuilder

- https://www.youtube.com/watch?v=FheQe8rflWQ&t=43s

World Builder Today (Available on Steam)



- https://www.youtube.com/watch?v=65u3W7wjXs0

Vision vs. Reality – Still Work to Do..

Natural interface
Gesture, speech
Wide field of view
Full body input

Limited input
Wireless, limited range tracking
Reduced field of view
2D GUI in VR

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

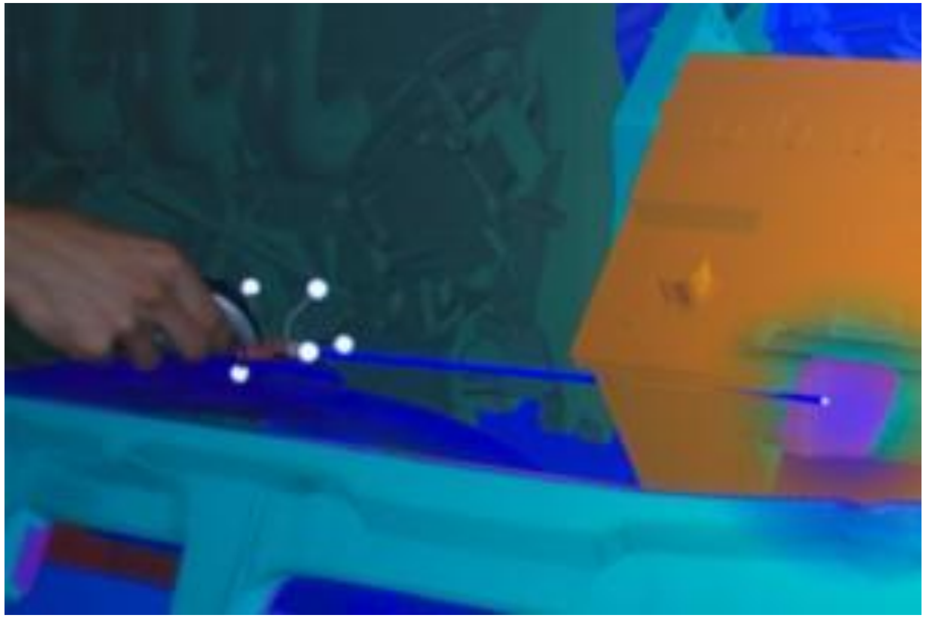
- Selection:
  - specifying one or more objects from a set
- Manipulation:
  - modifying object properties
    - <u>position</u>, <u>orientation</u>, scale, shape, color, texture, behavior, etc.

Goals of selection

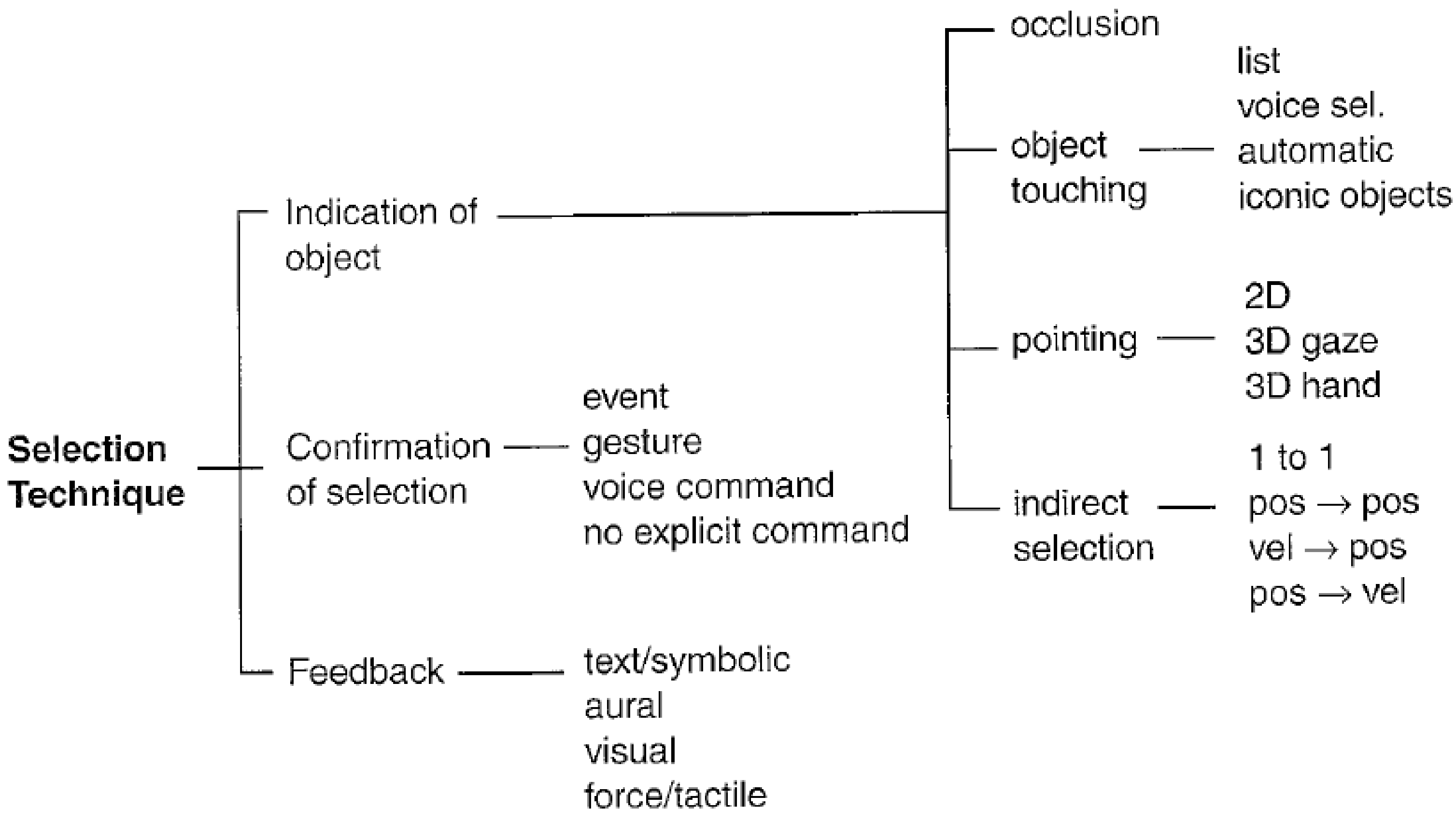
- Indicate action on object
- Query object
- Make object active
- Travel to object location
- Set up manipulation

Selection performance

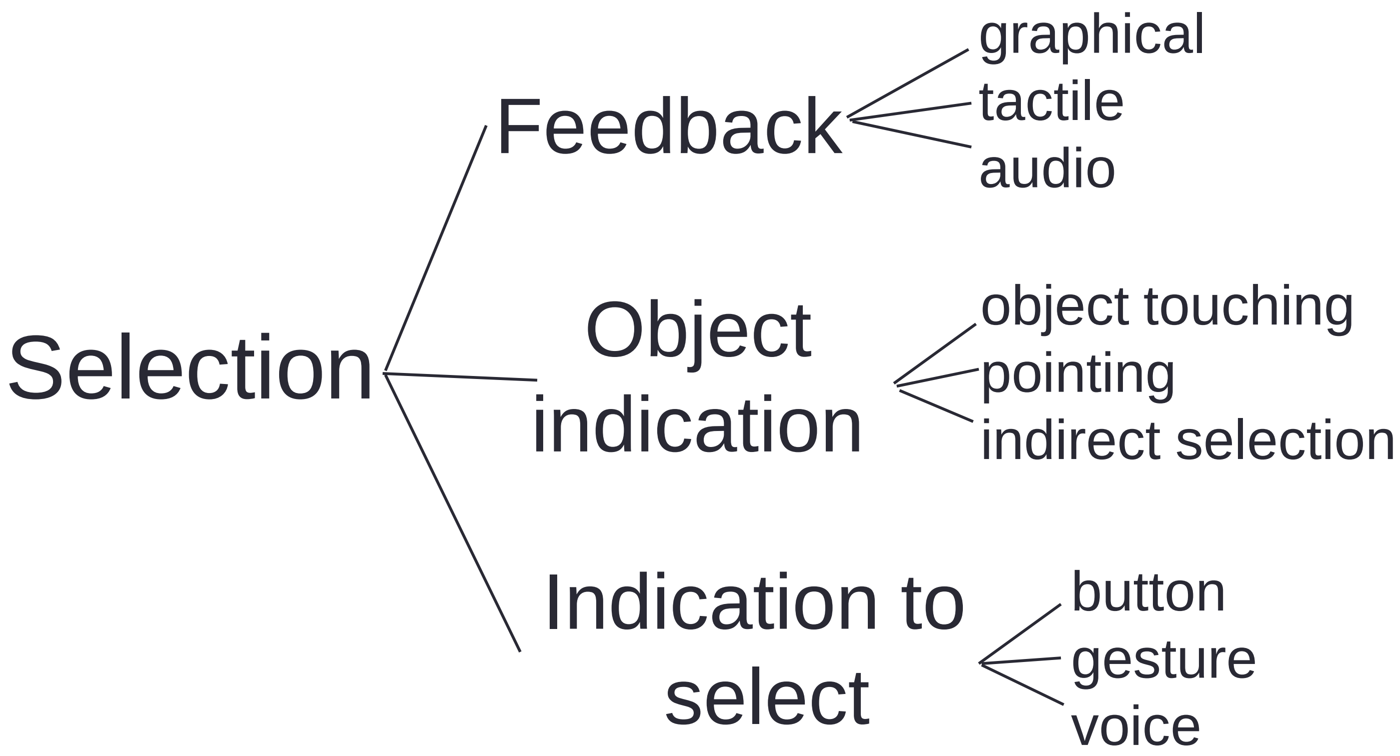
- Variables affecting user performance
  - Object distance from user
  - Object (visual) size
  - Density of objects in area
  - Occluders



Classification of Selection Techniques



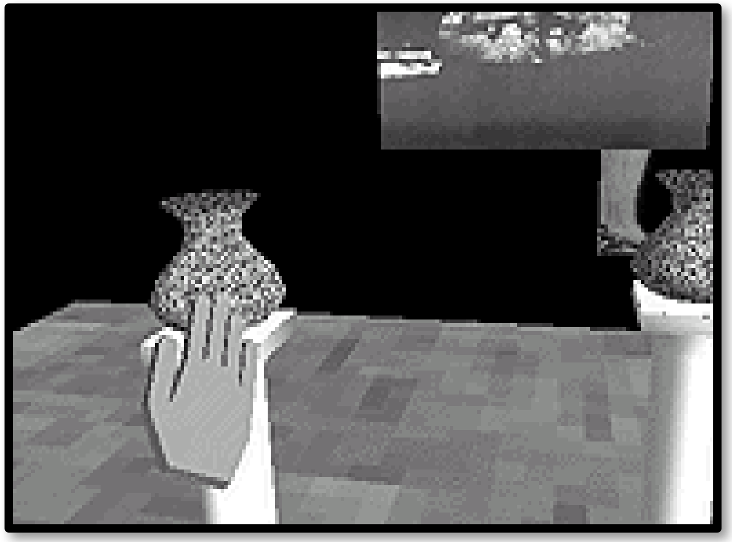
Selection classification

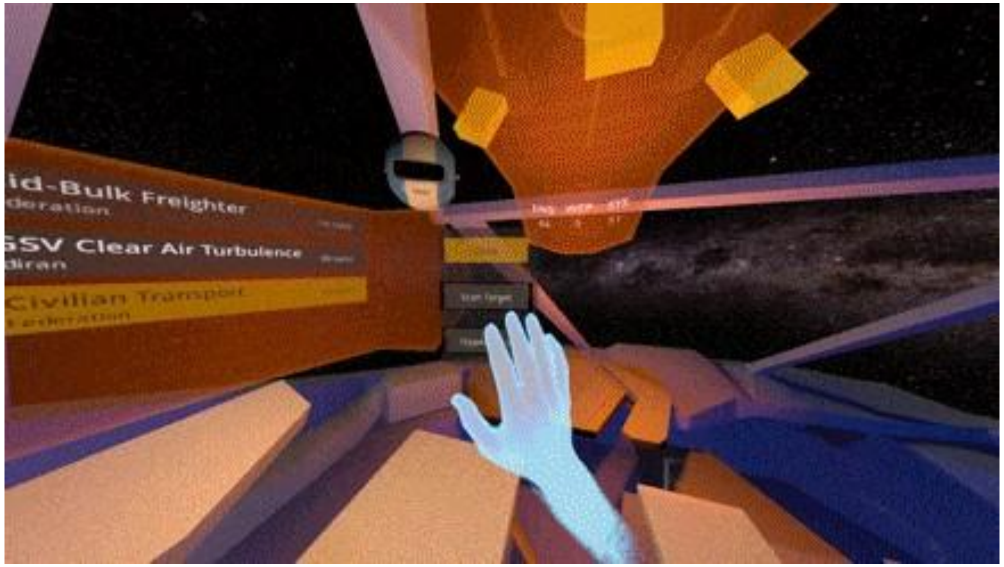


Common Selection Techniques

- Simple virtual hand
- Ray-casting
- Occlusion
- Go-go (arm-extension)

Simple virtual hand technique

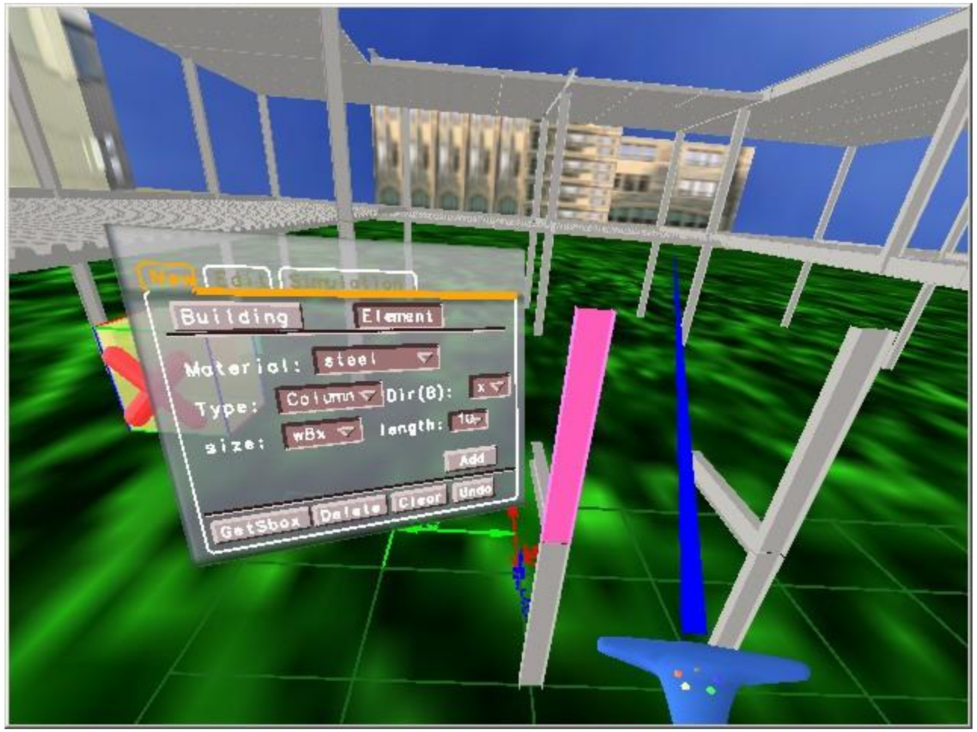




- Process
  - One-to-one mapping between physical and virtual hands
  - Object can be selected by “touching” with virtual hand
  - “Natural” mapping
- Limitation:
  - Only select objects in hand reach

Ray-casting technique

- "Laser pointer" attached to virtual hand
  - First object intersected by ray may be selected
  - User only needs to control 2 DOFs
- Proven to perform well for remote selection
- Variants:
  - Cone casting
  - Snap-to-object rays



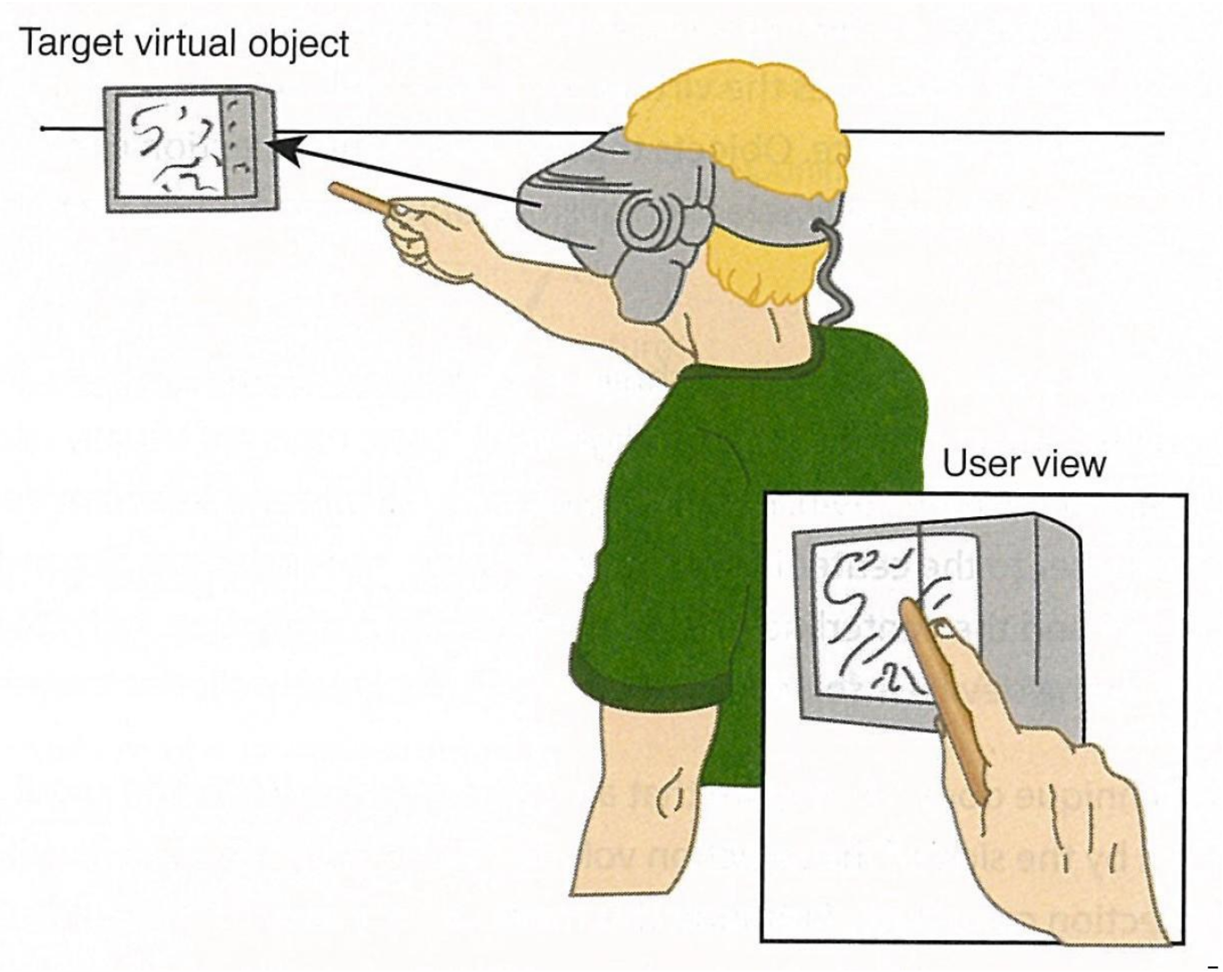
Example Ray Casting

- https://www.youtube.com/watch?v=W1ZUBTPCL3E

Occlusion technique

- Image-plane technique - truly 2D
- Occlude/cover desired object with selector object (e.g. finger)
- Nearest object along ray from eye through finger may be selected

Image Plane Interaction

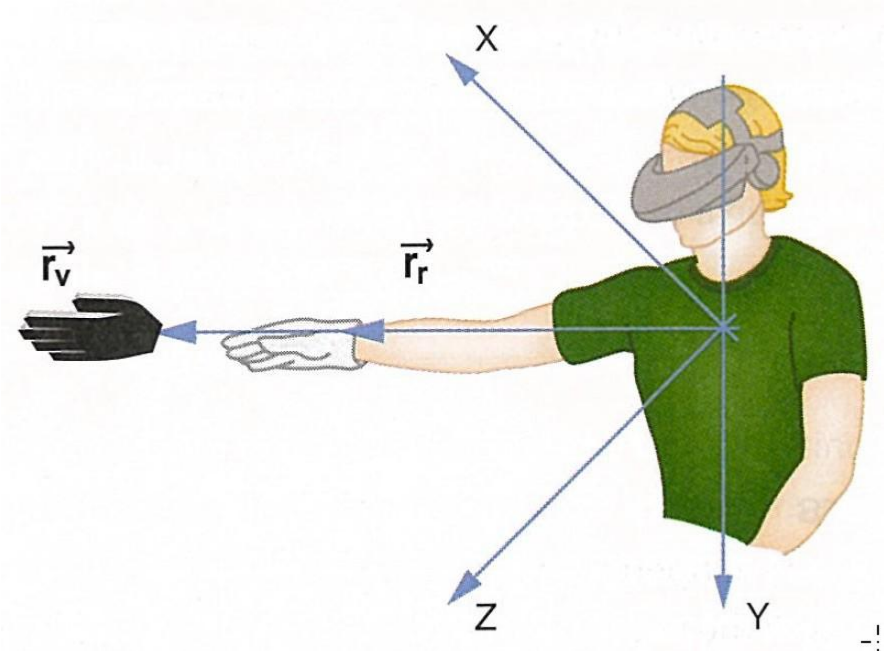


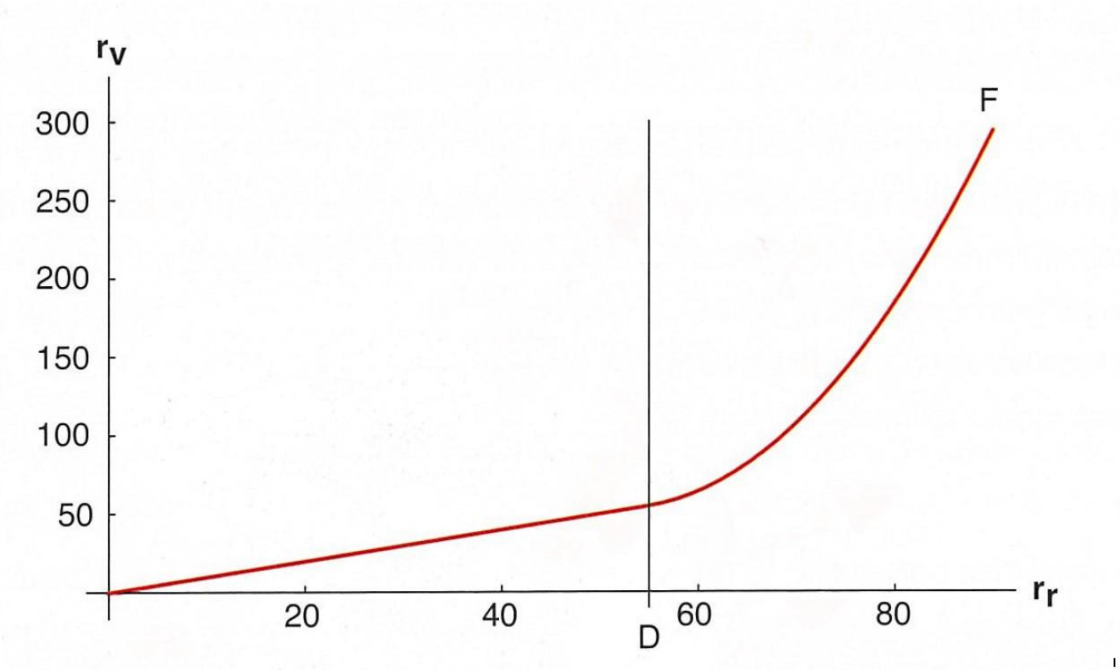
- Pierce, J., Forsberg, A., Conway, M., Hong, S., Zeleznik, R., & Mine, M. (1997). *Image Plane Interaction Techniques in 3D Immersive Environments.* Proceedings of the ACM Symposium on Interactive 3D Graphics, 39-44.

