ARIVE

ARIVE Lecture Series
XR: Virtual and Augmented Reality

Interactions and Design for Virtual Reality

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University of South Australia

INTERACTING IN VR

Public Service Announcement

- May, Kieran, Ian Hanan, Andrew Cunningham, and Bruce Thomas. "3DUITK: An Opensource Toolkit for Thirty Years of Three-Dimensional Interaction Research." In 2019 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct), pp. 175-180. IEEE, 2019.
- 3DUITK provides developers a set of interaction techniques to address a variety of task conditions, and provides researchers with baseline Unity implementations of classic techniques for further investigations.
- https://github.com/WearableComputerLab/VRInteractionToolkit

Typical Virtual Reality System

HMD

Input

User Interface

Tracking

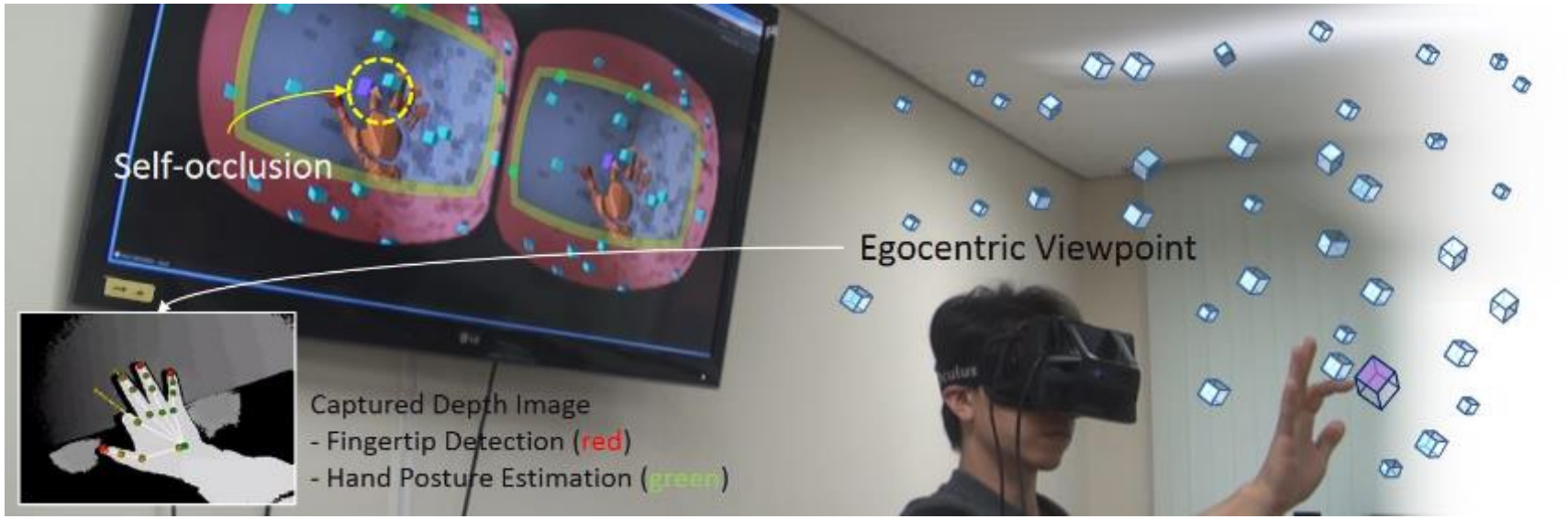
Why 3D Interaction?

- 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

What makes 3D interaction difficult?