Example

- https://www.youtube.com/watch?v=DBPkE9wsqlY

Go-Go Technique





- Arm-extension technique
- Non-linear mapping between physical and virtual hand position
- Local and distant regions (linear < D, non-linear > D)

Poupyrev, I., Billinghurst, M., Weghorst, S., & Ichikawa, T. (1996). The Go-Go Interaction Technique: Non-linear Mapping for Direct Manipulation in VR. *Proceedings of the ACM Symposium on User Interface Software and Technology,* 79-80.

Precise 3D selection techniques

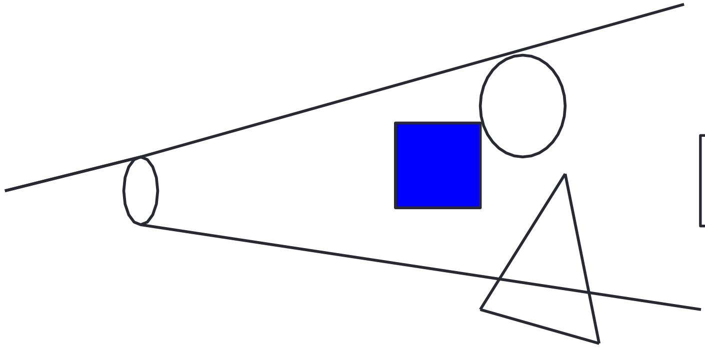
- Increase selection area
  - Cone-casting (Liang, 1993)
  - Snapping (de Haan, 2005)
  - 3D Bubble Cursor (Vanacken, 2007)
  - Sphere-casting (Kopper 2011)

Not ideal for cluttered environments (high density, occlusion)

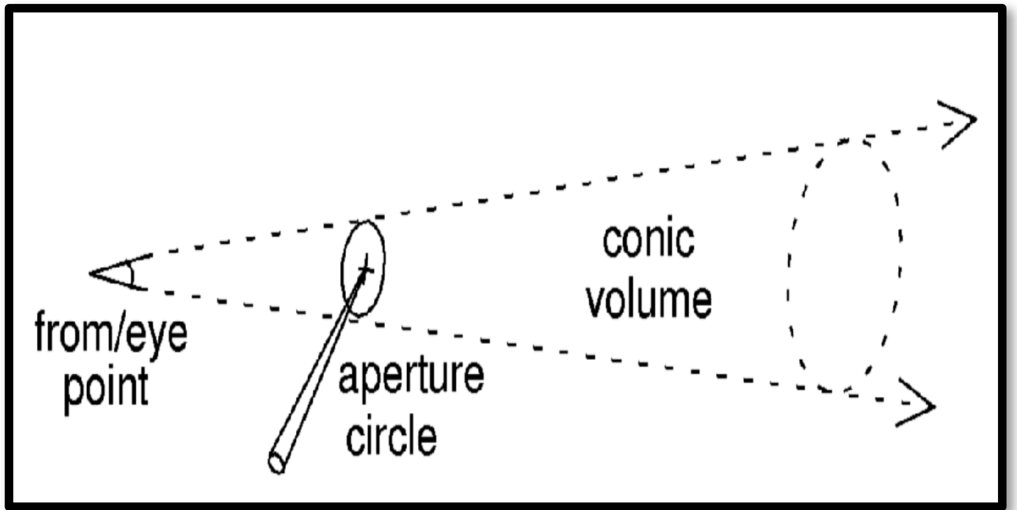
- Increase control/display ratio
  - PRISM (Frees, 2007)
  - ARM (Kopper, 2010)

May require careful interaction

Cone-Casting



Spotlight



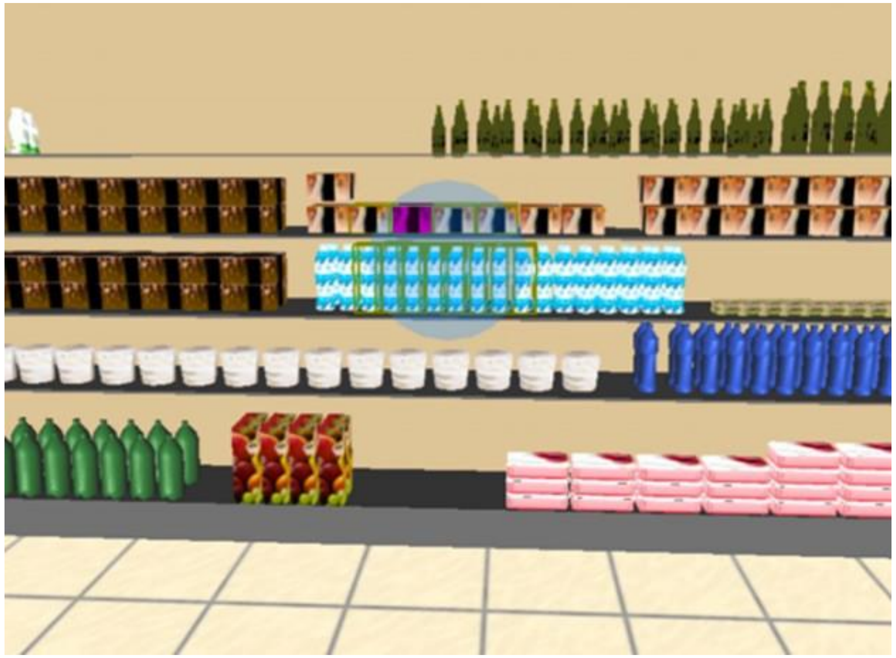
Aperture

Sphere-casting (SQUAD)

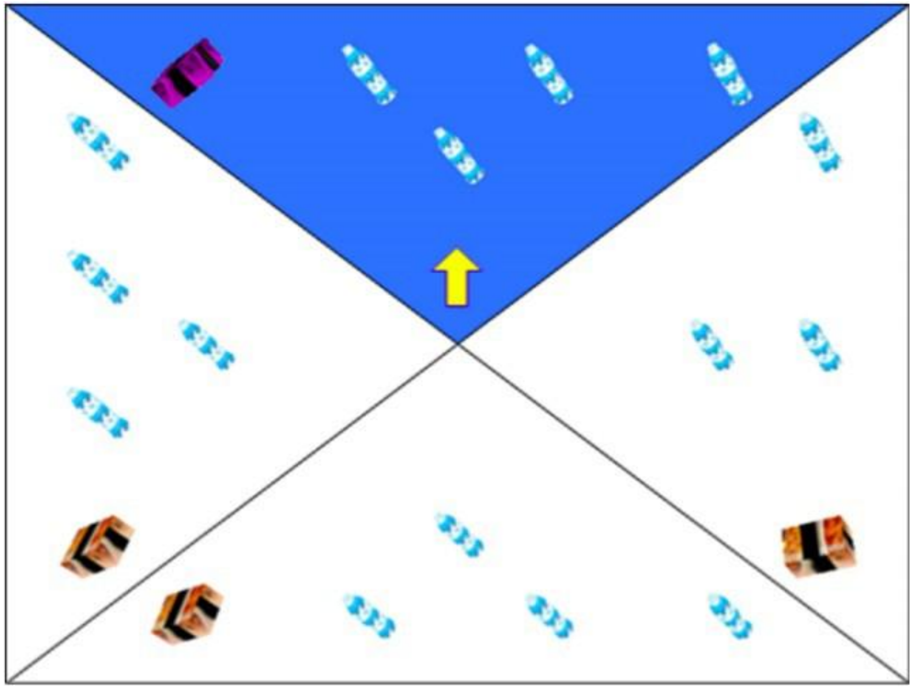
- Two phases
  - Sphere-casting followed by QUAD-menu selection
- Features
  - Multiple low precision selections
  - Scales well – at most $\log_4 n+1$ refinement steps
- Limitations
  - Quad-menu phase is done outside spatial context
  - Target needs to be unique or selectable among identical ones

Kopper, R., Bacim, F., & Bowman, D. A. (2011). Rapid and accurate 3D selection by progressive refinement. In *3D User Interfaces (3DUI), 2011 IEEE Symposium on* (pp. 67-74). IEEE.

SQUAD Selection

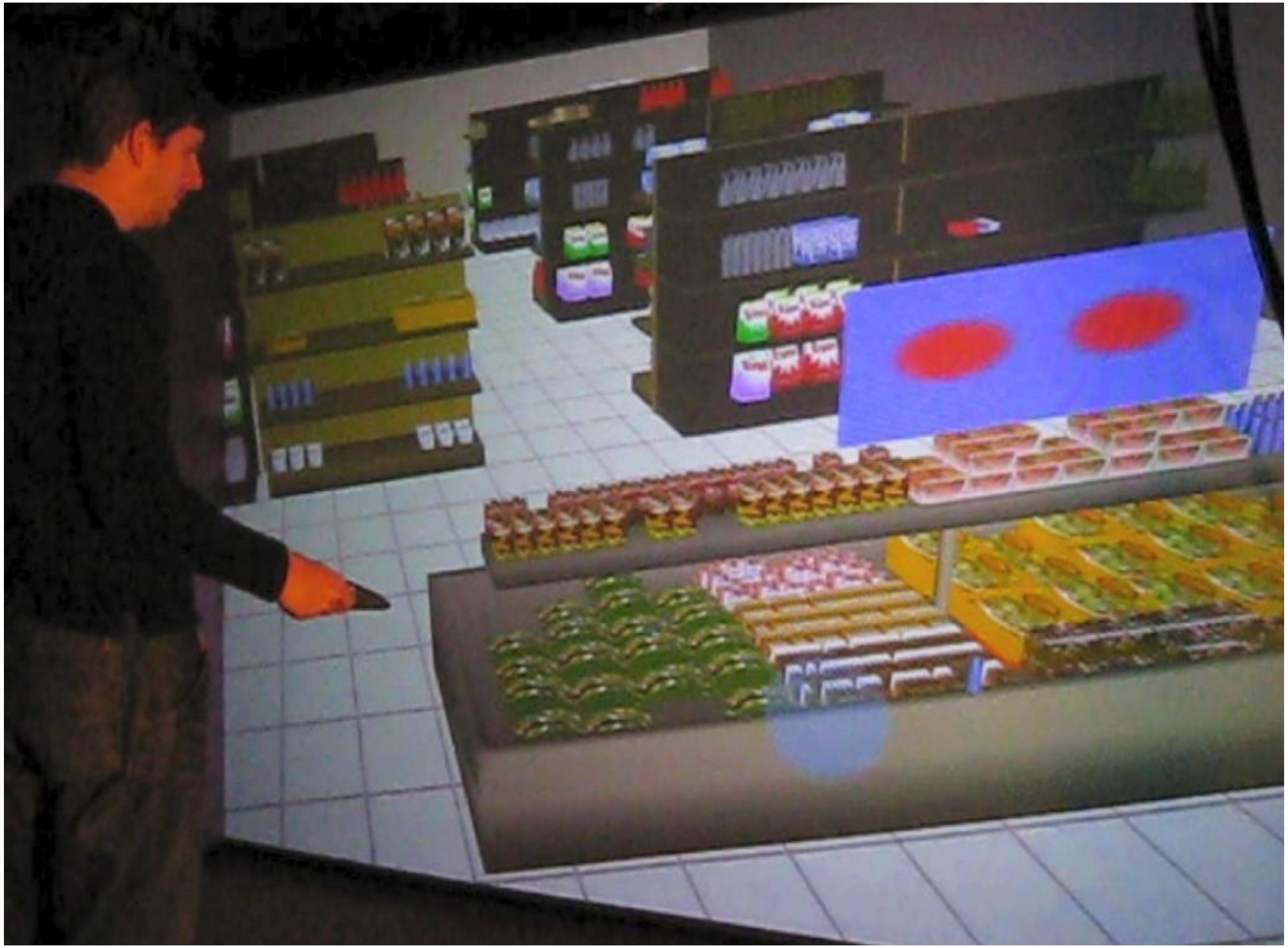


Sphere casting



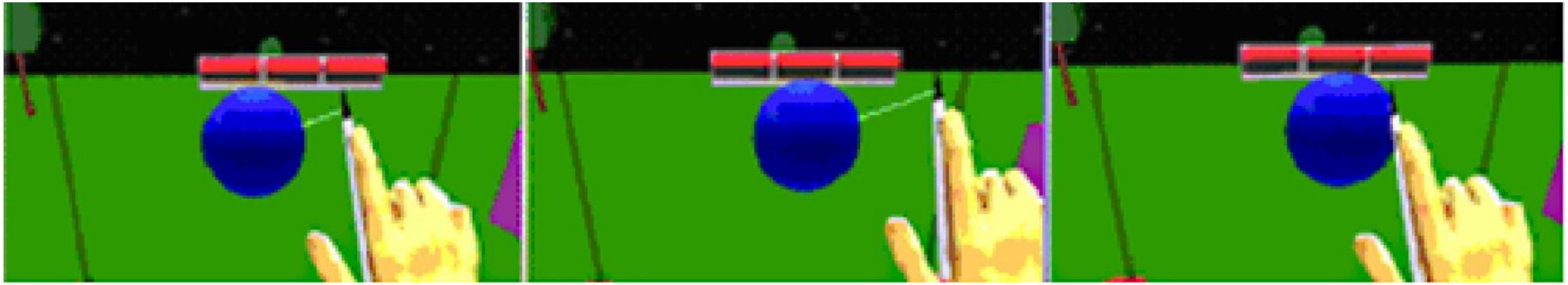
Quad Selection

Example: SQUAD Selection

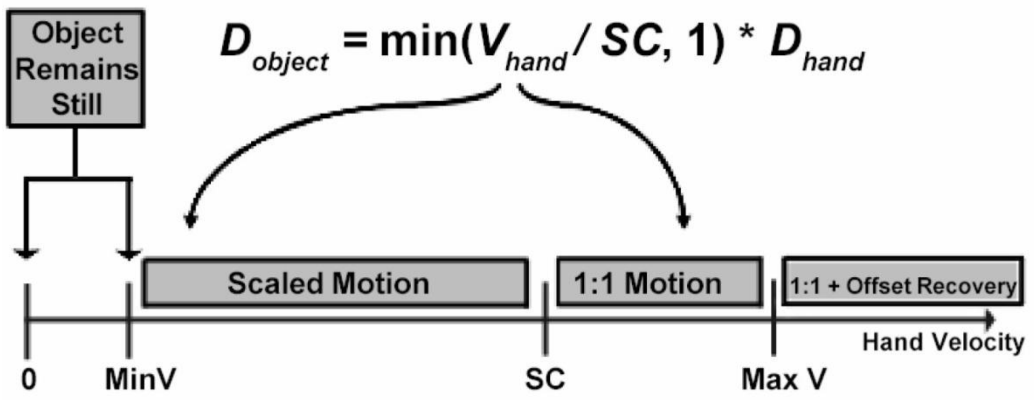


https://www.youtube.com/watch?v=e-4SaOTxf5Y

PRISM (Frees 2005)



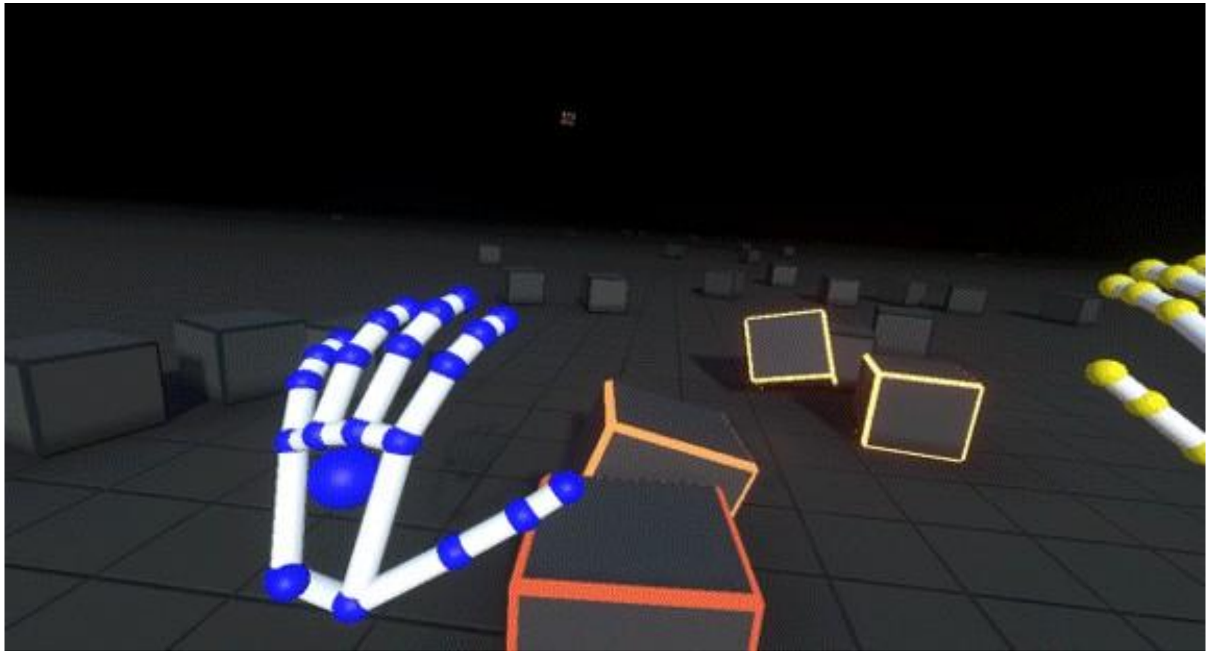
- Change Control/Gain ratio based on hand speed
  - As hand moves slower, scale down object motion
  - As hand moves faster, us 1:1 motion mapping
- Twice the performance for object docking tasks



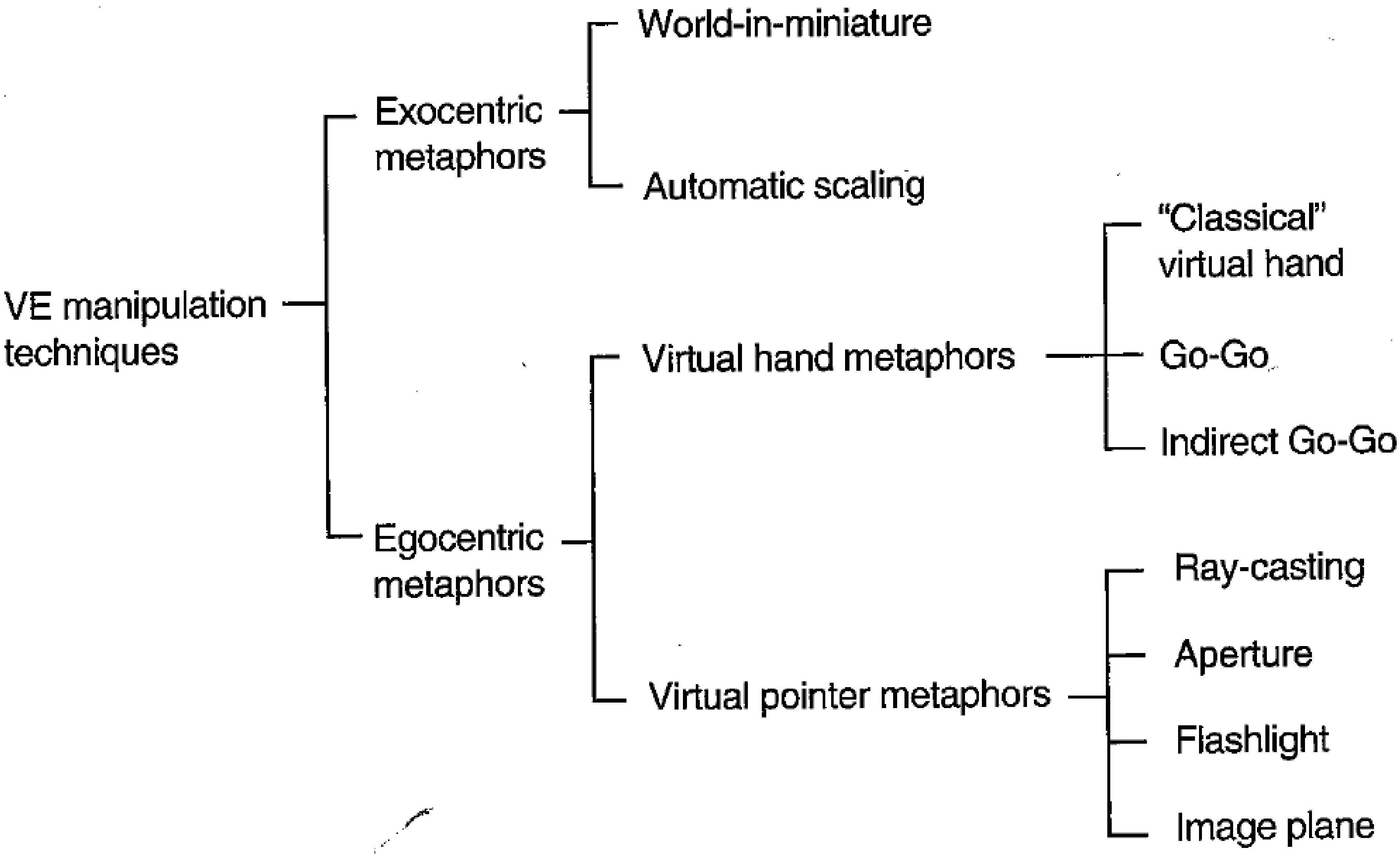
Frees, S., & Kessler, G. D. (2005). Precise and rapid interaction through scaled manipulation in immersive virtual environments. In *Virtual Reality, 2005. Proceedings. VR 2005. IEEE* (pp. 99-106).

Goals of manipulation

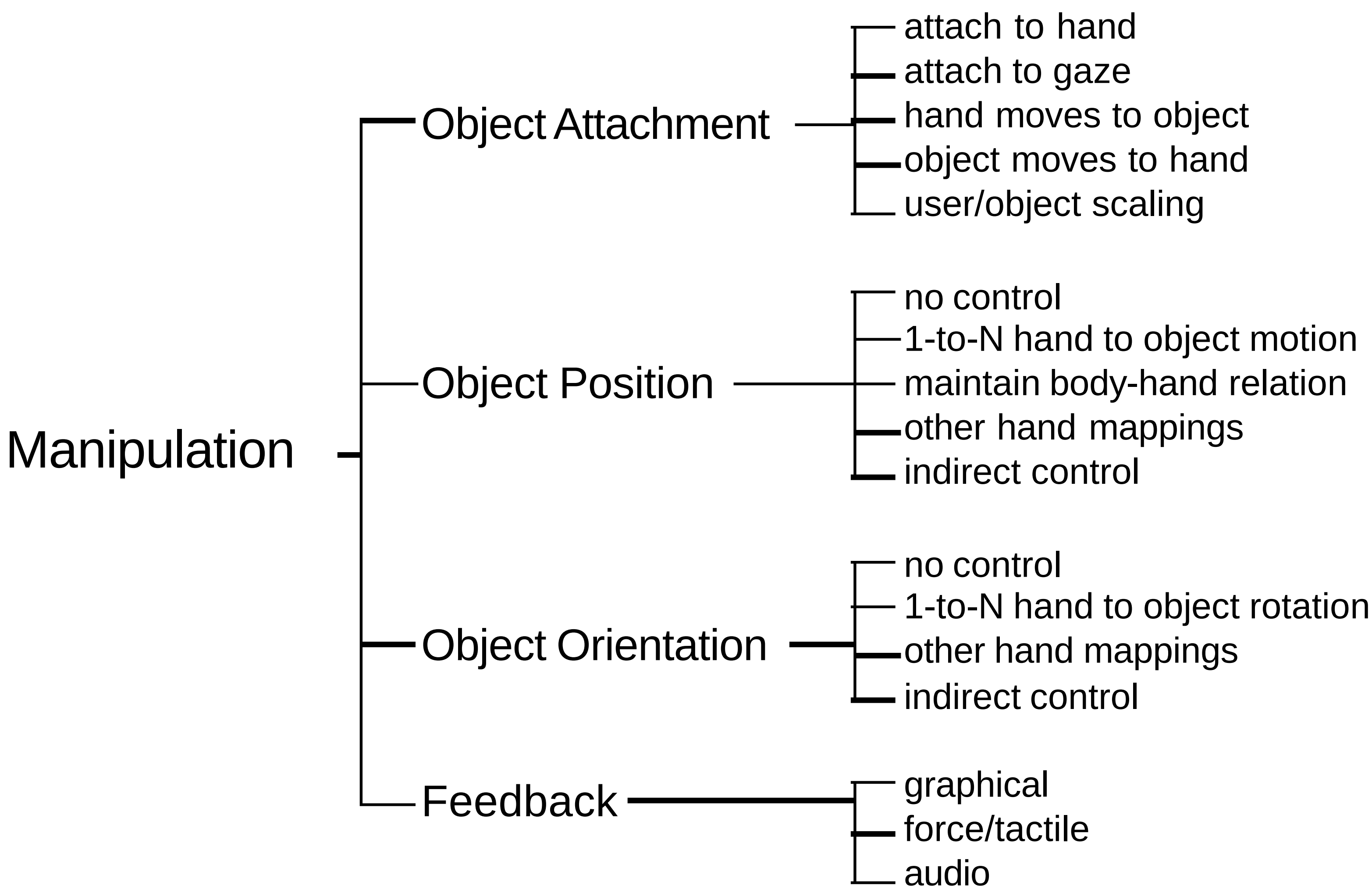
- Object placement
  - Design
  - Layout
  - Grouping
- Tool usage
- Travel



Classification of Manipulation Techniques



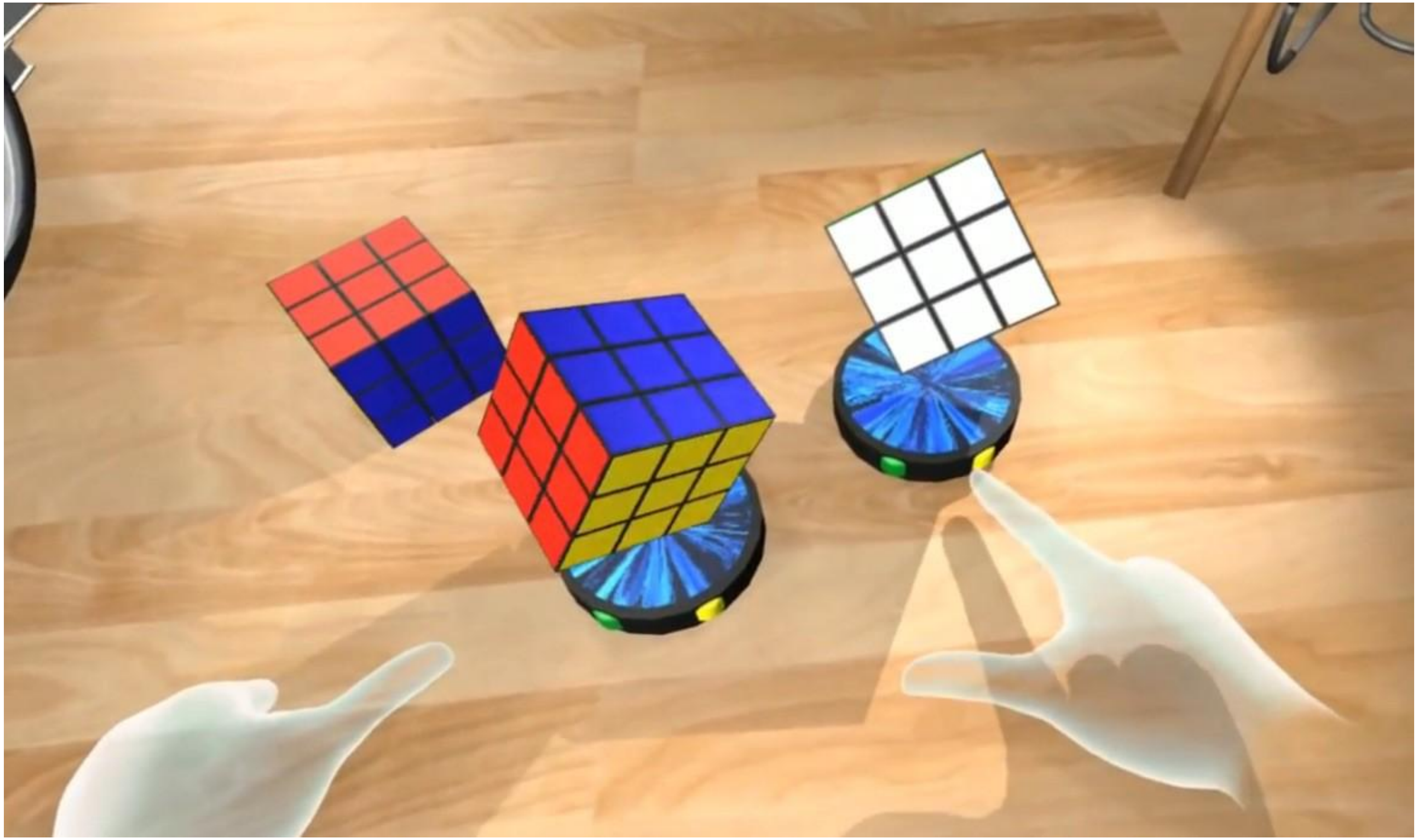
Technique Classification by Components



Common Manipulation Techniques

- Simple virtual hand
- HOMER
- Scaled-world grab
- World-in-miniature

Simple Virtual Hand Manipulation



https://www.youtube.com/watch?v=_OgfREa4ggw

HOMER technique

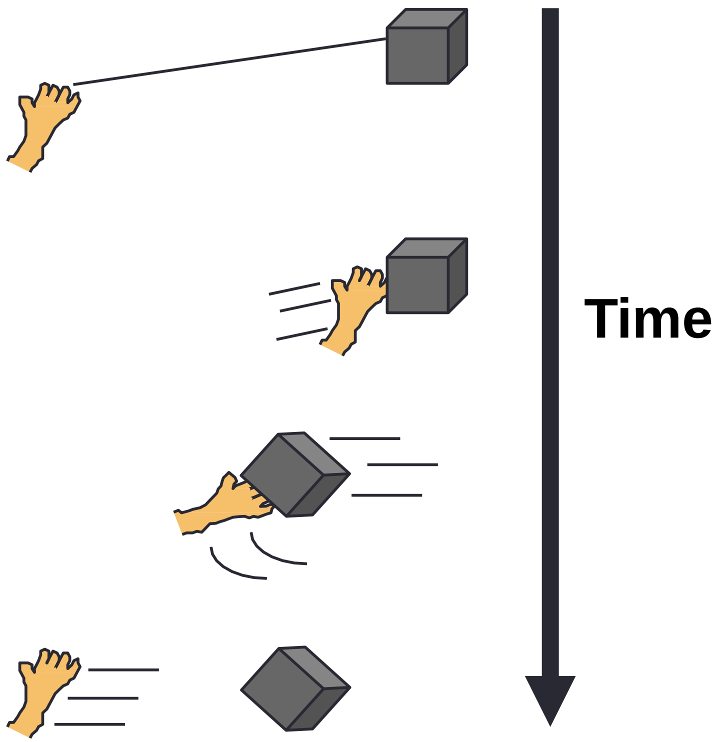
Hand-Centered

Object

Manipulation

Extending

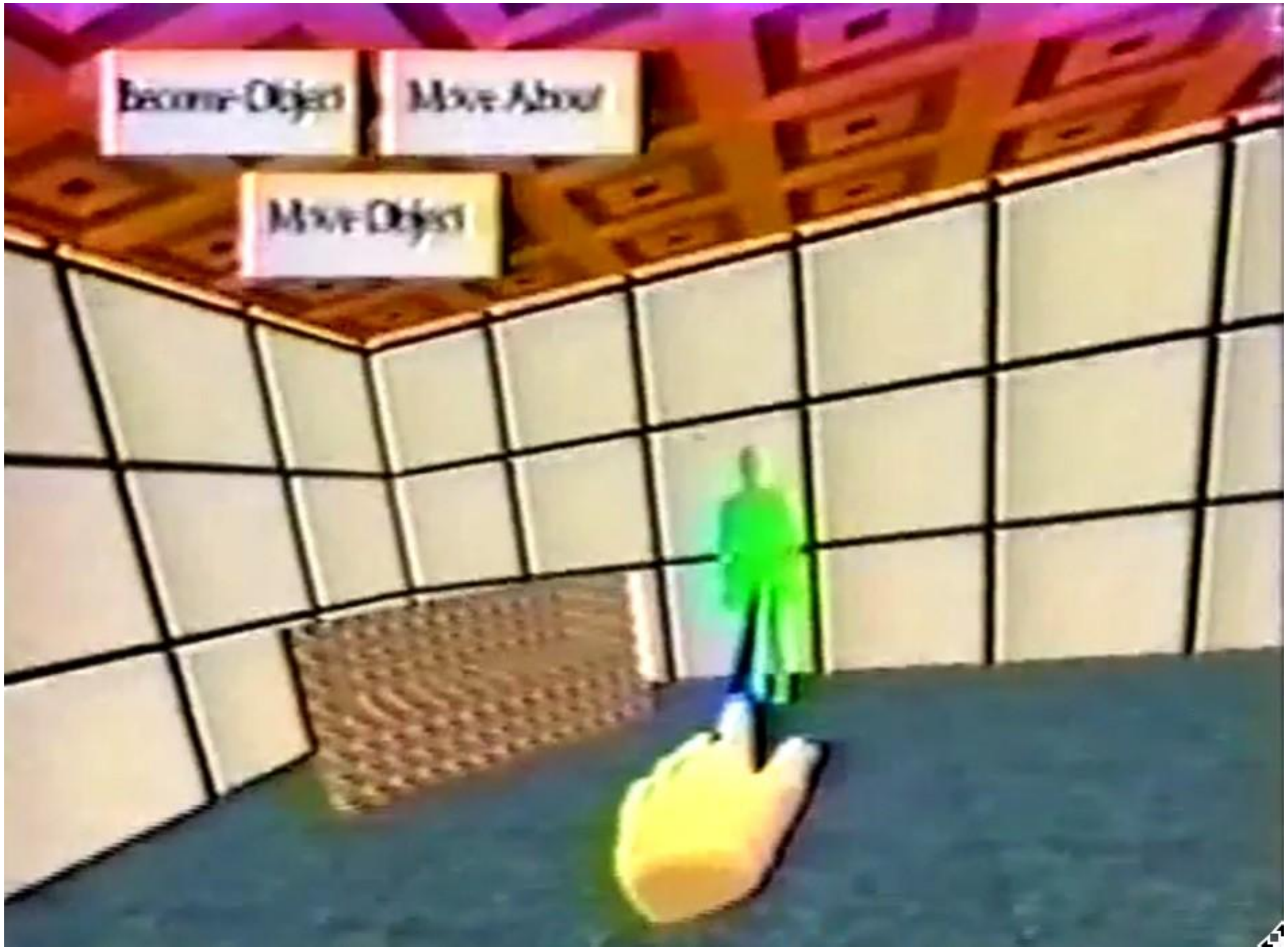
Ray-Casting



- Selection: ray-casting
- Manipulate: directly with virtual hand
- Include linear mapping to allow wider range of placement in depth

Bowman, D., & Hodges, L. (1997). *An Evaluation of Techniques for Grabbing and Manipulating Remote Objects in Immersive Virtual Environments.* Proceedings of the ACM Symposium on Interactive 3D Graphics, 35-38.

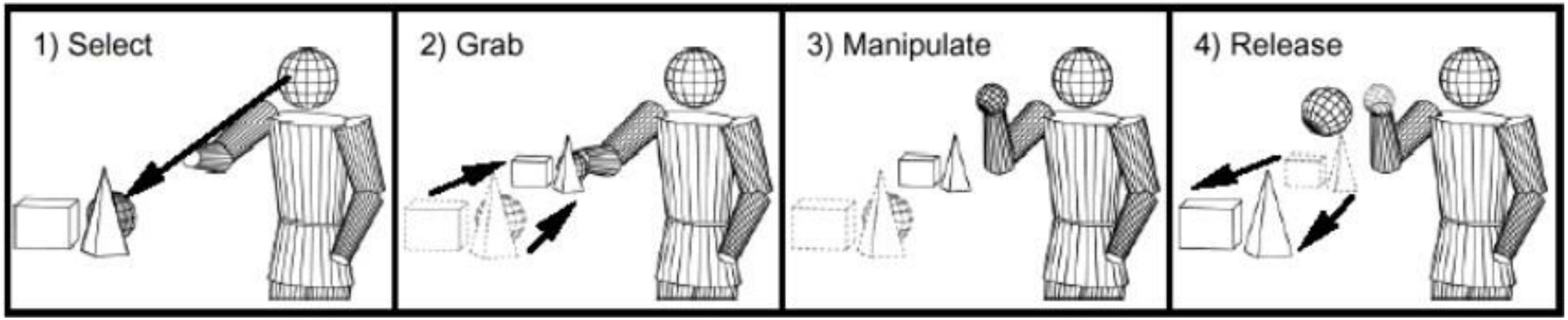
Example



- https://www.youtube.com/watch?v=V6Fo3iza5cY

Scaled-world Grab Technique

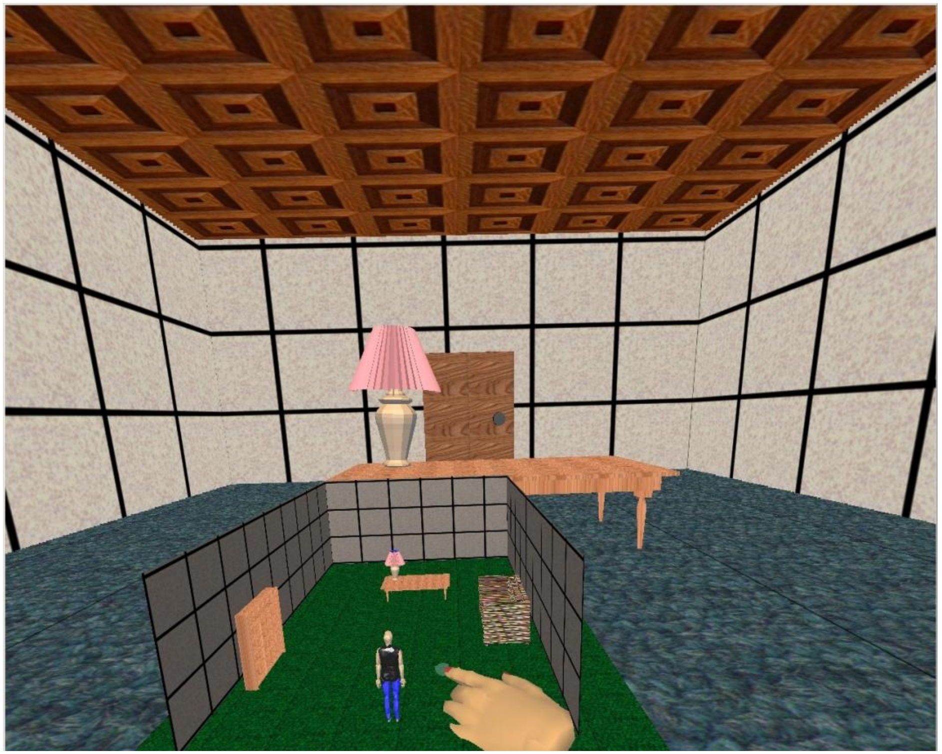
- Often used w/ occlusion
- At selection, scale user up (or world down) so that virtual hand is actually touching selected object
- User doesn‘t notice a change in the image until he moves



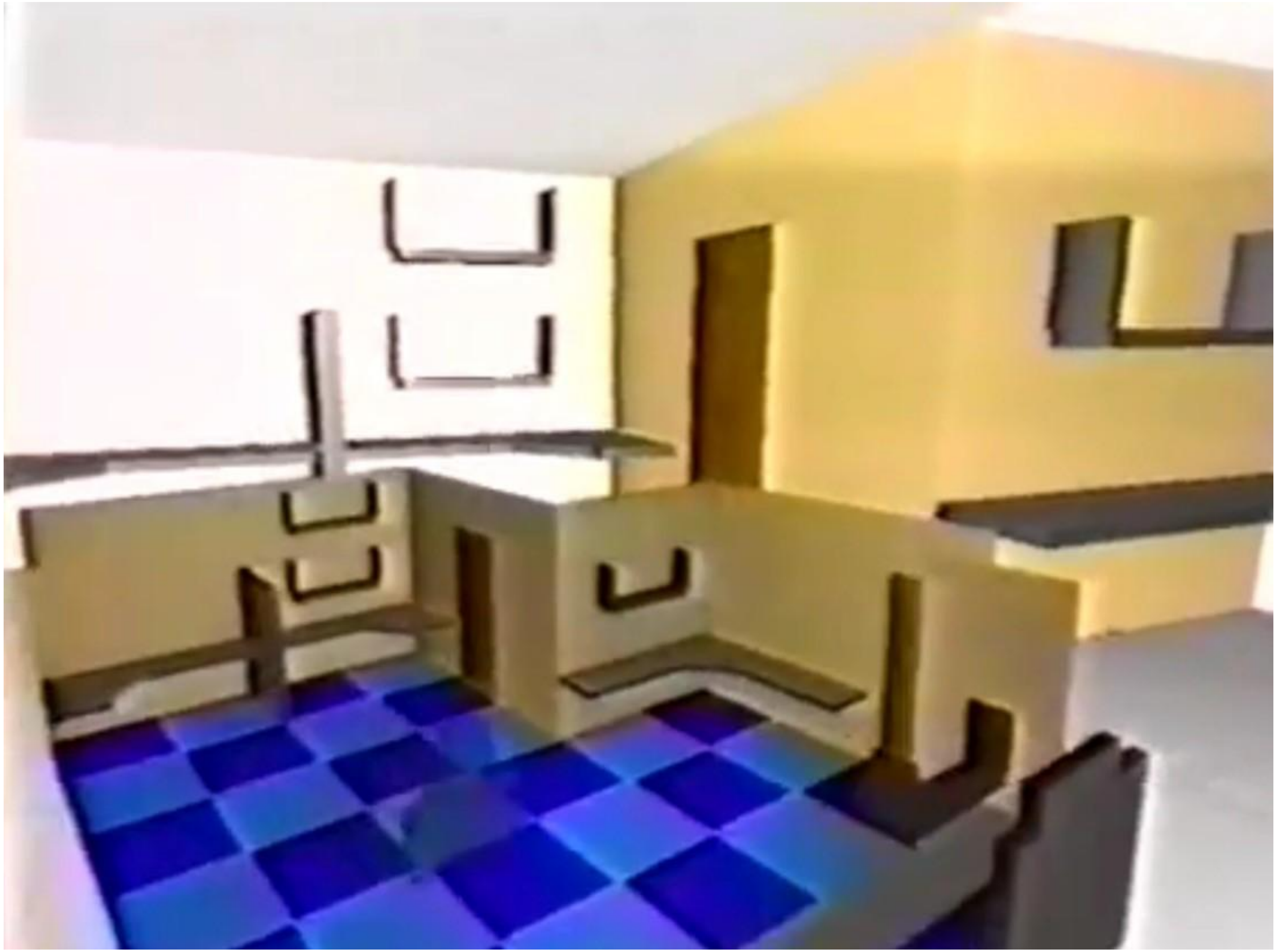
Mine, M., Brooks, F., & Sequin, C. (1997). *Moving Objects in Space: Exploiting Proprioception in Virtual Environment Interaction.* Proceedings of ACM SIGGRAPH, 19-26