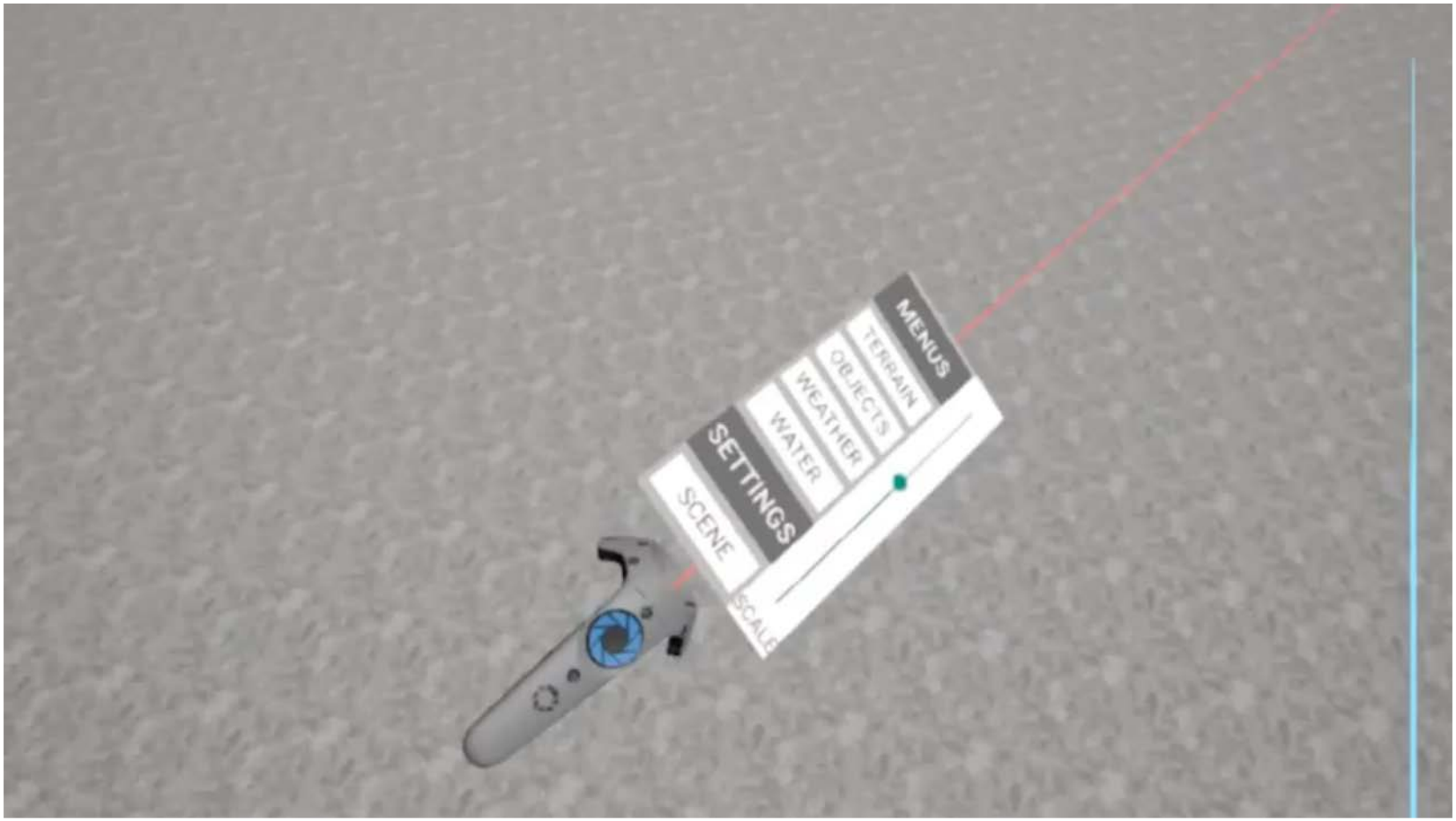


- Spatial input
- Lack of constraints
- Lack of standards
- Lack of tools
- Lack of precision
- Fatigue
- Layout more complex
- Perception

Natural Interface Concept - WorldBuilder

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

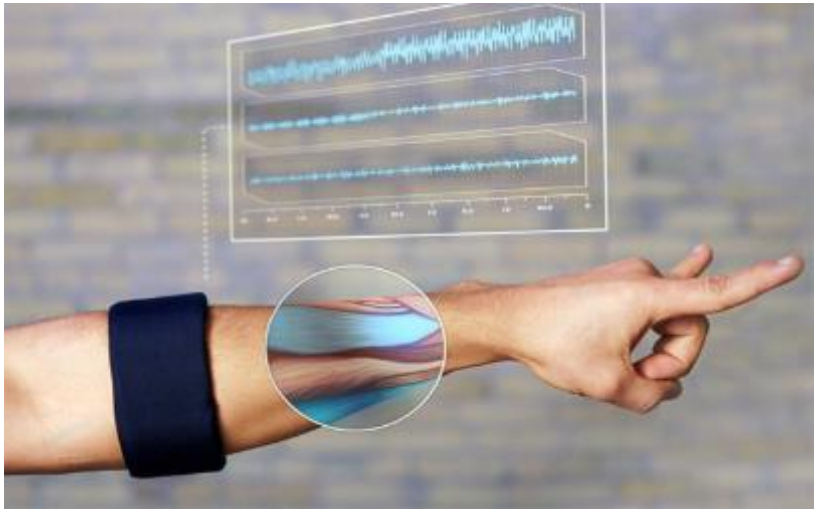
World Builder Today (Available on Steam)