World-in-miniature (WIM) technique

- “Dollhouse” world held in user’s hand
- Miniature objects can be manipulated directly
- Moving miniature objects affects full-scale objects
- Can also be used for navigation



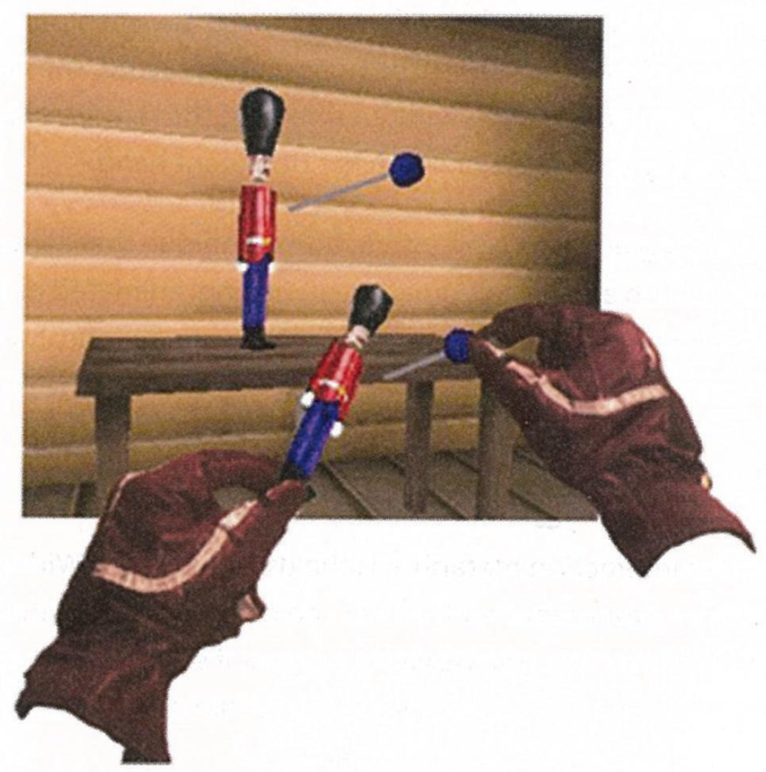
Stoakley, R., Conway, M., & Pausch, R. (1995). *Virtual Reality on a WIM: Interactive Worlds in Miniature.* Proceedings of CHI: Human Factors in Computing Systems, 265-272, and
Pausch, R., Burnette, T., Brockway, D., & Weiblen, M. (1995). *Navigation and Locomotion in Virtual Worlds via Flight into Hand-Held Miniatures.* Proceedings of ACM SIGGRAPH, 399-400.



https://www.youtube.com/watch?v=Ytc3ix-He4E

Voodoo Doll Interaction

- Manipulate miniature objects
  - Act on copy of objects
  - Actions duplicated on actual object
  - Supports action at a distance
- Two handed technique
  - One hand sets stationary reference frame
  - Second hand manipulates object



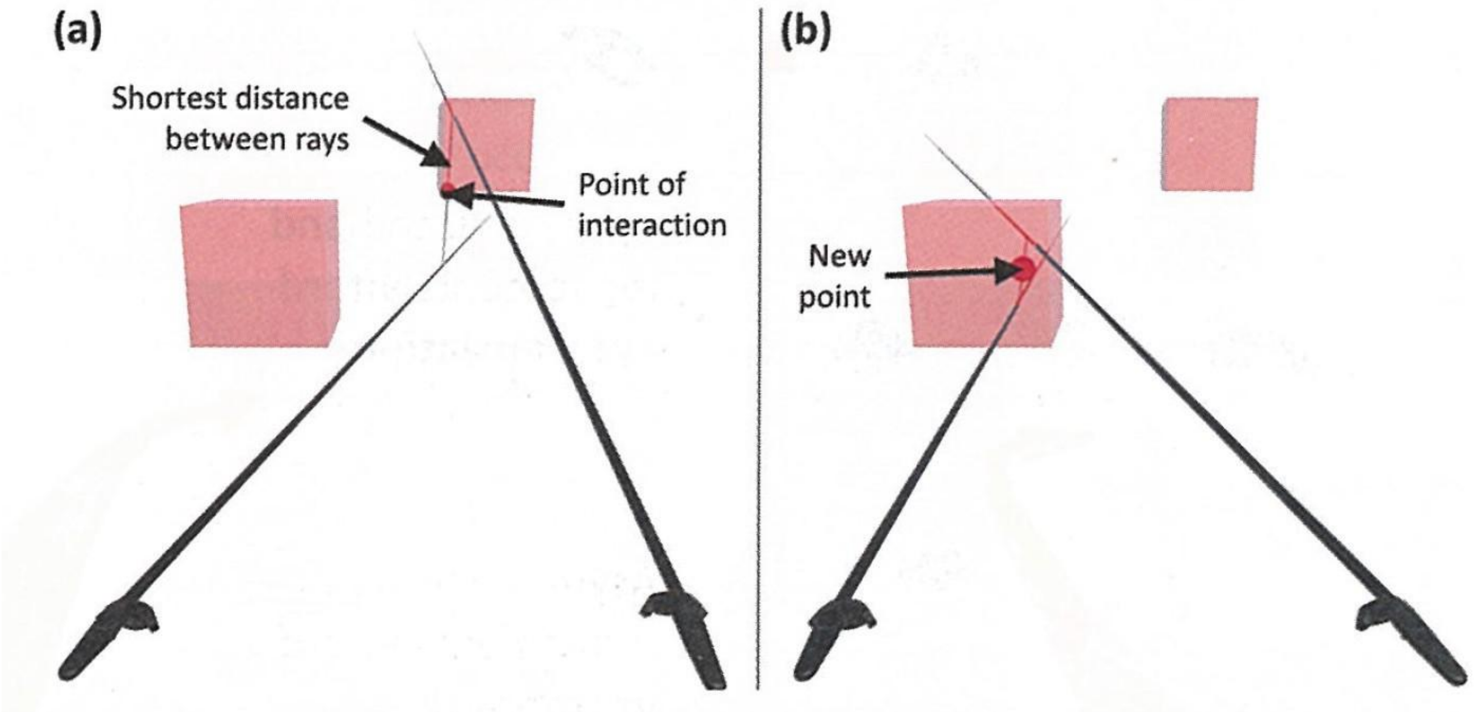
Pierce, J. S., Stearns, B. C., & Pausch, R. (1999). Voodoo dolls: seamless interaction at multiple scales in virtual environments. In *Proceedings of the 1999 symposium on Interactive 3D graphics* (pp. 141-145). ACM.

Two-Handed Interaction

- Symmetric vs. Asymmetric
  - Symmetric: both hands performing same actions
  - Asymmetric: both hands performing different actions
- Dominant (D) vs. non-dominant (ND) hand
  - Guiard’s principles
  - ND hand provides frame of reference
  - ND hand used for coarse tasks, D hand for fine-grained tasks
  - Manipulation initiated by ND hand

Guiard, Y., "Asymmetric Division of Labor in Human Skilled Bimanual Action: The Kinematic Chain as a Model," *J. Motor Behavior*, 19 (4), 1987, pp. 486-517.

Symmetric Bimanual Technique

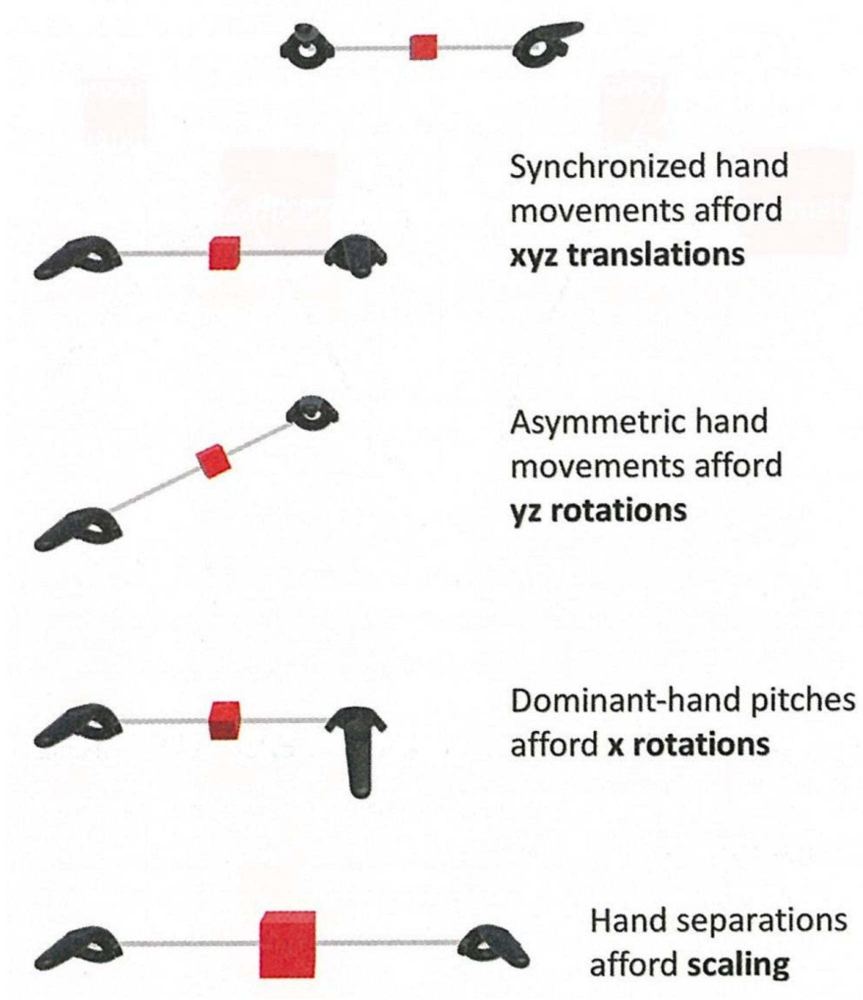


- iSith (Wyss 2006)
- Using two 6 DOF controllers each ray casting
- Intersection point of two rays determines interaction point

Wyss, H. P., Blach, R., & Bues, M. (2006, March). iSith-Intersection-based spatial interaction for two hands. In *3D User Interfaces, 2006. 3DUI 2006. IEEE Symposium on* (pp. 59-61). IEEE.

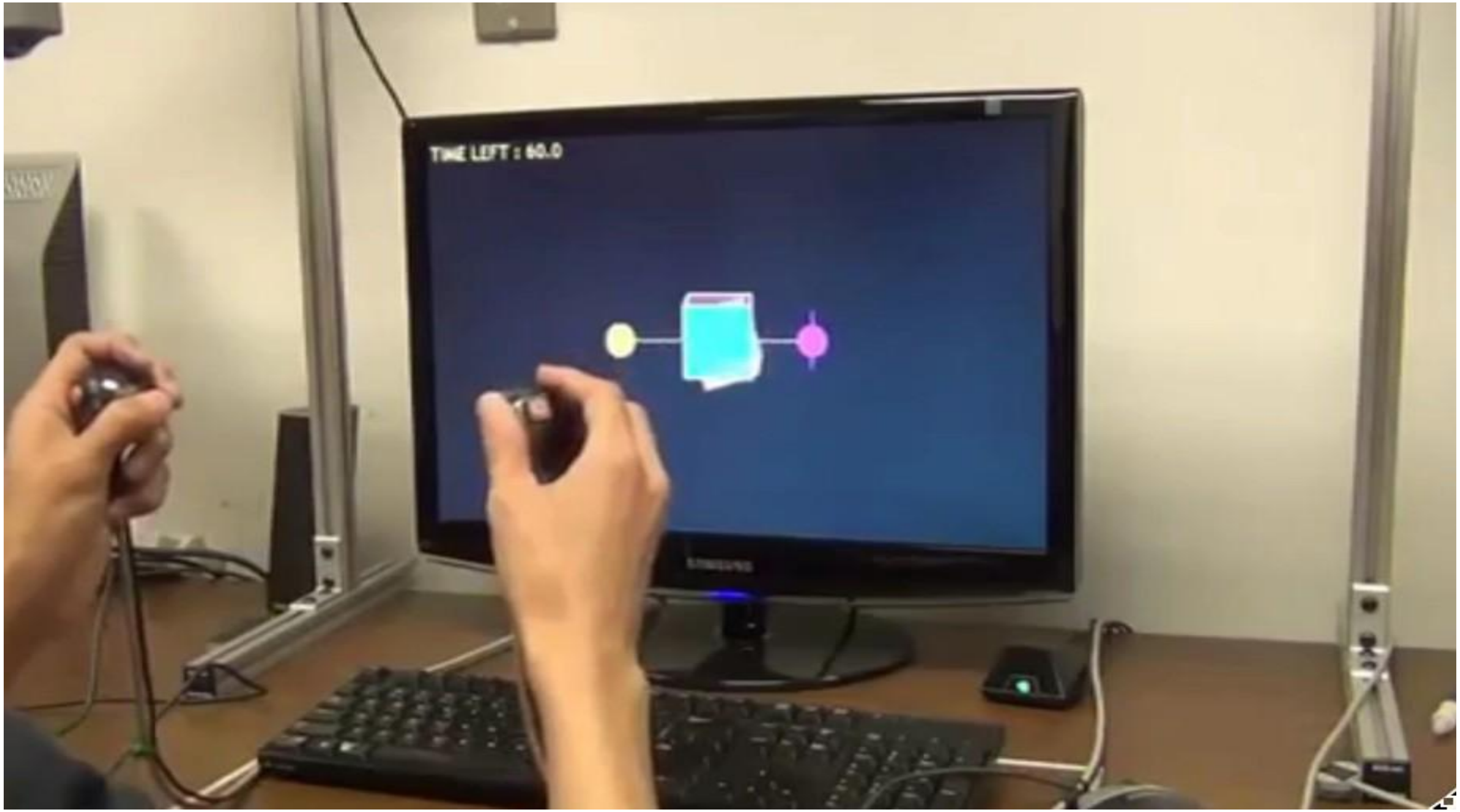
Asymmetric Bimanual Technique

- Spindle + Wheel (Cho 2015)
- Two 6 DOF handheld controls
  - One dominant, one ND
- Movement one hand relative to other provides 7 DOF input



Cho, I., & Wartell, Z. (2015). Evaluation of a bimanual simultaneous 7DOF interaction technique in virtual environments. In *3D User Interfaces, 2015 IEEE Symposium on* (pp. 133-136). IEEE.

Demo: Spindle + Wheel 7 DOF Input



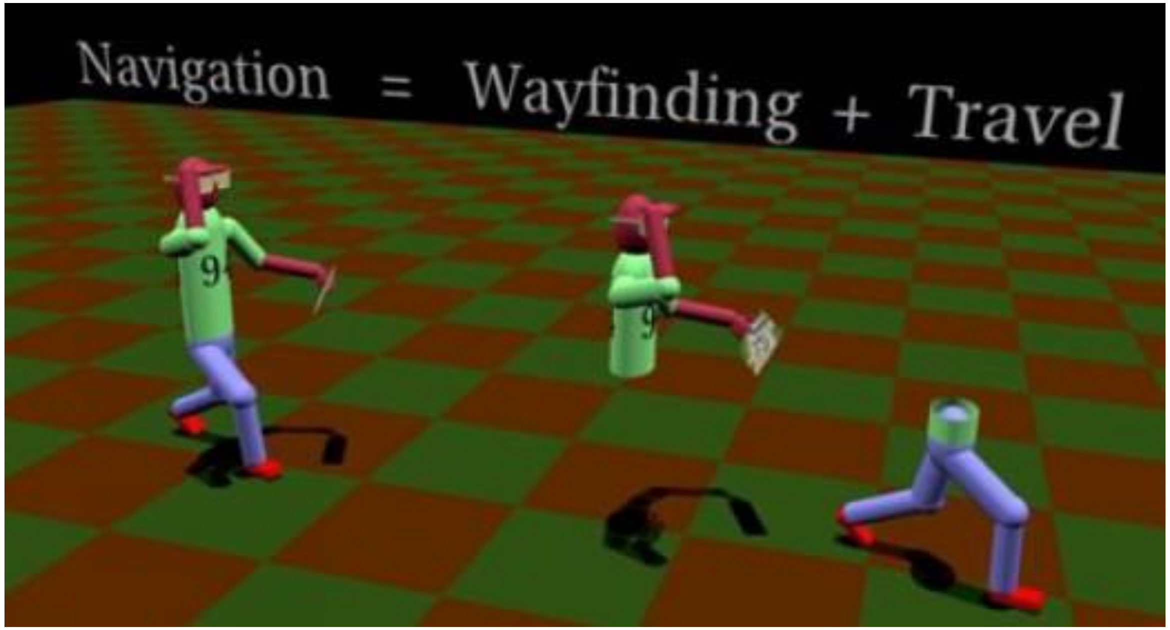
- https://www.youtube.com/watch?v=nF4egFHyLYM

Design Guidelines for Manipulation

- There is no single best manipulation technique
- Map the interaction technique to the device
- Reduce degrees of freedom when possible
- Use techniques that can help to reduce clutching
- Consider the use of grasp-sensitive object selection
- Use pointing techniques for selection and grasping techniques for manipulation
- Use existing techniques unless there is a large amount of benefit from designing a new application-specific method
- Consider the trade-off between technique design and environmental design

NAVIGATION

Navigation



- How we move from place to place within an environment
- The combination of travel with wayfinding
  - *Wayfinding*: cognitive component of navigation
  - *Travel:* motor component of navigation
- Travel without wayfinding: "exploring", "wandering”

Travel

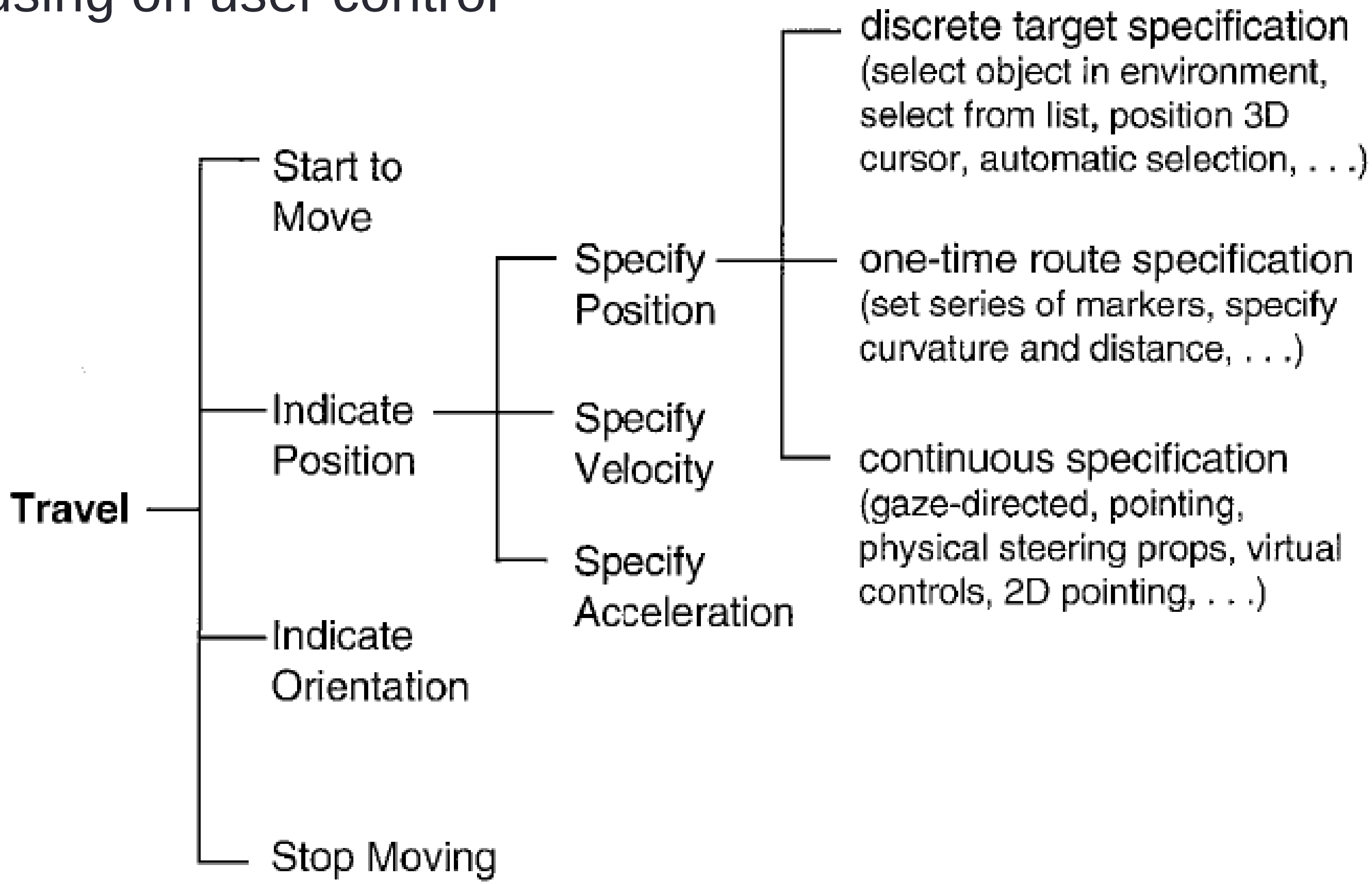
- The motor component of navigation
- Movement between 2 locations, setting the position (and orientation) of the user's viewpoint
- The most basic and common VE interaction technique, used in almost any large-scale VE

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
- Maneuvering
  - Short, precise movements changing viewpoint

Movement Process

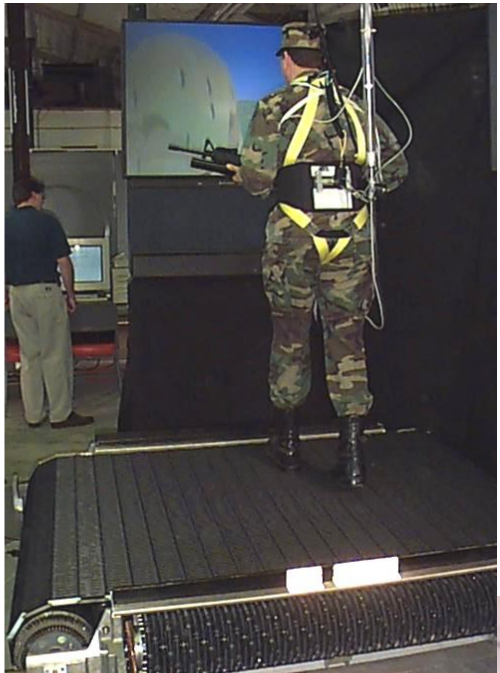
- Focusing on user control



Technique classification

- Physical locomotion metaphors
  - treadmills, cycles, etc…
- Steering metaphor
- Route planning metaphor
- Target specification metaphor
- Manual manipulation metaphor
- Scaling metaphor