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

Universal 3D Interaction Tasks in VR

- Object Interaction
- Navigation
- System control



OBJECT INTERACTION

Selection and Manipulation

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

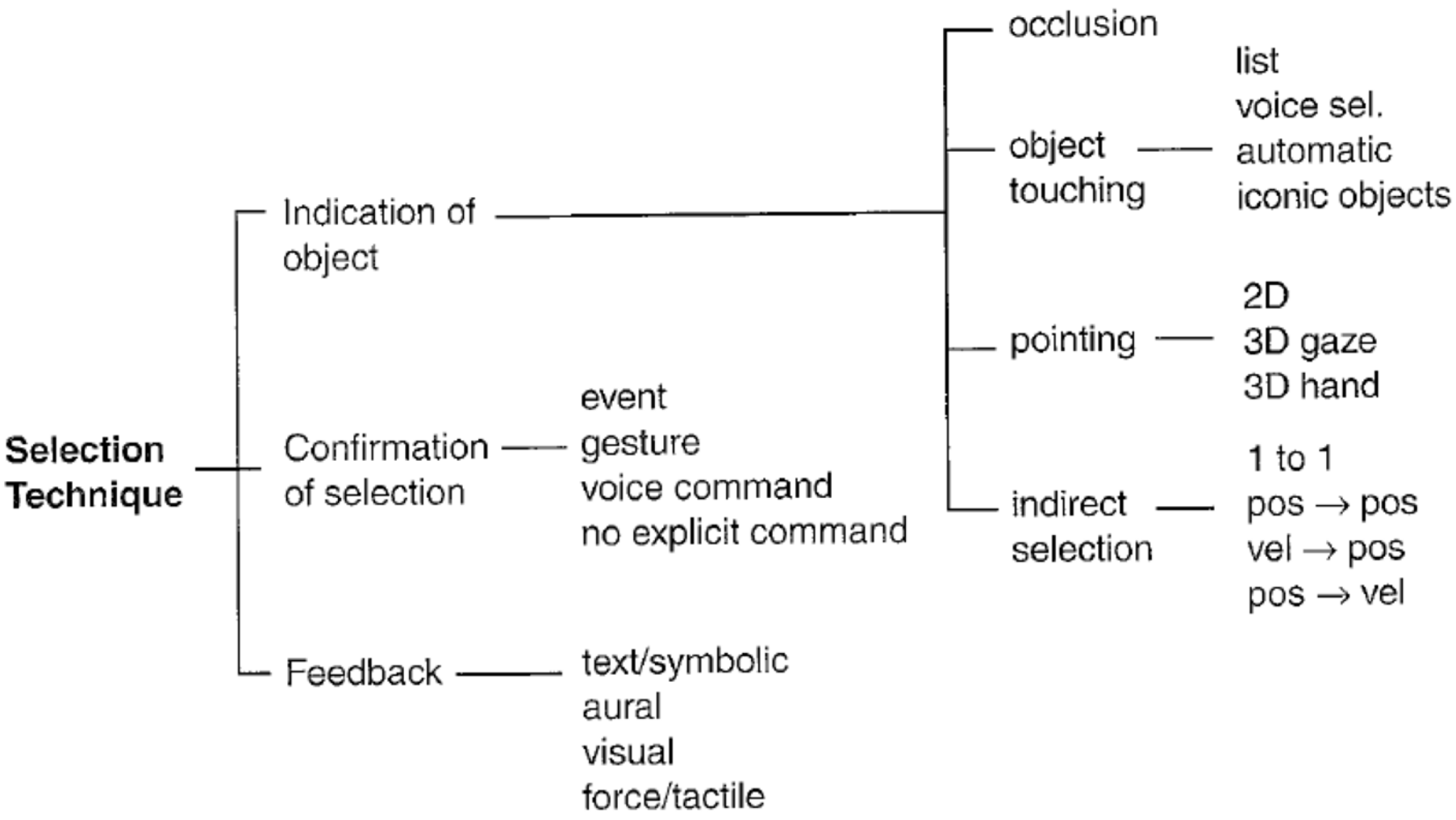