Different Locomotion Devices





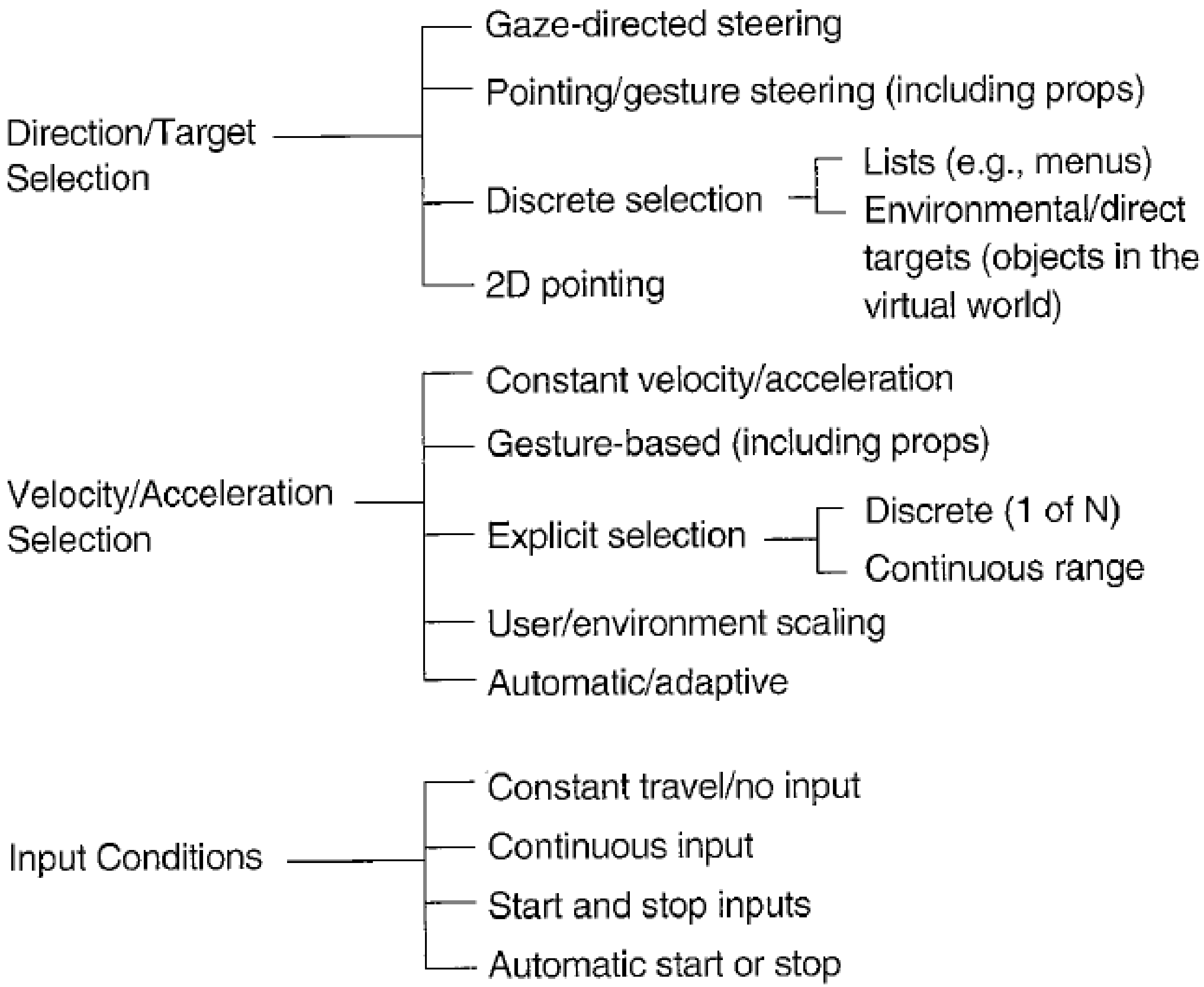
Classification of Travel and Locomotion

Can classify locomotion devices in terms of real vs. virtual travel

	Virtual turning	**Real turning**
Virtual translation	Desktop VEs Vehicle simulators CAVE wand	Most HMD systems Walking in place Magic Carpet
Real translation	Stationary cycles Treadport Biport	Wide-area tracking UNIPORT ODT

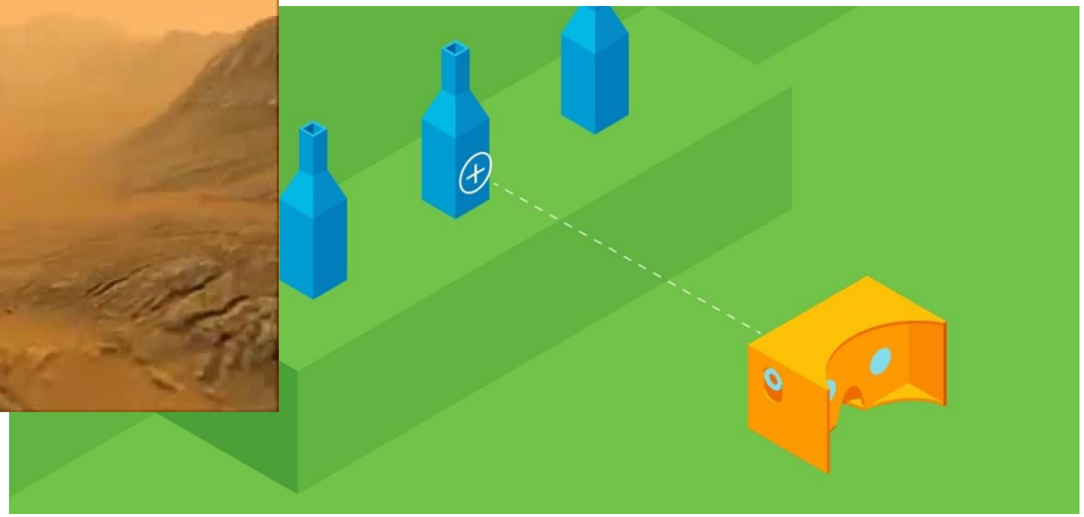
Taxonomy of Travel Techniques

- Focusing on sub-task of travel



Bowman, D. A., Koller, D., & Hodges, L. F. (1997, March). Travel in immersive virtual environments: An evaluation of viewpoint motion control techniques. In *Virtual Reality Annual International Symposium, 1997., IEEE 1997* (pp. 45-52). IEEE.

Gaze Directed Steering

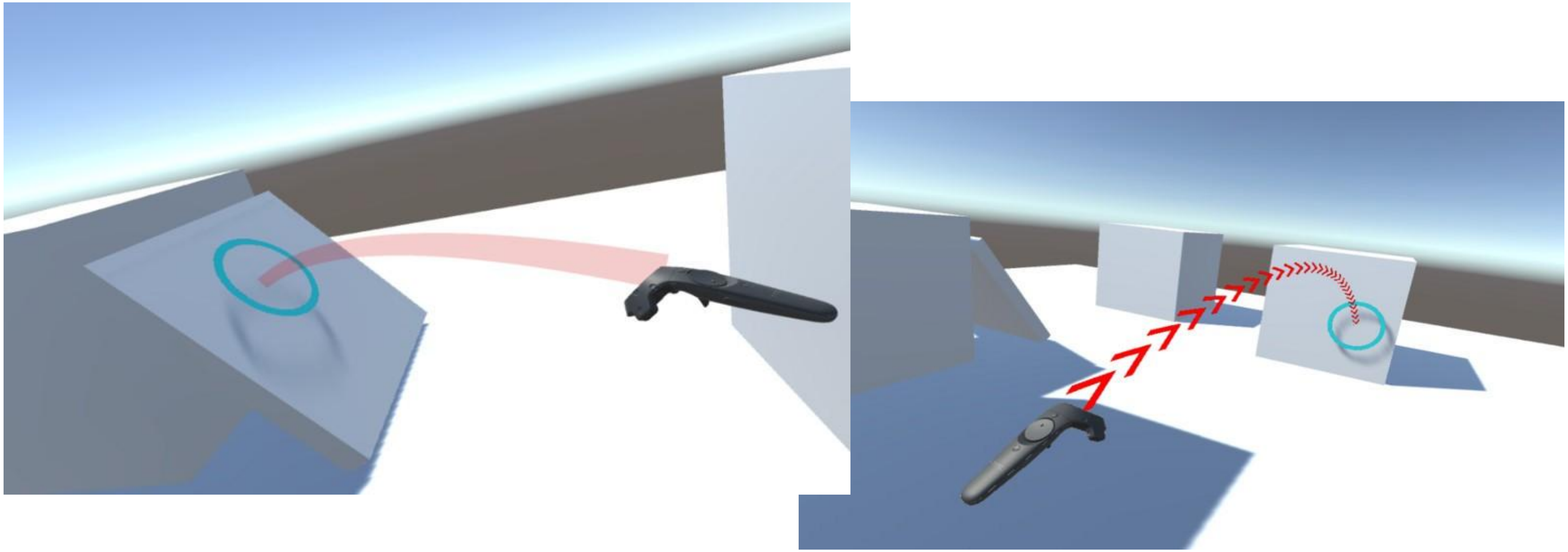


- Move in direction that you are looking
- Very intuitive, natural navigation
- Can be used on simple HMDs (e.g. Google Cardboard)
- But: Can’t look in different direction while moving

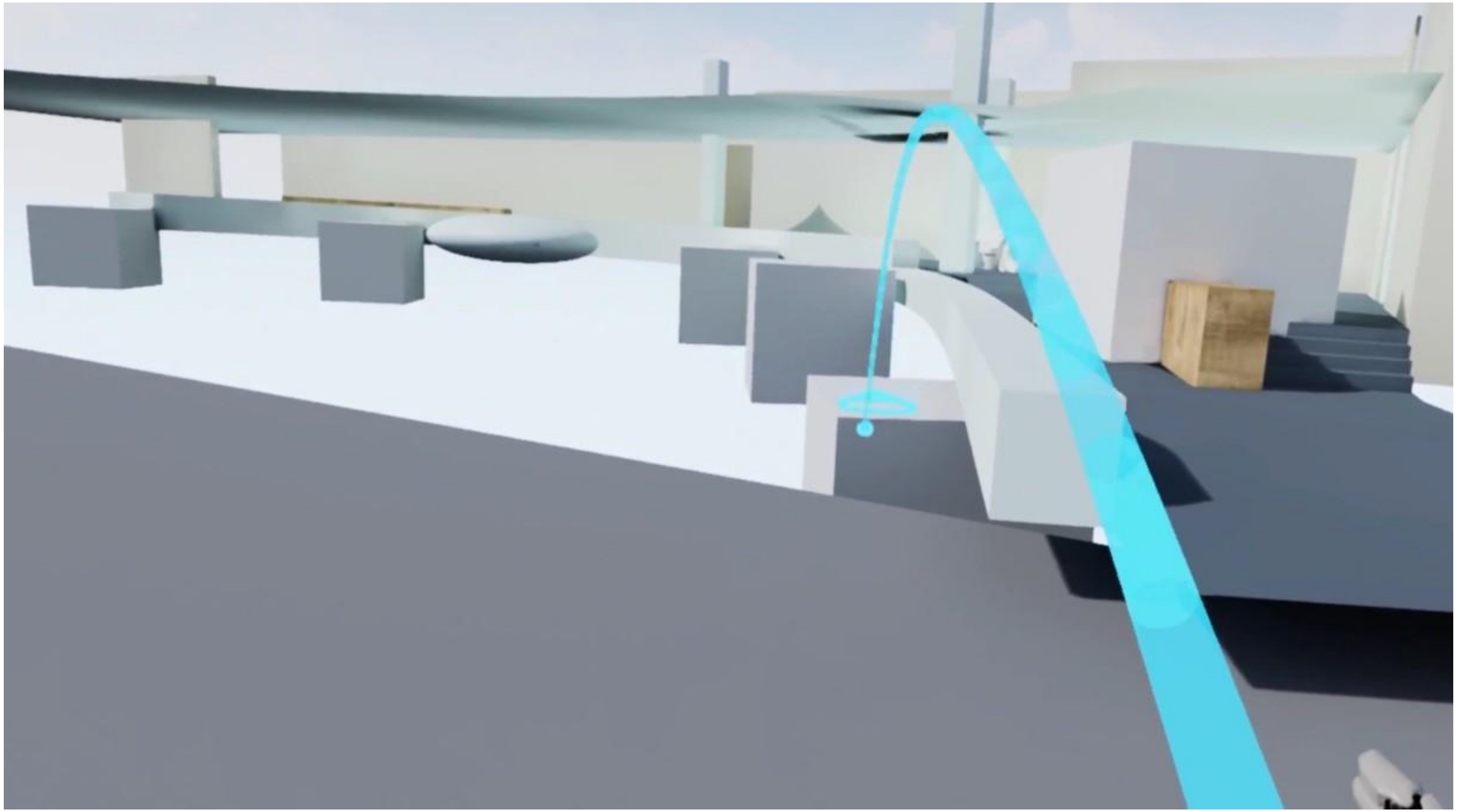
Example: Gaze Directed Steering

- https://www.youtube.com/watch?v=6iKxser1Wic

TelePortation

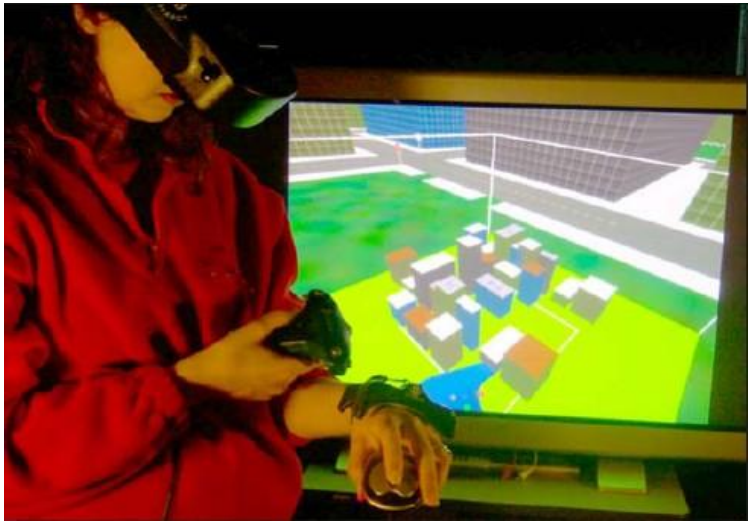


- Use controller to select end point
  - Usable with 3DOF contoller
- Jump to a fixed point in VR
- Discrete motion can be confusing/cause sickness



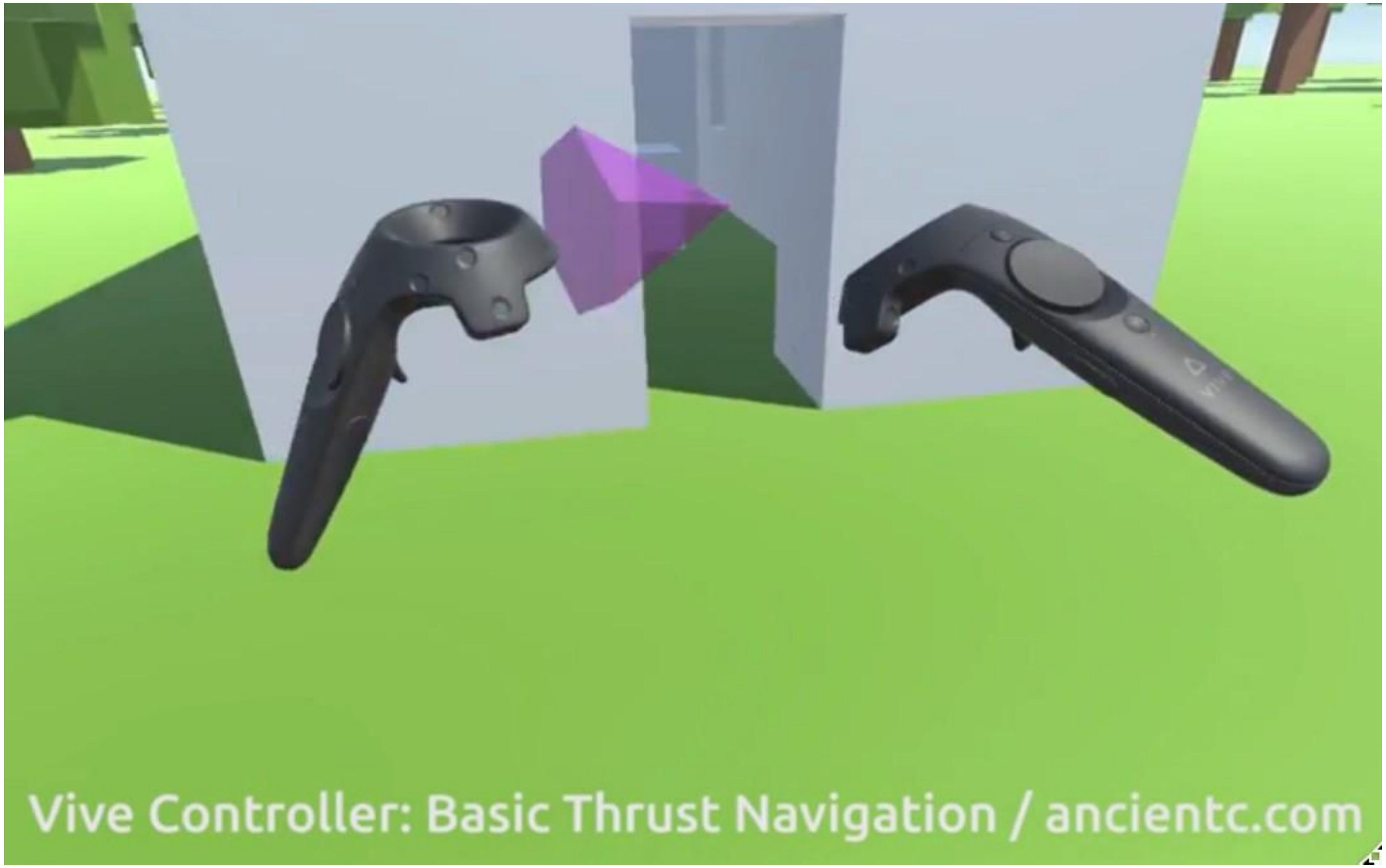
https://www.youtube.com/watch?v=SbxgNnOeyF8

Pointing Technique



- A “steering” technique
- Use hand tracker instead of head tracker
  - Point in direction you want to go
- Slightly more complex, than gaze-directed steering
- Allows travel and gaze in different directions
  - good for relative motion, look one way, move another

Example: VIVE Thrust



- https://www.youtube.com/watch?v=JRgCe_8q4vE

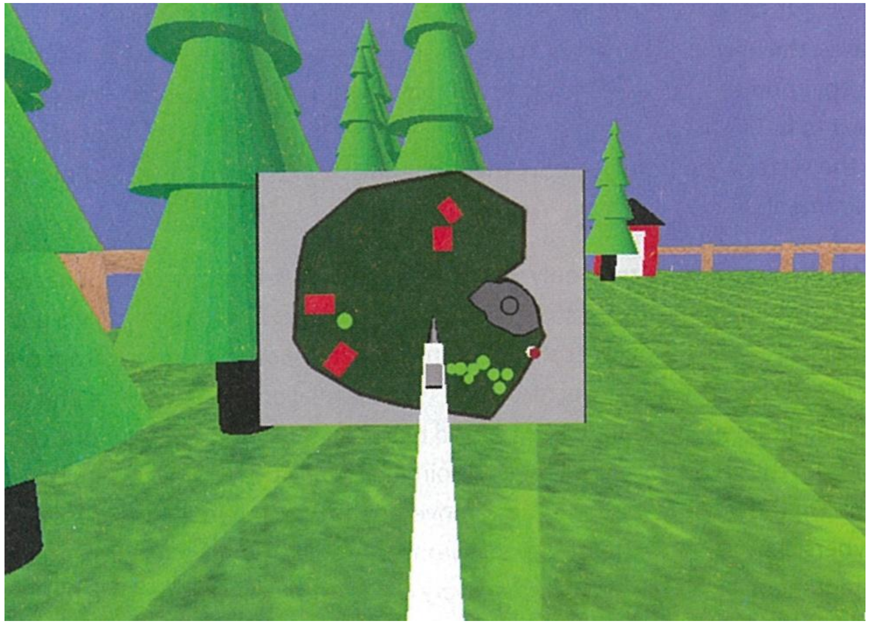
Grabbing the Air Technique

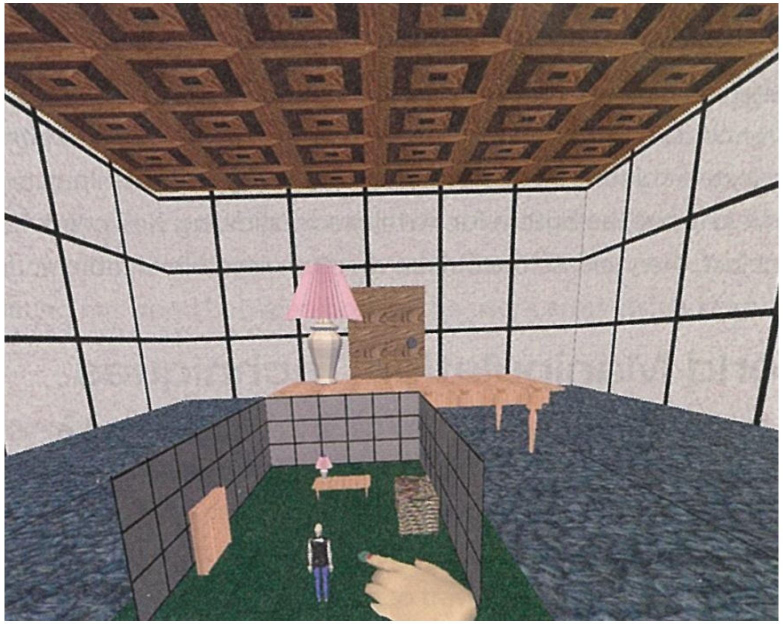
- Use hand gestures to move yourself through the world
- Metaphor of pulling a rope
- Often a two-handed technique
- May be implemented using Pinch Gloves

Mapes, D., & Moshell, J. (1995). A Two-Handed Interface for Object Manipulation in Virtual Environments. *Presence: Teleoperators and Virtual Environments, 4*(4), 403-416.