Goals of selection

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

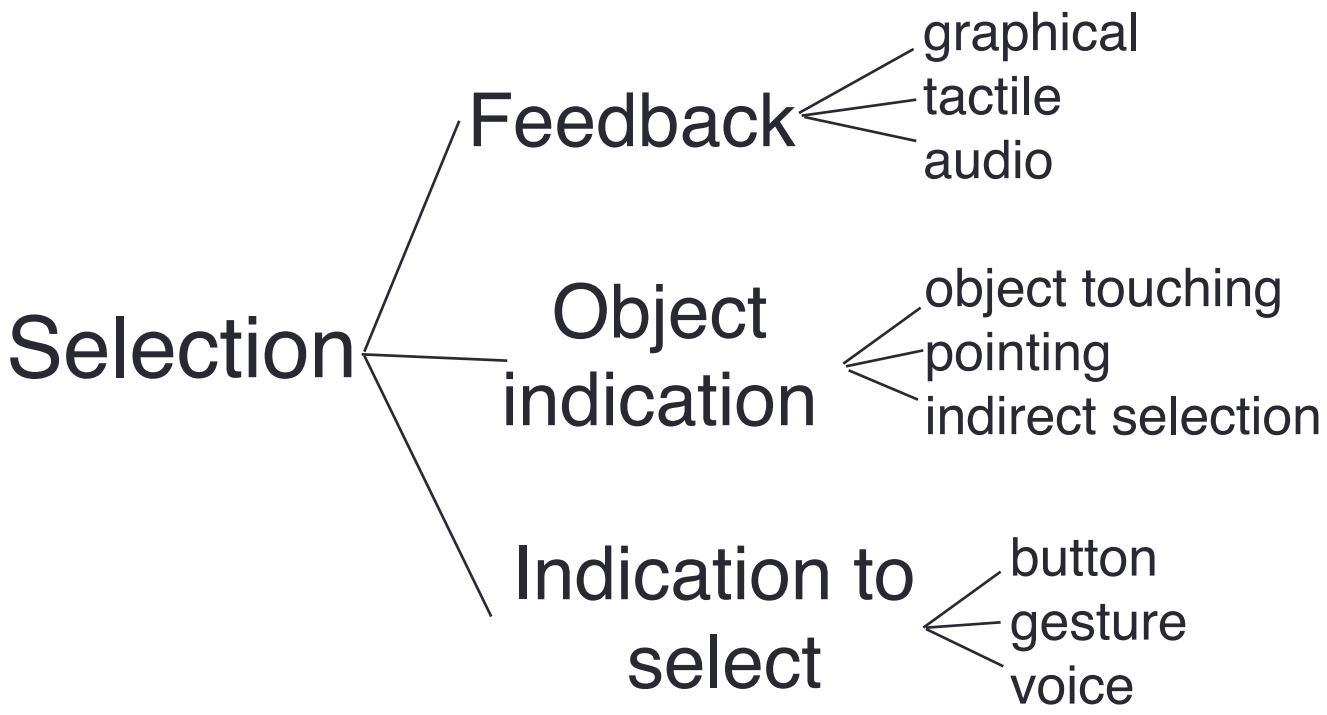
Selection performance

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

Classification of Selection Techniques

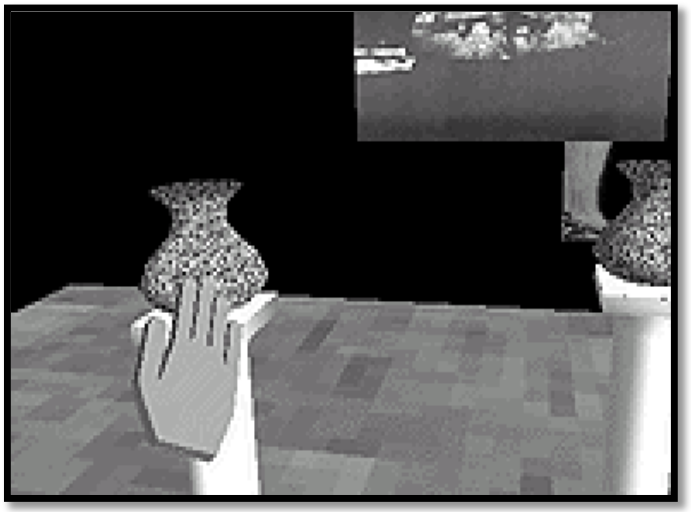


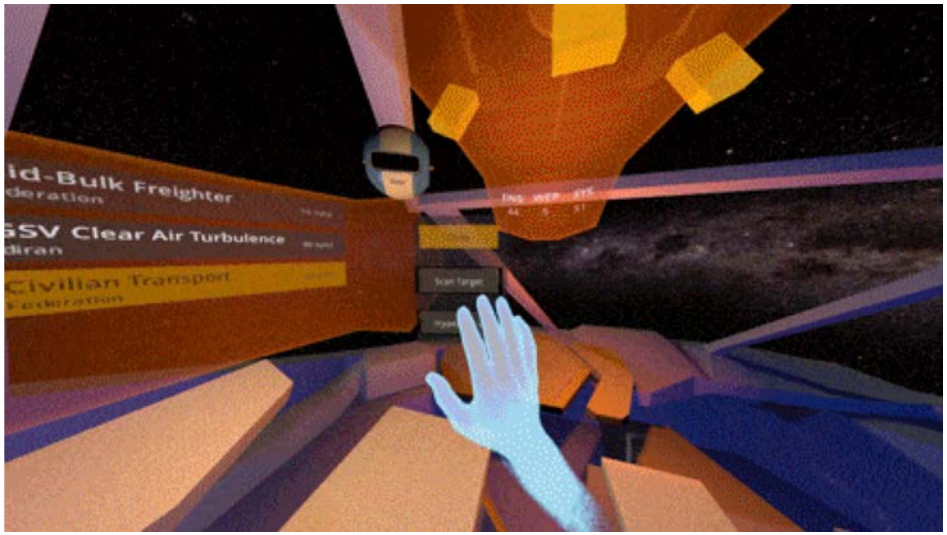
Selection classification



Common Selection Techniques

Simple virtual hand 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

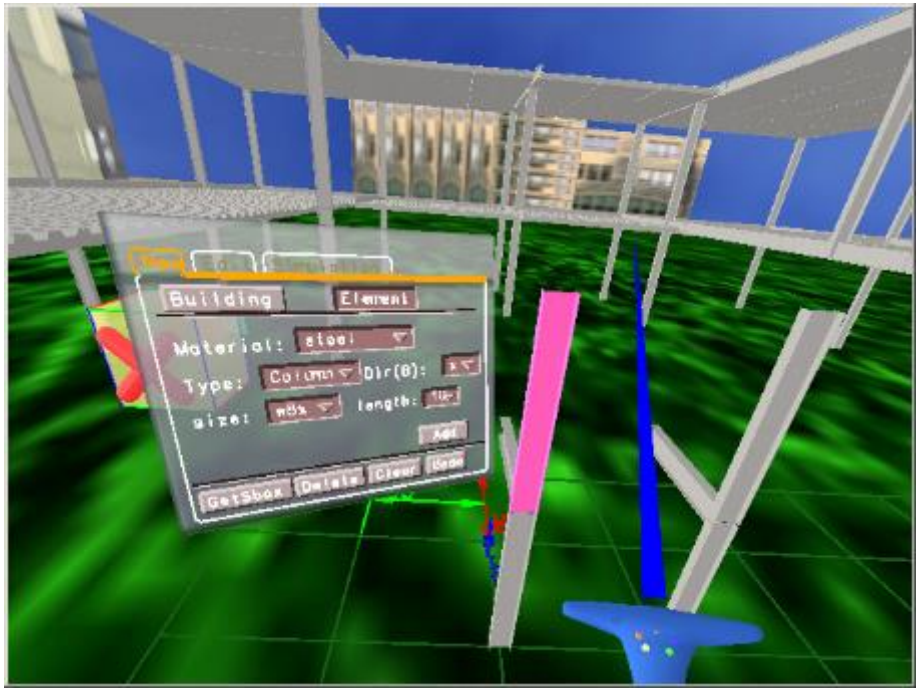
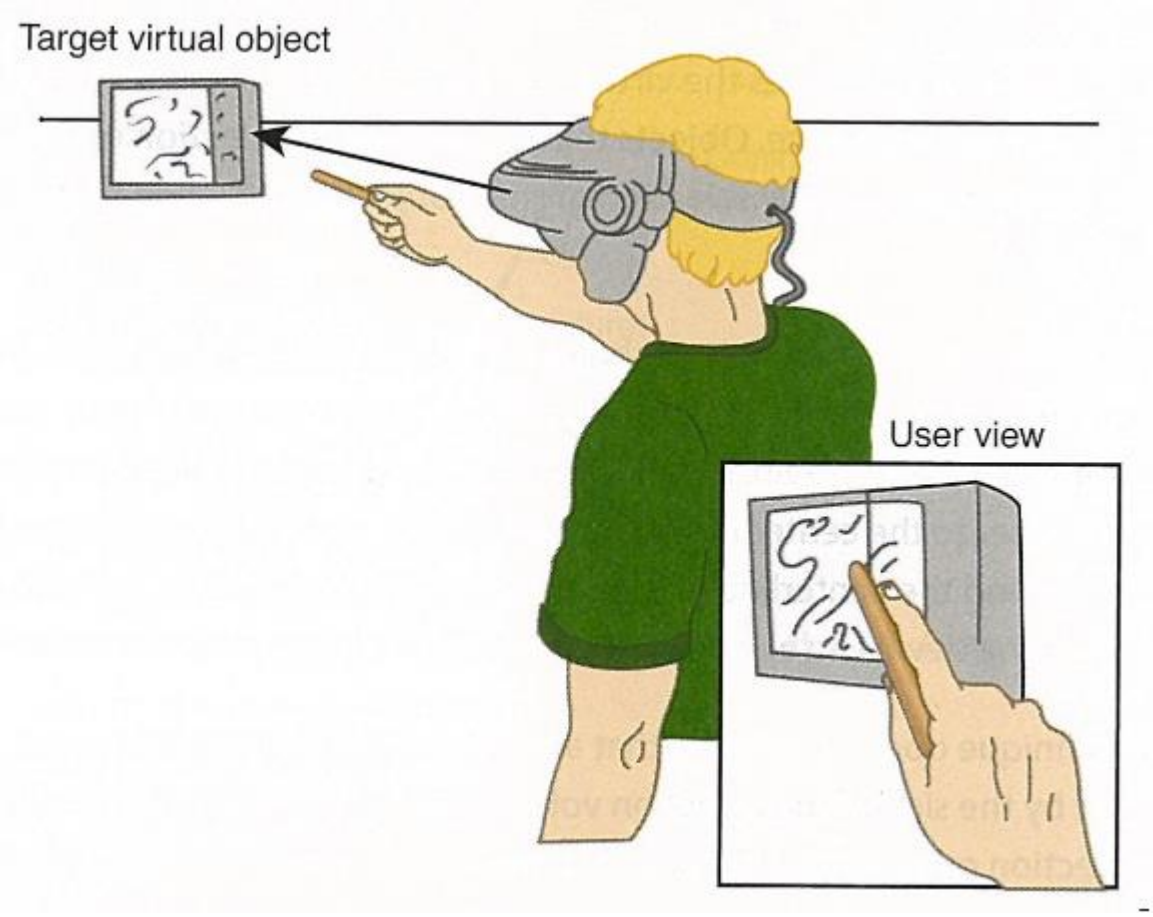