Moving Your Own Body



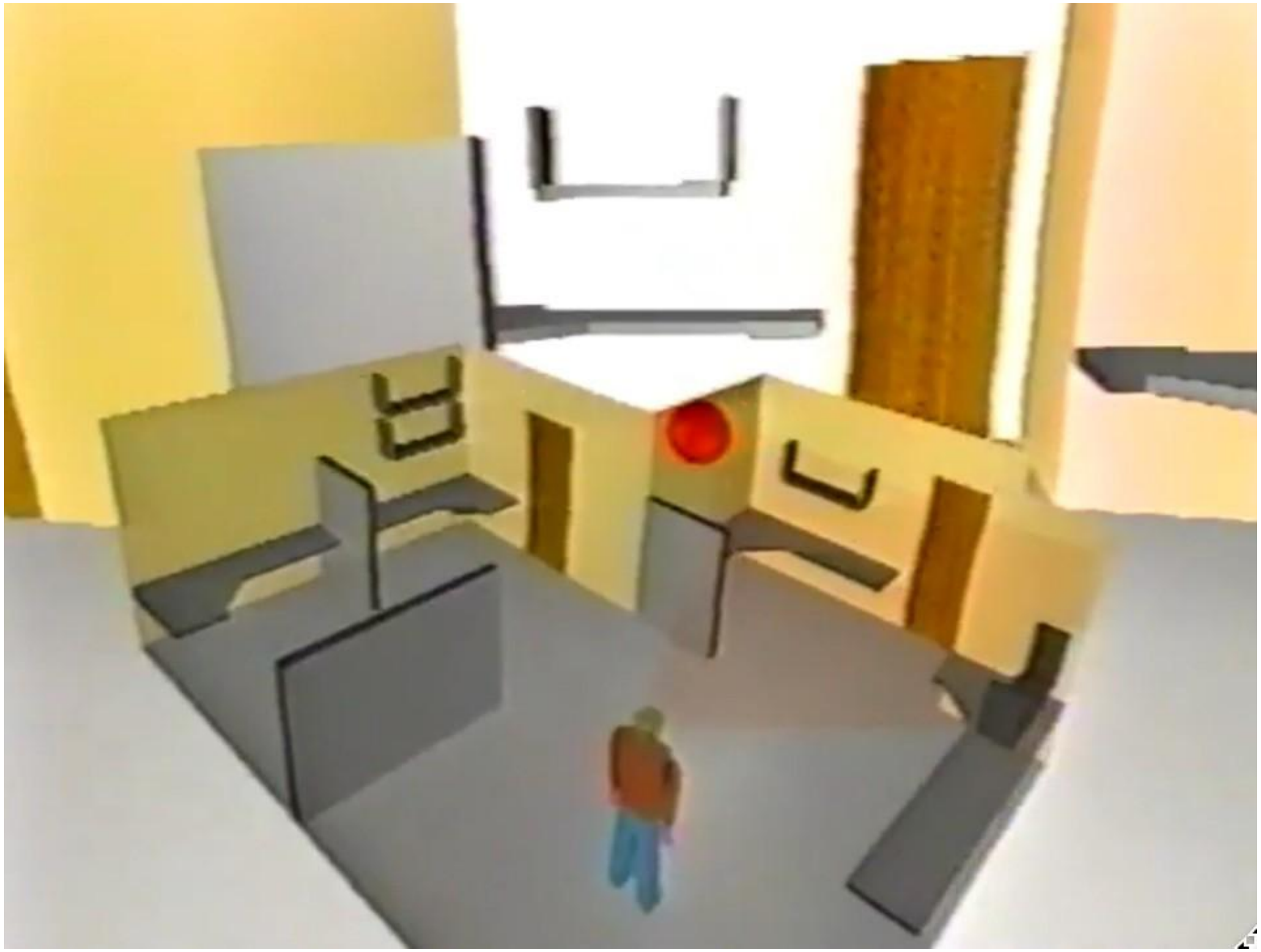
Moving avatar in Map View



Moving avatar in WIM view

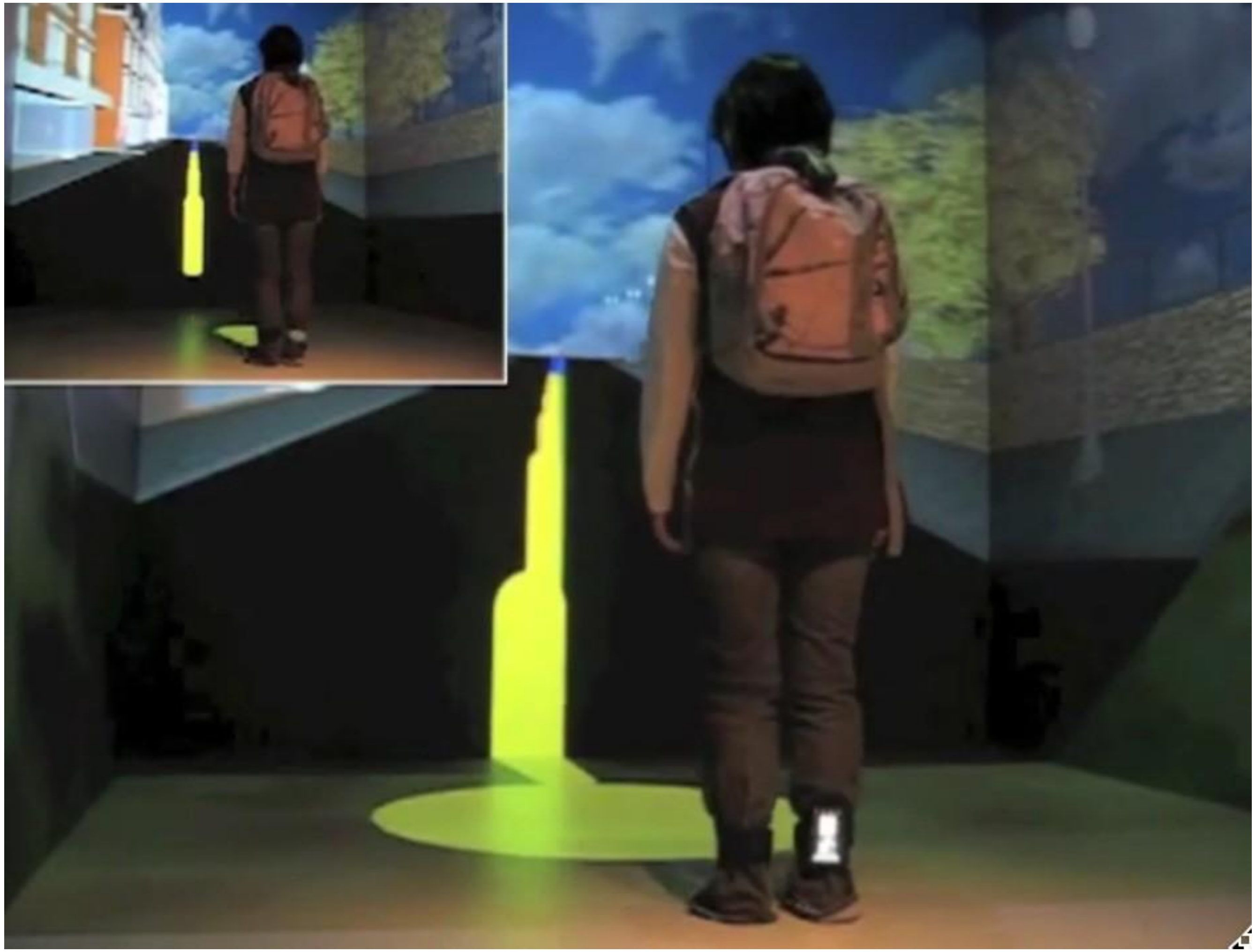
- Can move your own body
  - In World in Miniature, or map view
- Grab avatar and move to desired point
- Immediate teleportation to new position in VE

Example: Navigation Using WIM



- https://www.youtube.com/watch?v=VxGqIjMlTs8

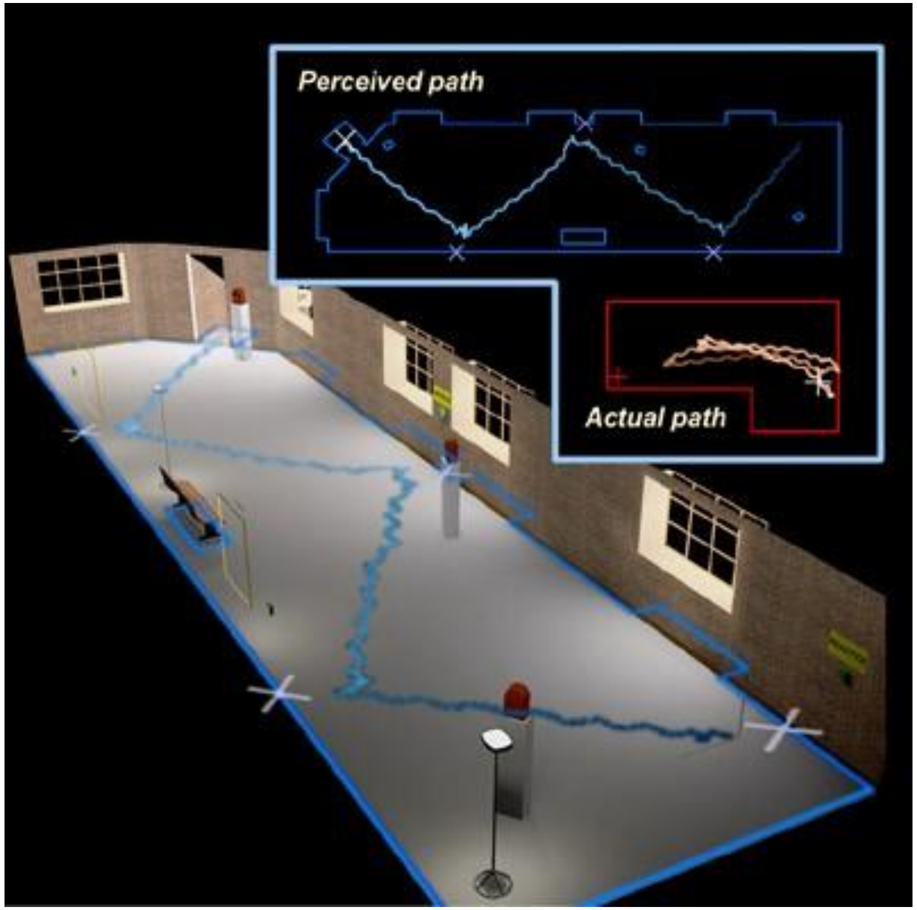
Walking in Place



- https://www.youtube.com/watch?v=J_yQfW1qYGI

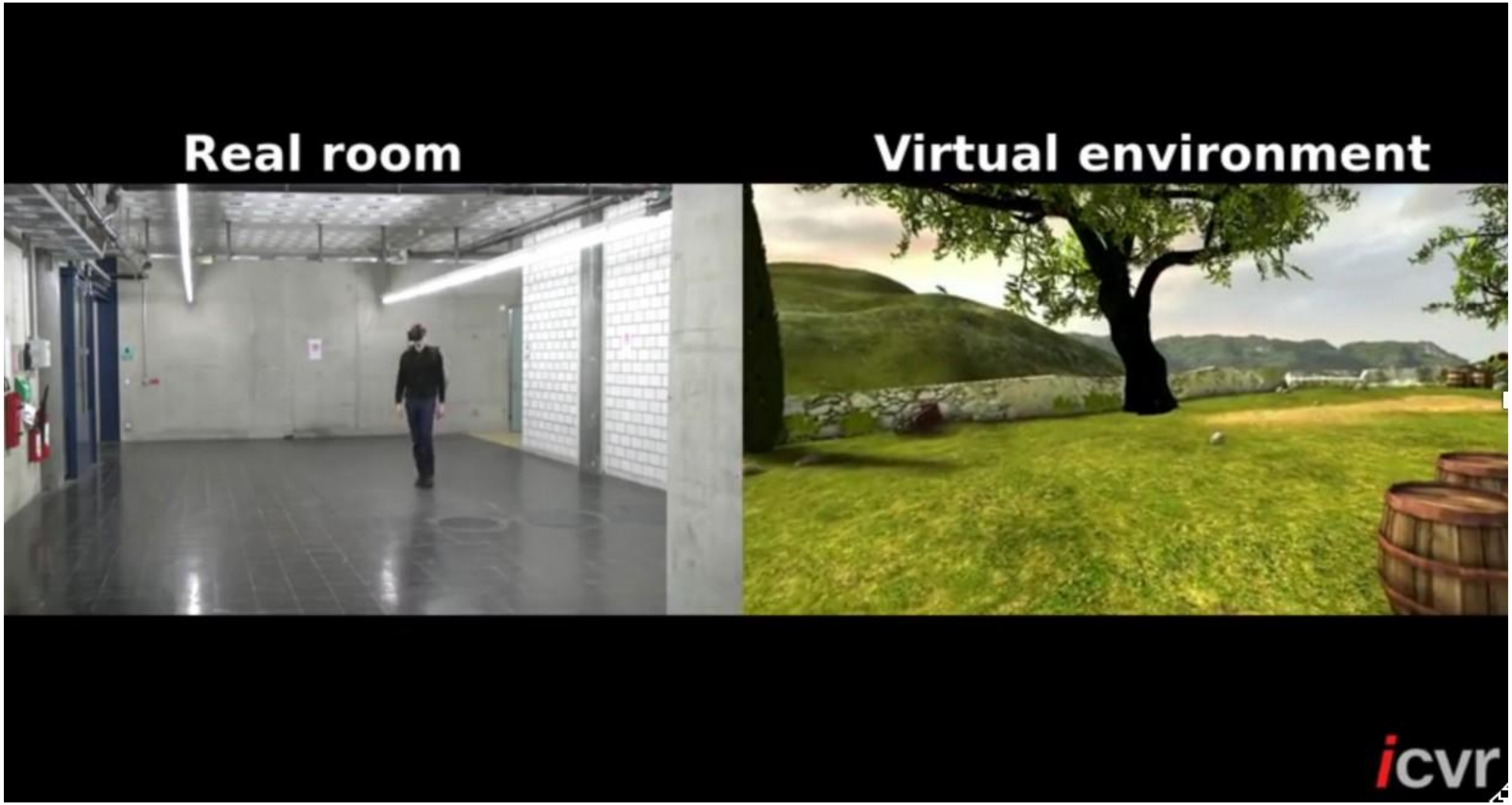
Redirected Walking

- Address problem of limited walking space
- Warp VR graphics view of space
- Create illusion of walking straight, while walking in circles



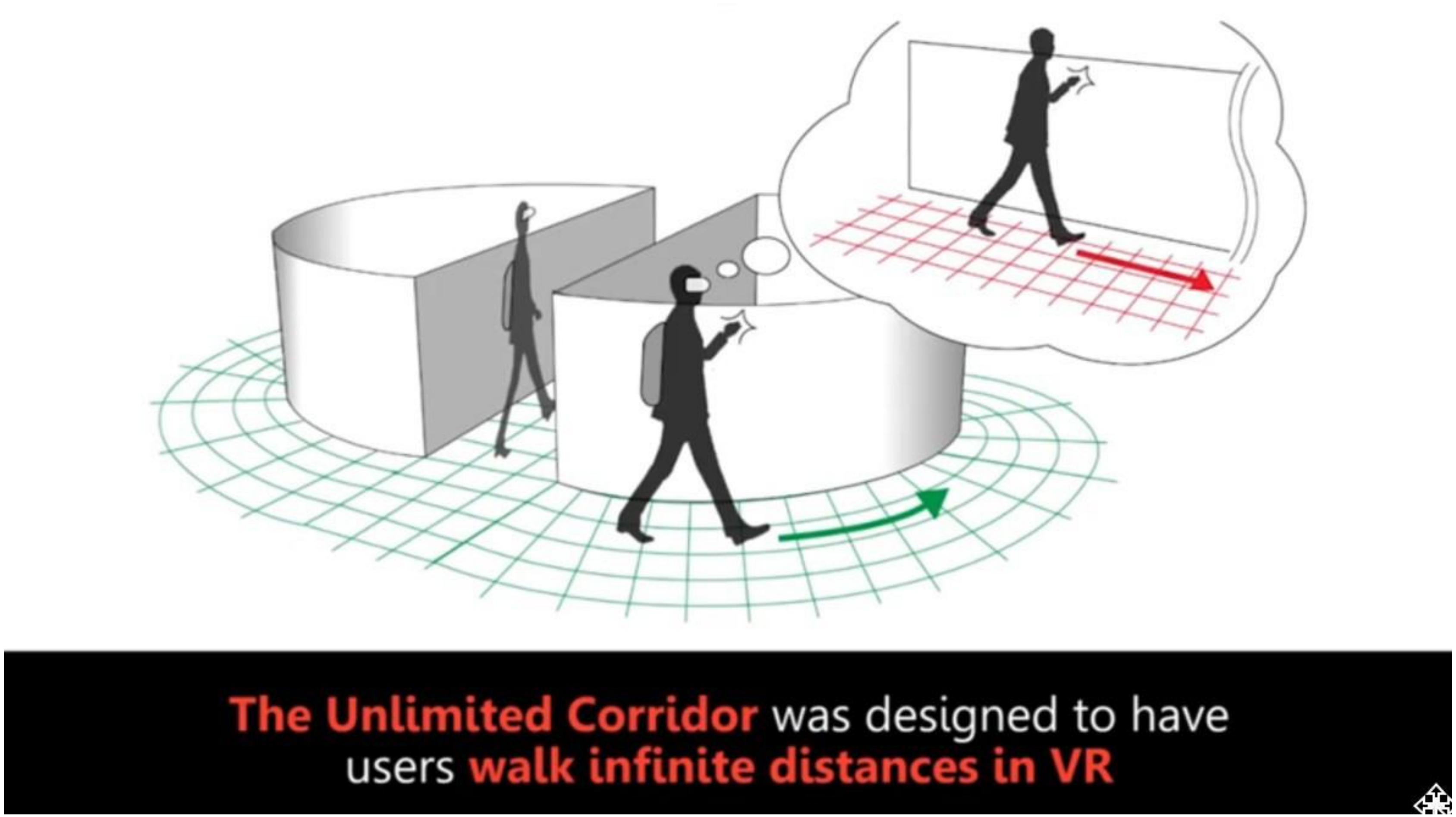
Razzaque, S., Kohn, Z., & Whitton, M. C. (2001, September). Redirected walking. In *Proceedings of EUROGRAPHICS* (Vol. 9, pp. 105-106).

Redirected Walking



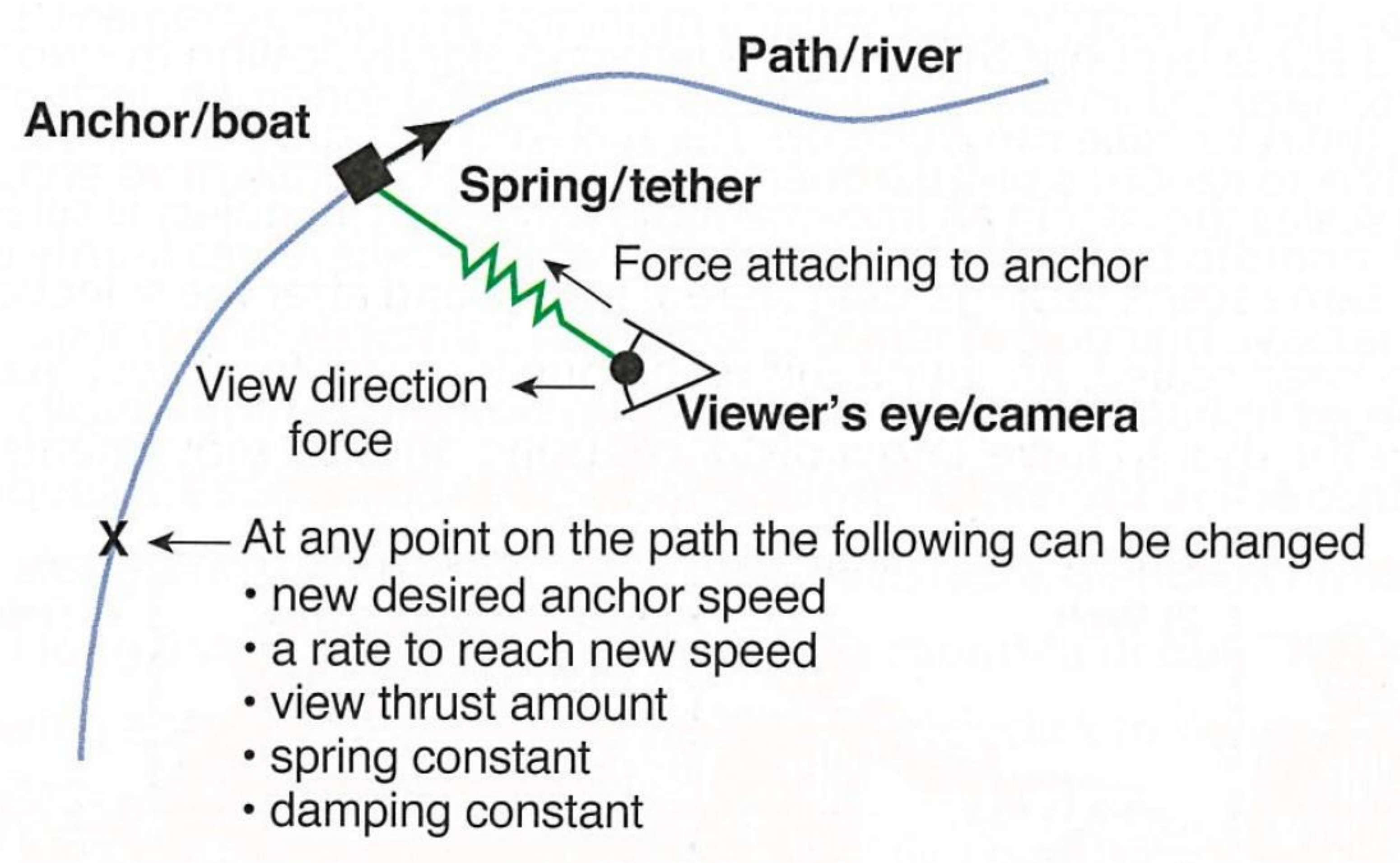
- https://www.youtube.com/watch?v=KVQBRkAq6OY

Redirected Walking with Walls



- https://www.youtube.com/watch?v=u8pw81VbMUU

Guided Navigation Technique



- Water skiing metaphor for VR movement
- Good for moving in a fixed direction, while giving user some control