Image Plane Interaction

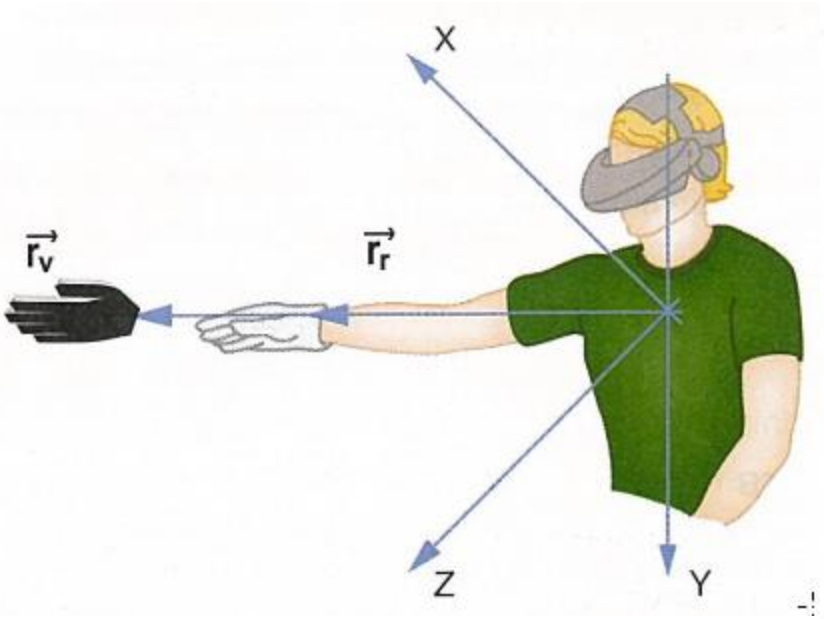


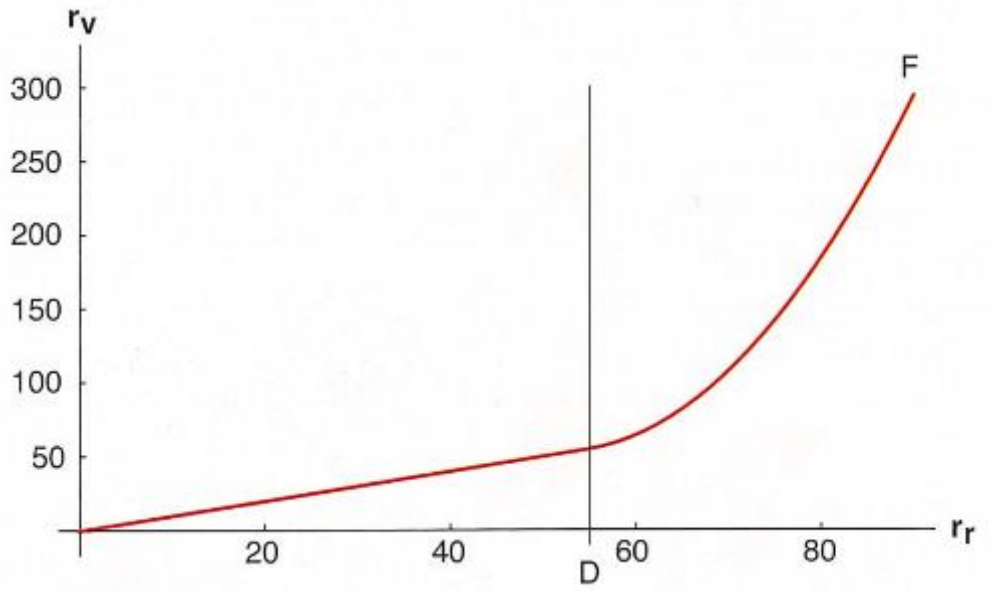
- Pierce, J., Forsberg, A., Conway, M., Hong, S., Zeleznik, R., & Mine, M. (1997). *Image Plane Interaction Techniques in 3D Immersive Environments.* Proceedings of the ACM Symposium on Interactive 3D Graphics, 39-44.

Example

- https://www.youtube.com/watch?v=DBPkE9wsqIY

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

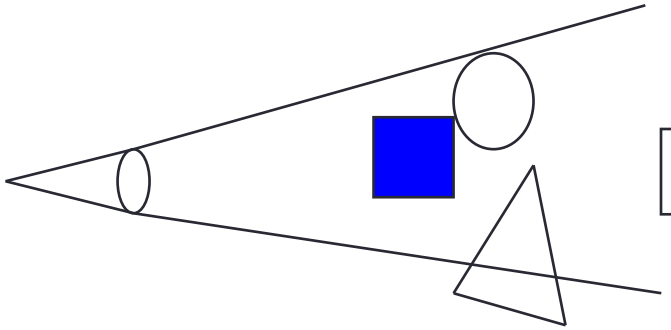
- Increase selection area
  - Cone-casting (Liang, 1993)
  - Snapping (de Haan, 2005)
  - 3D Bubble Cursor (Vanacken, 2007)
  - Sphere-casting (Kopper 2011)

Not ideal for cluttered environments (high density, occlusion)

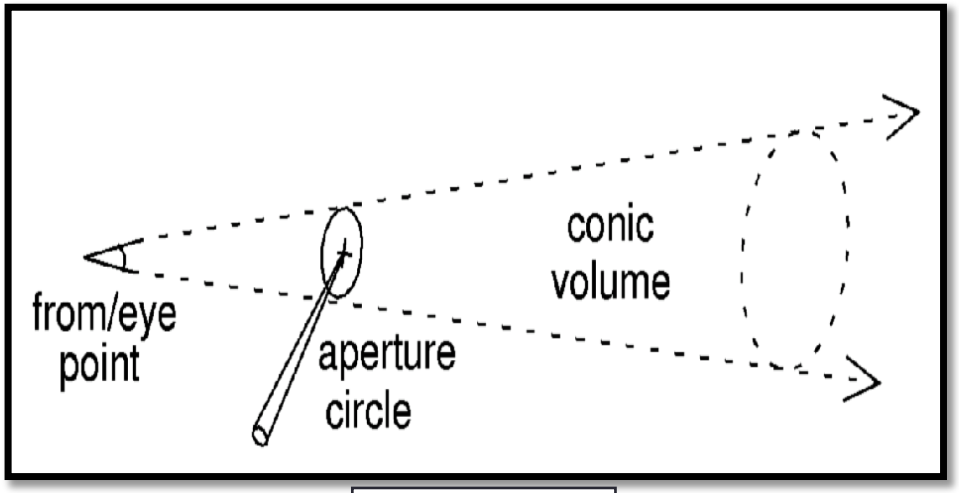
- Increase control/display ratio
  - PRISM (Frees, 2007)
  - ARM (Kopper, 2010)