Example

Virtual Jungle Cruise
DisneyQuest

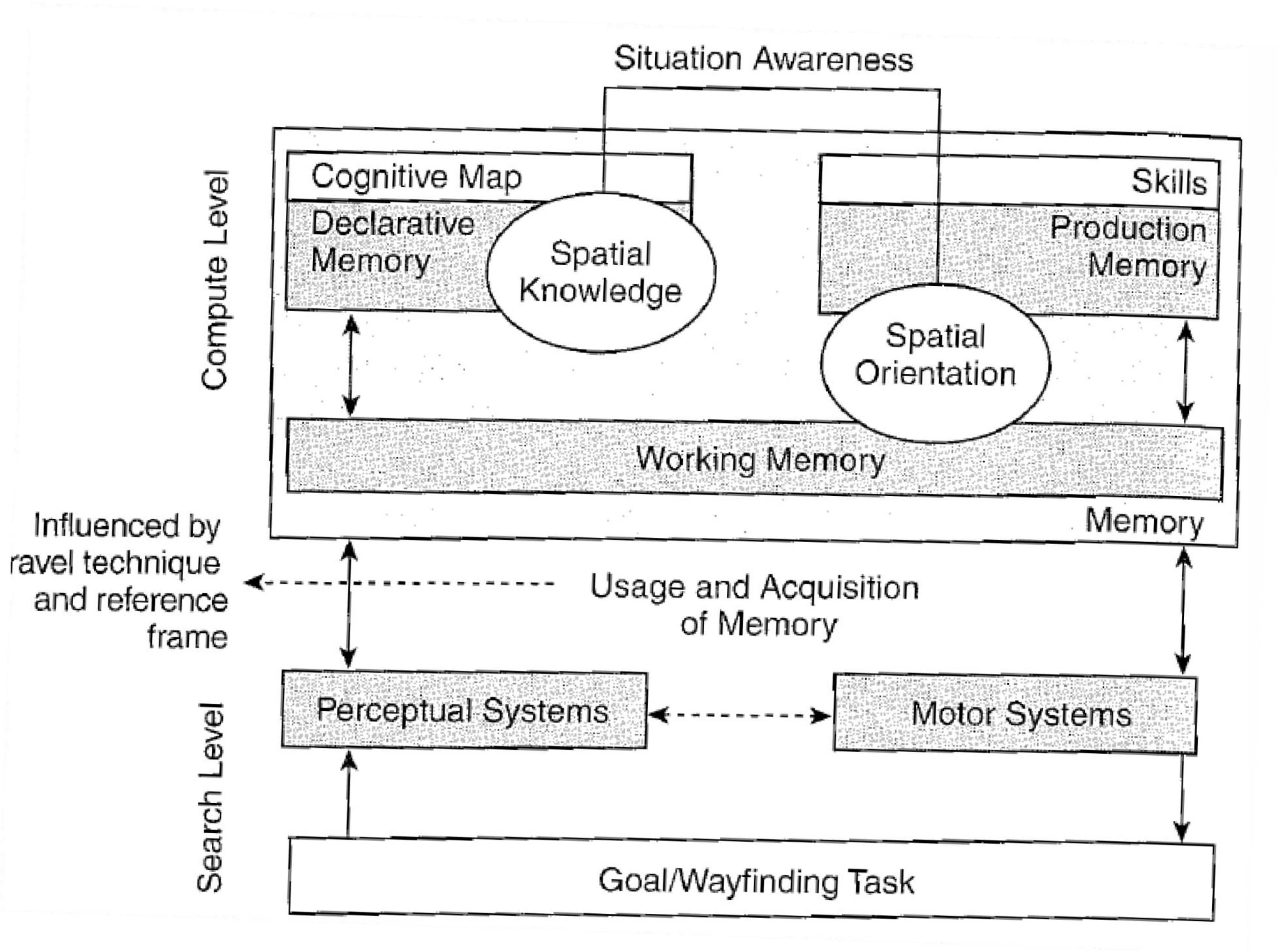
Wayfinding

- The means of
  - determining (and maintaining) awareness of where one is located (in space and time),
  - and ascertaining a path through the environment to the desired destination
- Problem: 6DOF makes wayfinding hard
  - human beings have different abilities to orient themselves in an environment, extra freedom can disorient people easily
- Purposes of wayfinding tasks in virtual environments
  - Transferring spatial knowledge to the real world
  - Navigation through complex environments in support of other tasks

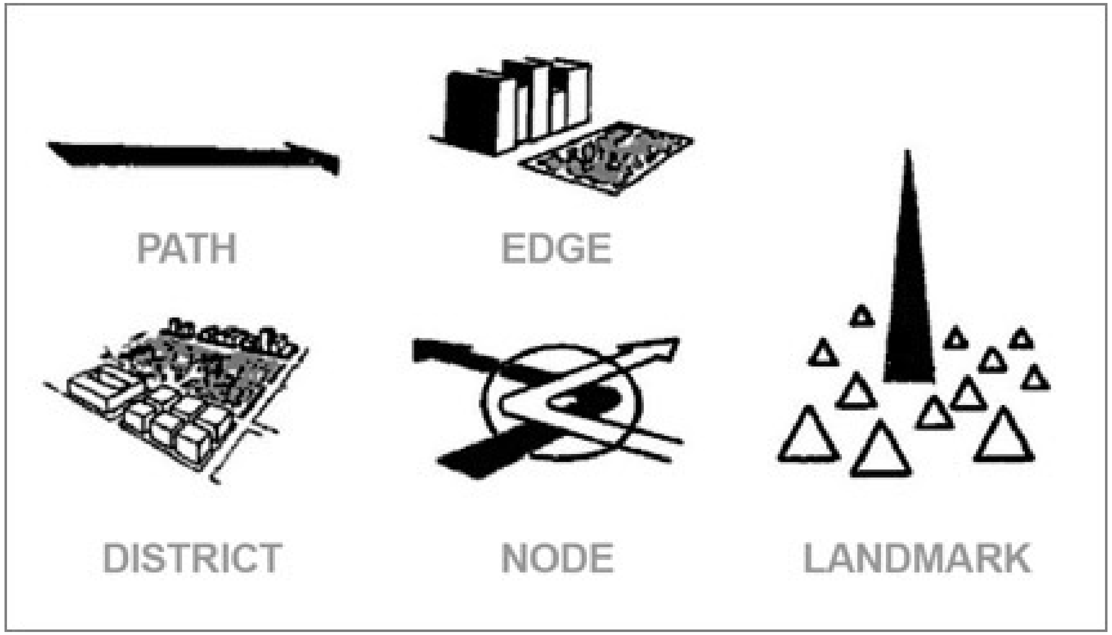
Wayfinding – Making Cognitive Maps

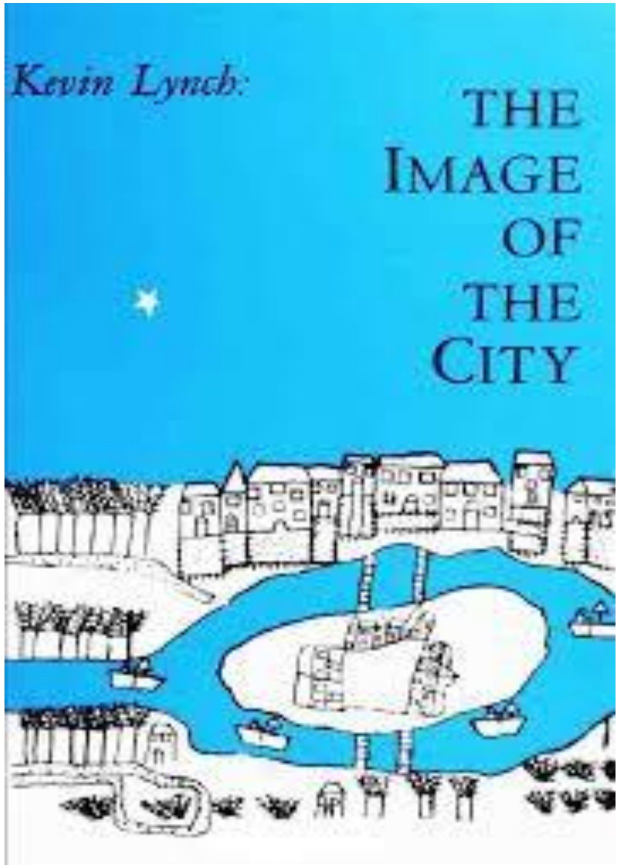
- Goal of Wayfinding is to build Mental Model (Cognitive Map)
- Types of spatial knowledge in a mental model
  - landmark knowledge
  - procedural knowledge (sequence of actions required to follow a path)
  - map-like (topological) knowledge
- Creating a mental model
  - systematic study of a map
  - exploration of the real space
  - exploration of a copy of the real space
- Problem: Sometimes perceptual judgments are incorrect within a virtual environment
  - e.g. users wearing a HMD often underestimate dimensions of space, possibly caused by limited field of view

Wayfinding as a Decision Making Process



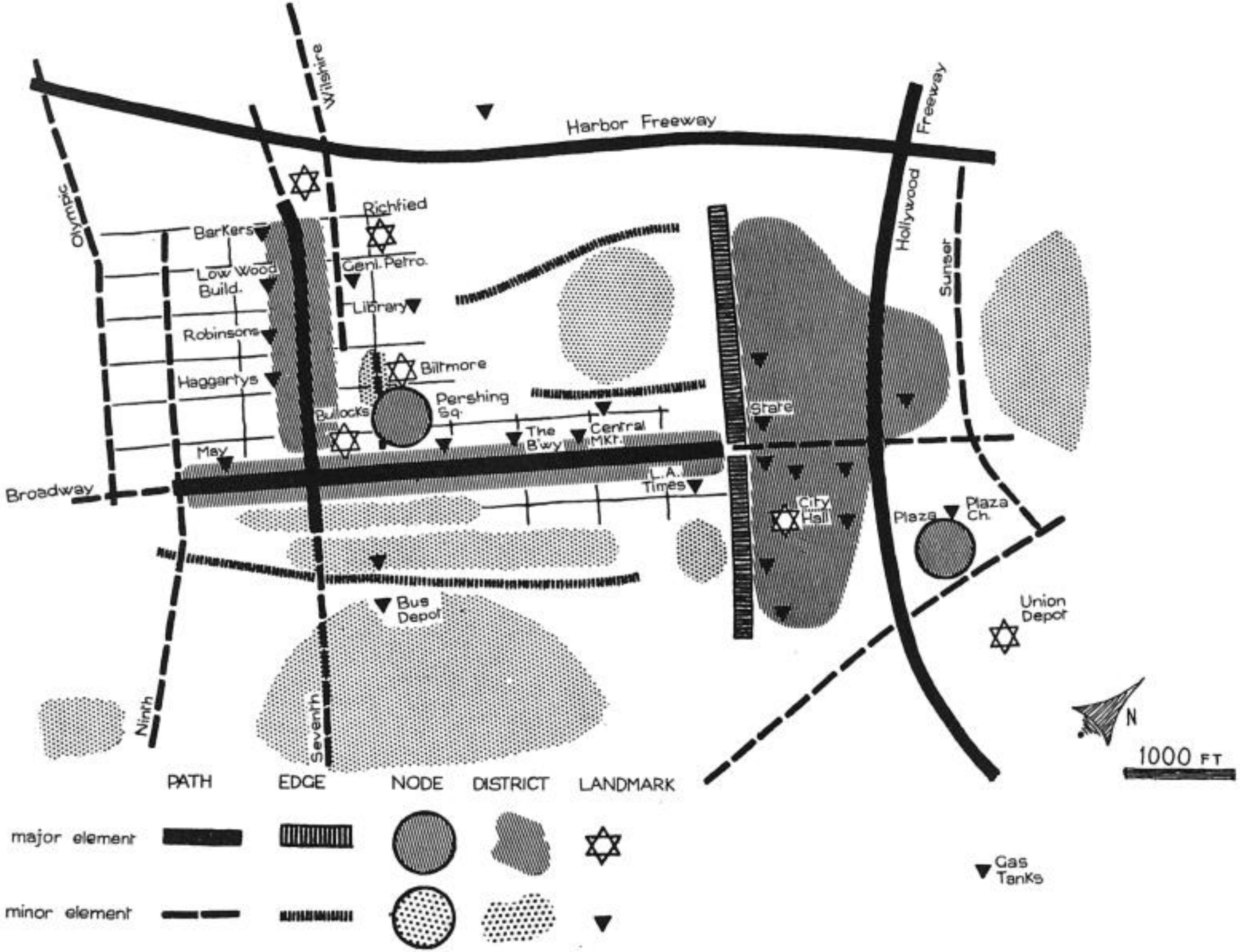
Kevin Lynch – The Image of the City





- In real cities, five elements
  - Path, Edge, District, Node, Landmark
- VR environments the same

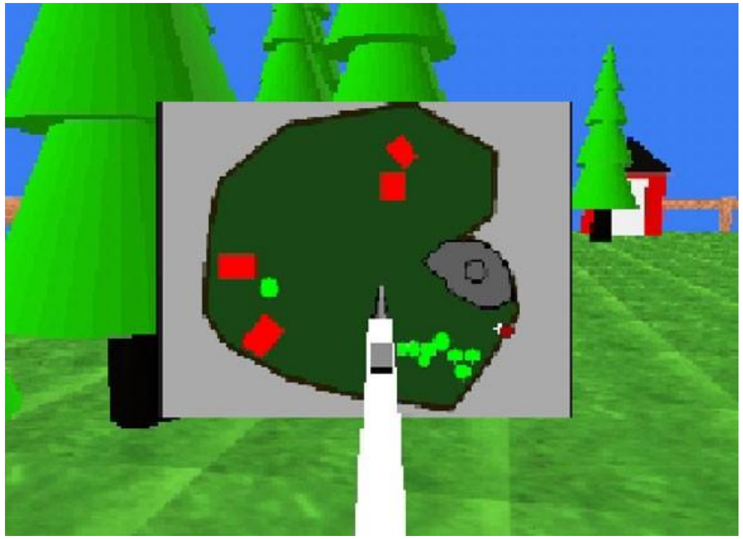
FIG. 14. *The visual form of Los Angeles as seen in the field*



Designing VE to Support Wayfinding

- Provide Landmarks
  - Any obvious, distinct and non-mobile object can serve as a landmark
  - A good landmark can be seen from several locations (e.g. tall)
  - Audio beacons can also serve as landmarks

- Use Maps
  - Copy real world maps
  - Ego-centric vs. Exocentric map cues
  - World in Miniature
  - Map based navigation



Wayfinding Aids

- Path following
  - Easy method of wayfinding
  - Multiple paths through a single space may be denoted by colors
    - For example, hospitals that use colored lines to indicate how to get to certain locations.
- Bread crumbs (leaving a trail)
  - leaving a trail of markers - like Hänsel and Gretel
  - allows participant to know when they've been somewhere before
  - having too many markers can make the space be overly cluttered
- Compass
  - may also be other form of direction indicator (e.g. artificial horizon)
  - may specify directions in 2D space or 3D space

Examples

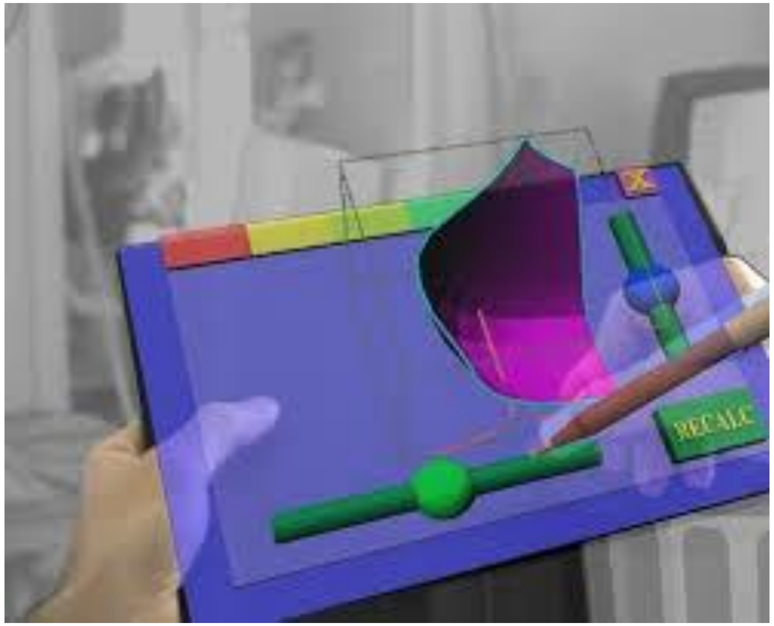
Design Guidelines for Navigation

- Match the travel technique to the application
- Use an appropriate combination of travel technique, display devices, and input devices
- The most common travel tasks should require a minimum of effort from the user
- Use physical locomotion technique if user exertion or naturalism is required
- Use target-based techniques for goal-oriented travel and steering techniques for exploration and search
- Provide multiple travel techniques to support different travel tasks in the same application
- Choose travel techniques that can be easily integrated with other interaction techniques in the application

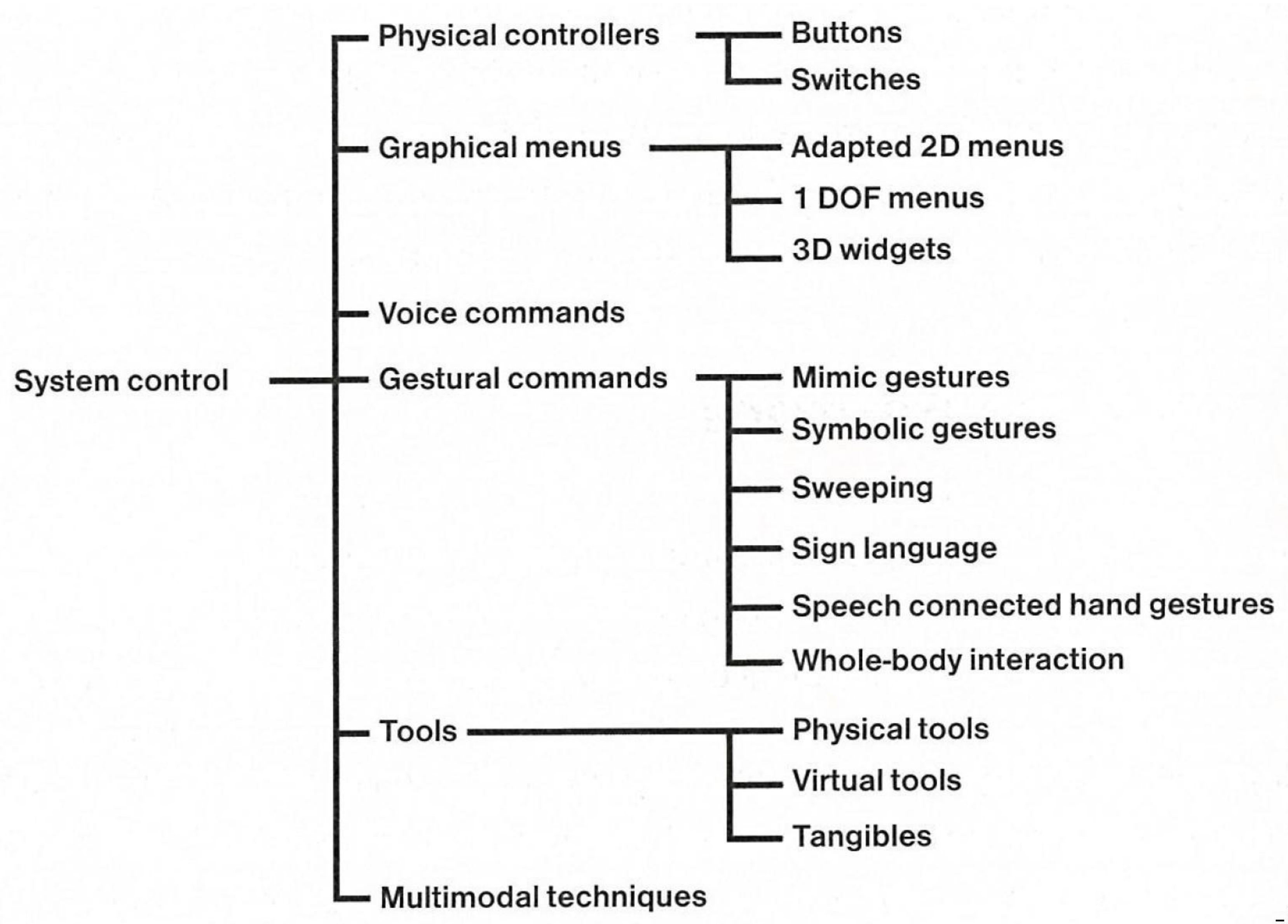
SYSTEM CONTROL

System Control

- Issuing a command to change system state or mode
- Examples
  - Launching application
  - Changing system settings
  - Opening a file
  - Etc.
- Key points
  - Make commands visible to user
  - Support easy selection



System Control Options

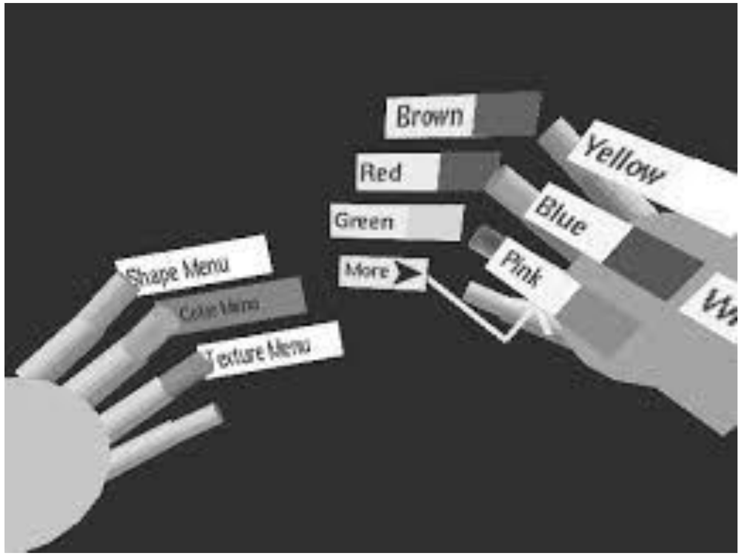


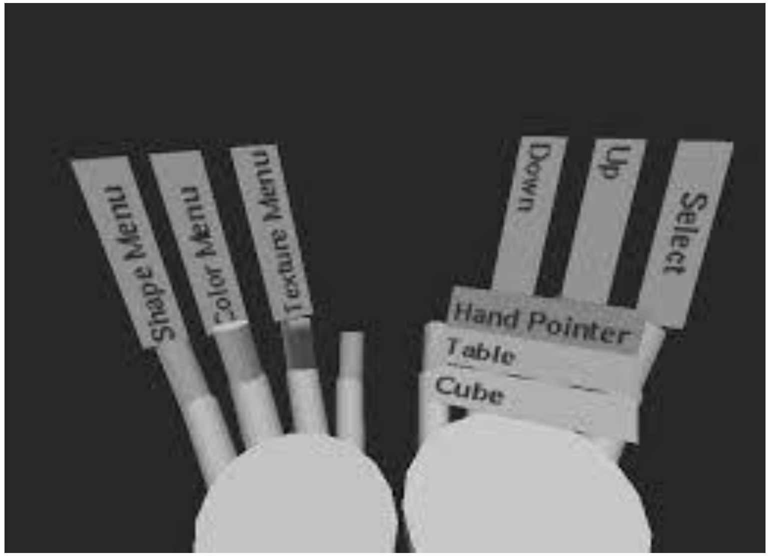
Example: GearVR Interface

- 2D Interface in 3D Environment
- Head pointing and click to select

https://www.youtube.com/watch?v=qMadjF1B3rI

TULIP Menu

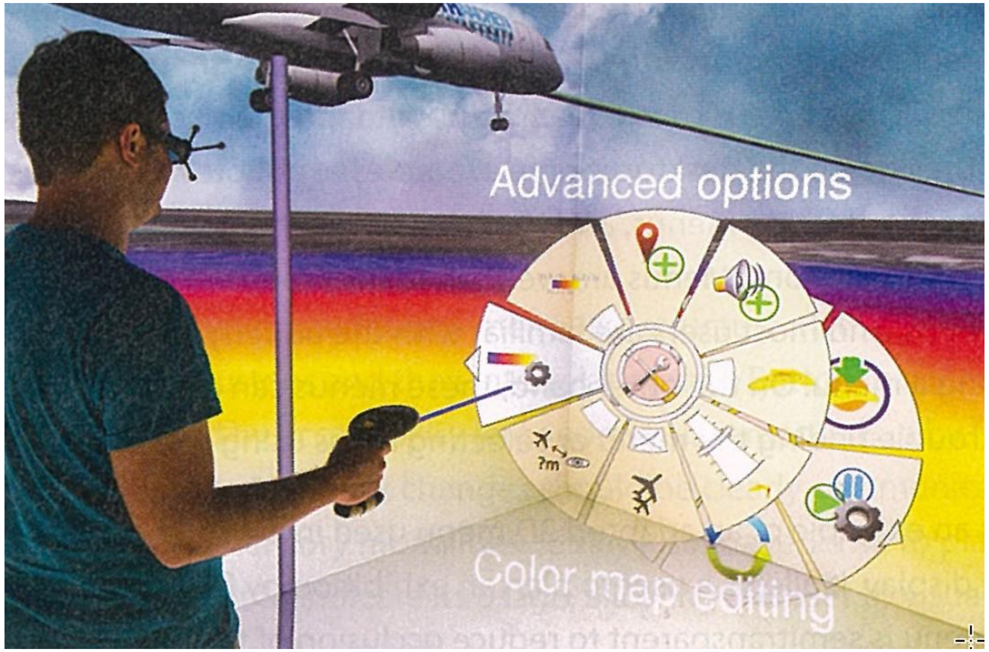




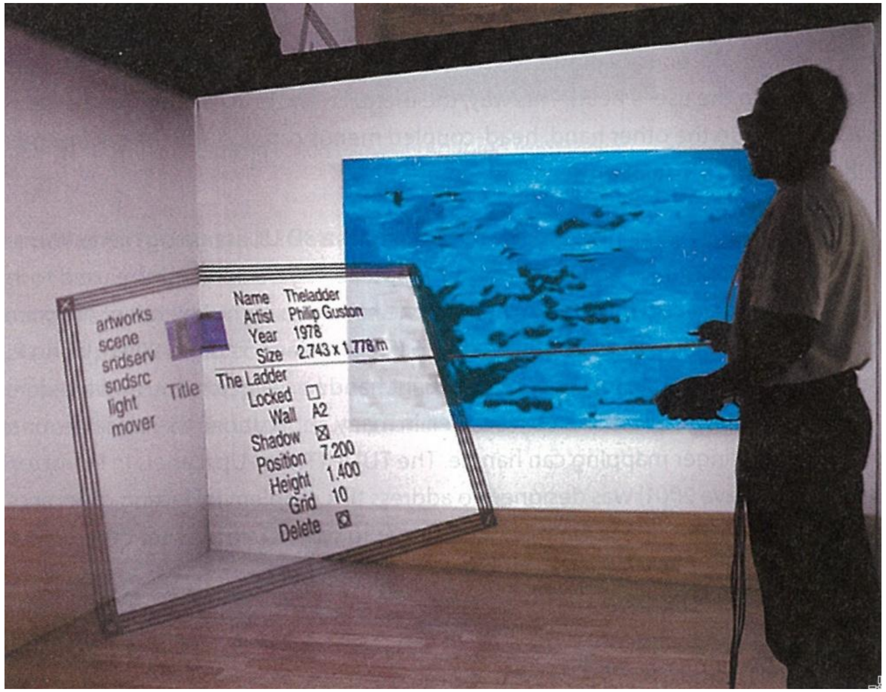
- Menu items attached to virtual finger tips
- Ideal for pinch glove interaction
- Use one finger to select menu option from another

Bowman, D. A., & Wingrave, C. A. (2001, March). Design and evaluation of menu systems for immersive virtual environments. In *Virtual Reality, 2001. Proceedings. IEEE* (pp. 149-156). IEEE.

2D Menus in VR



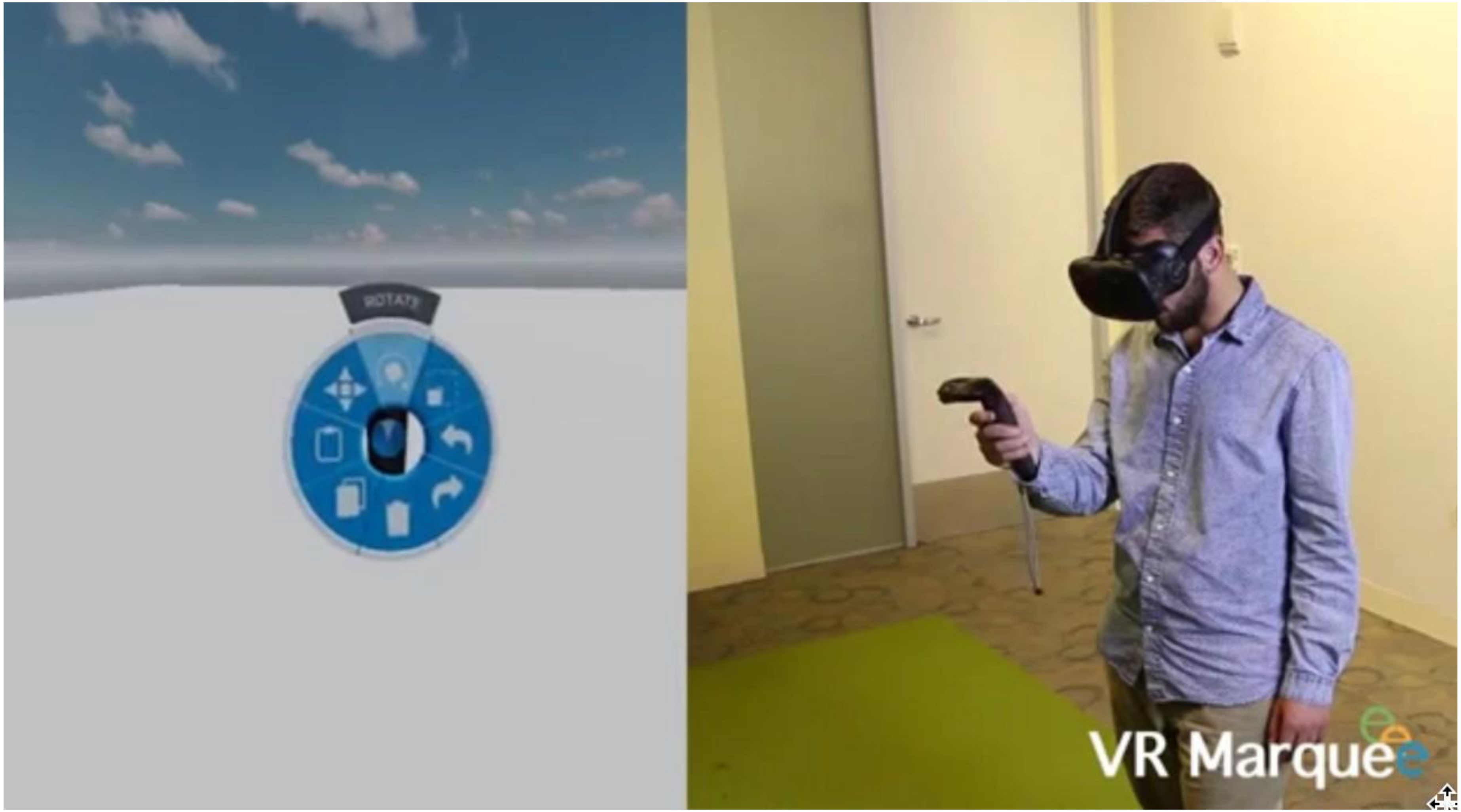
Nested Pie Menu



2D Menu in VR CAVE

- Many examples of 2D GUI and floating menus in VR

Example: Marking Menu in VR

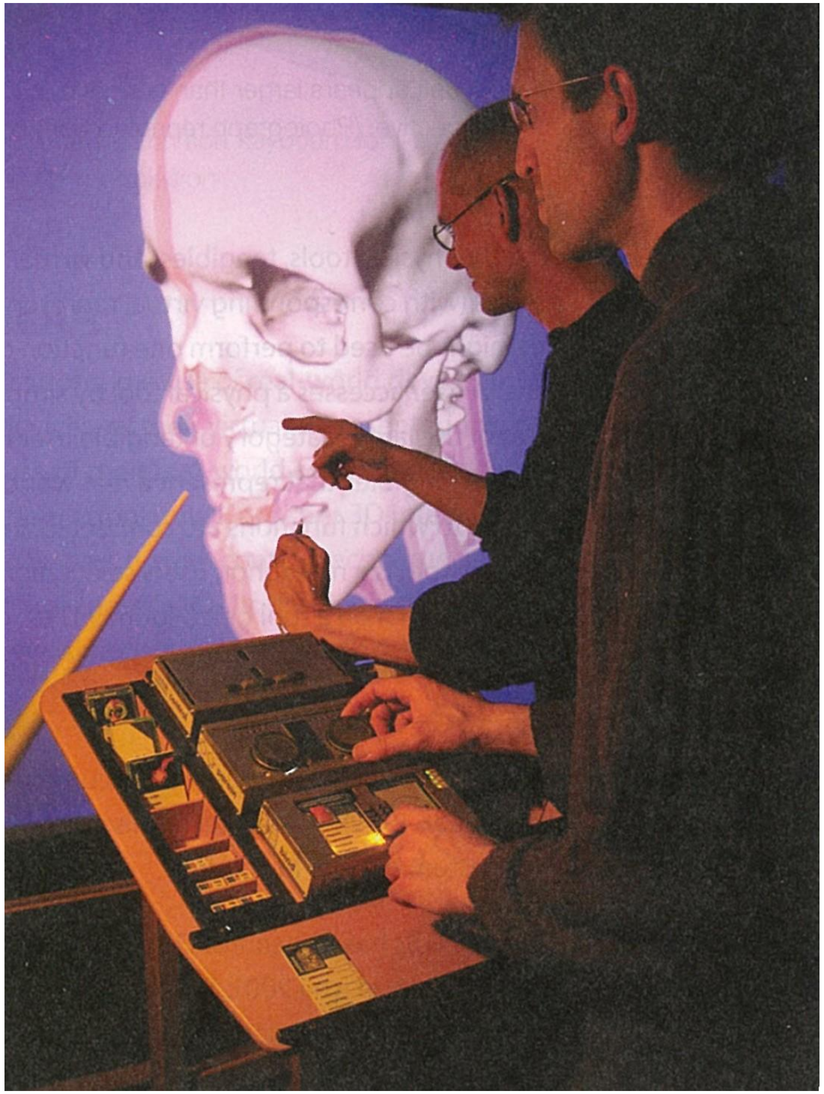


- https://www.youtube.com/watch?v=BTTBgZ94lAc

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

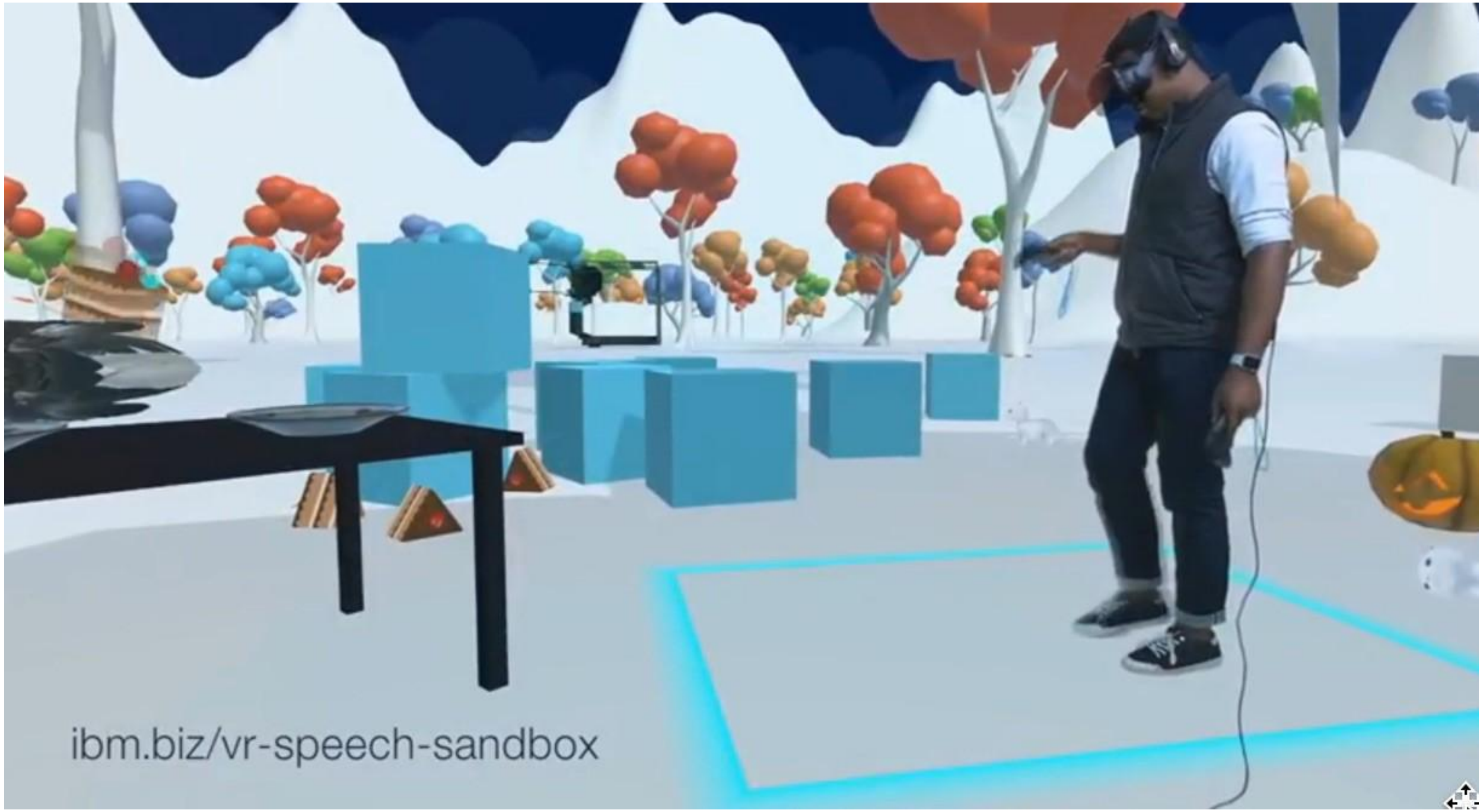


Tangible interface for CAVE

Voice Input

- 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

Example – IBM VR Speech Sandbox



- https://www.youtube.com/watch?v=NoO2R3Pz5Go
- Available from: http://ibm.biz/vr-speech-sandbox

Design Guidelines for System Control

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

CONCLUSION

Conclusions

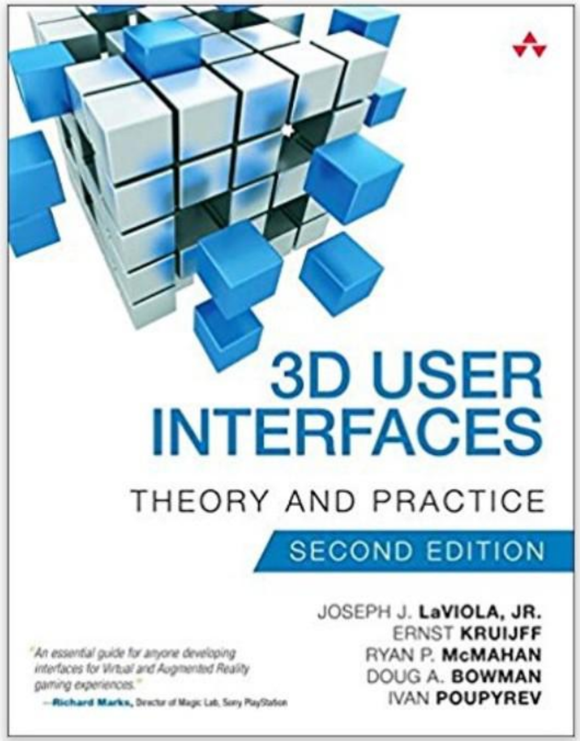
- Usability one of the most crucial issues facing VE applications
- Implementation details critical to ensure usability
- Ease of coding not equal to ease of use
- Simply adapting 2D interfaces is not sufficient

Conclusions

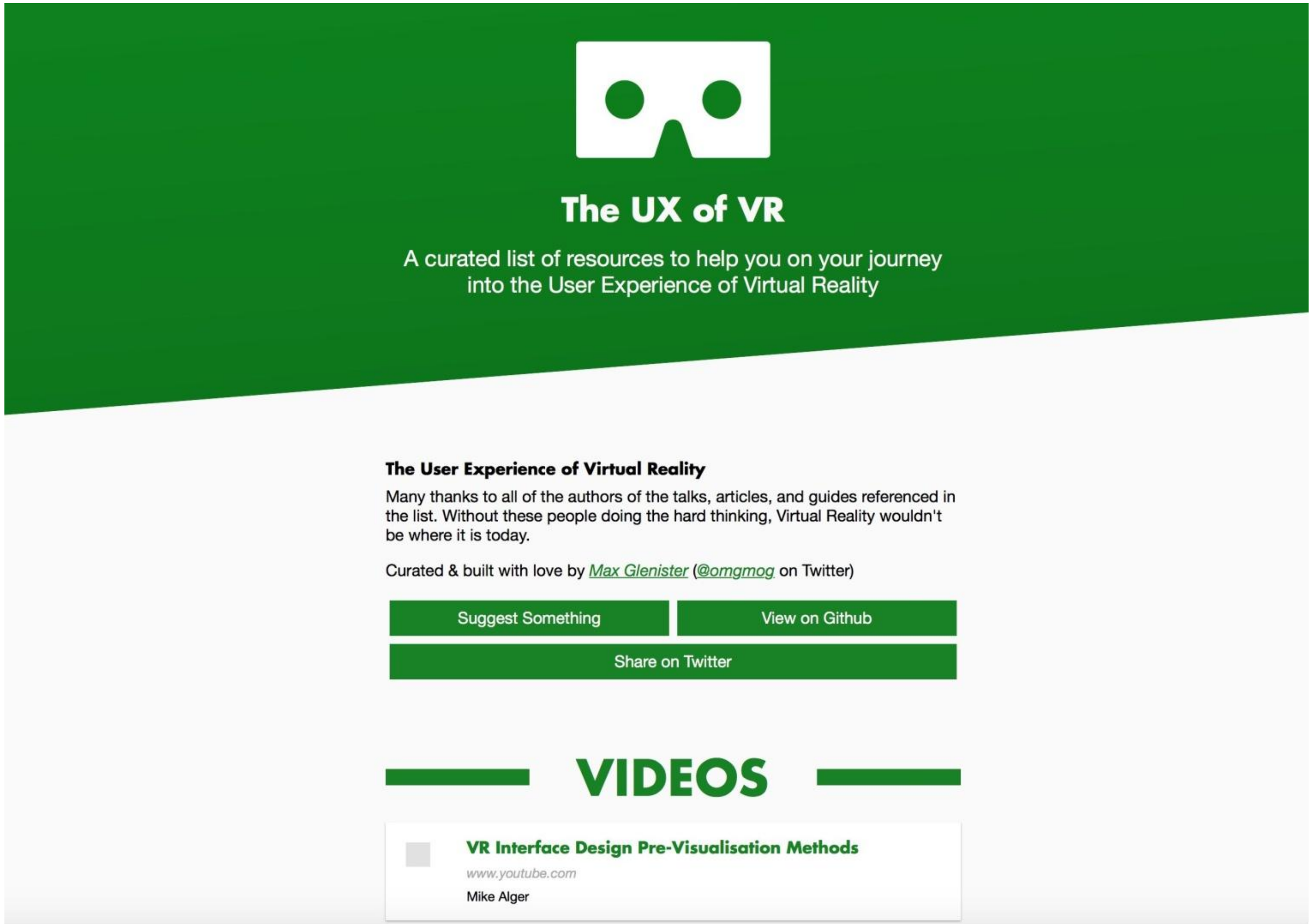
- User interface key for good VR experience
  - Need 3D user interface techniques
- Design for
  - Selection/Manipulation
  - Navigation
  - System control
- Follow good design guidelines
  - Cannot just implement 2D techniques in VR

Resources

- Excellent book
  - 3D User Interfaces: Theory and Practice
    - Doug Bowman, Ernst Kruijff, Joseph, LaViola, Ivan Poupyrev
- Great Website
  - http://www.uxofvr.com/
- 3D UI research at Virginia Tech.
  - research.cs.vt.edu/3di/



UX of VR Website - www.uxofvr.com



- Many examples of great interaction techniques
- Videos, books, articles, slides, code, etc..

Acknowledgments – Content From

- Doug Bowman, Virginia Tech
- Joe LaViola, University of Central Florida
- Ernst Kruijff, Graz Univ. of Technology
- Ivan Poupyrev, Google

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