May require careful interaction

Cone-Casting



Spotlight



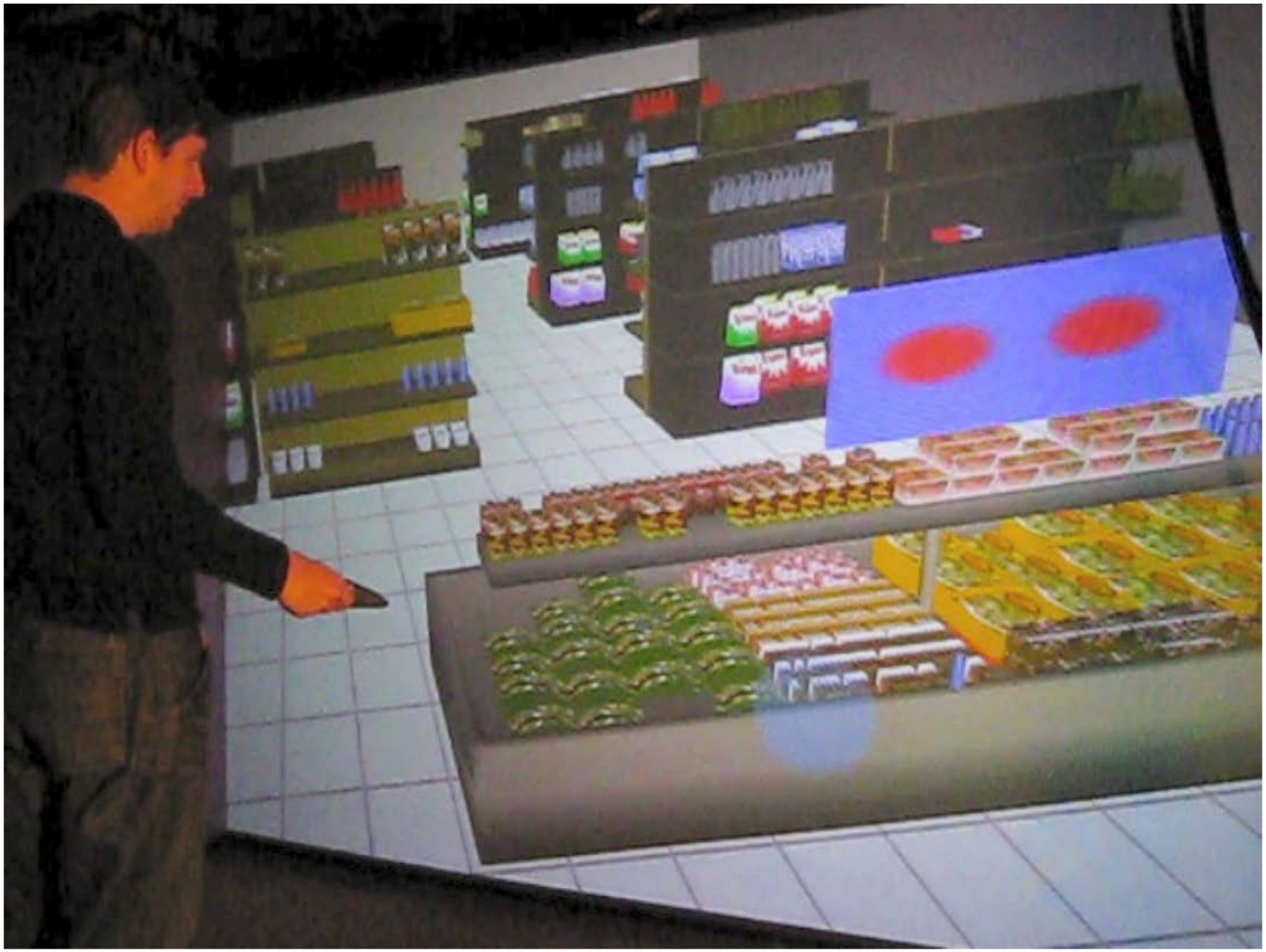
Aperture

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

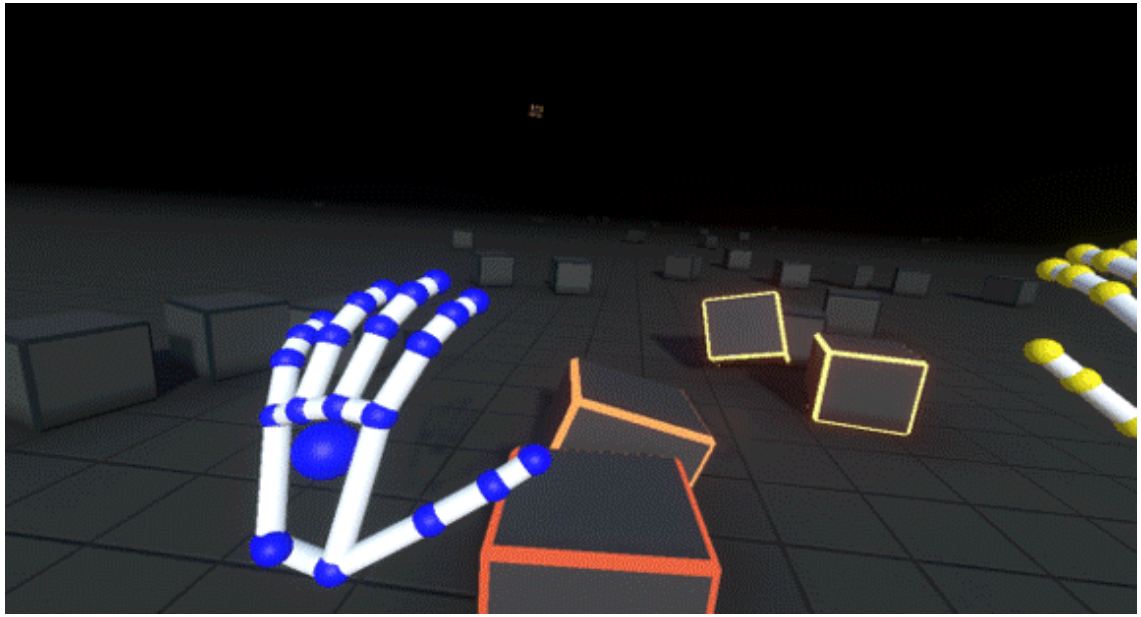
Kopper, R., Bacim, F., & Bowman, D. A. (2011). Rapid and accurate 3D selection by progressive refinement. In *3D User Interfaces (3DUI), 2011 IEEE Symposium on* (pp. 67-74). IEEE.

Example: SQUAD Selection

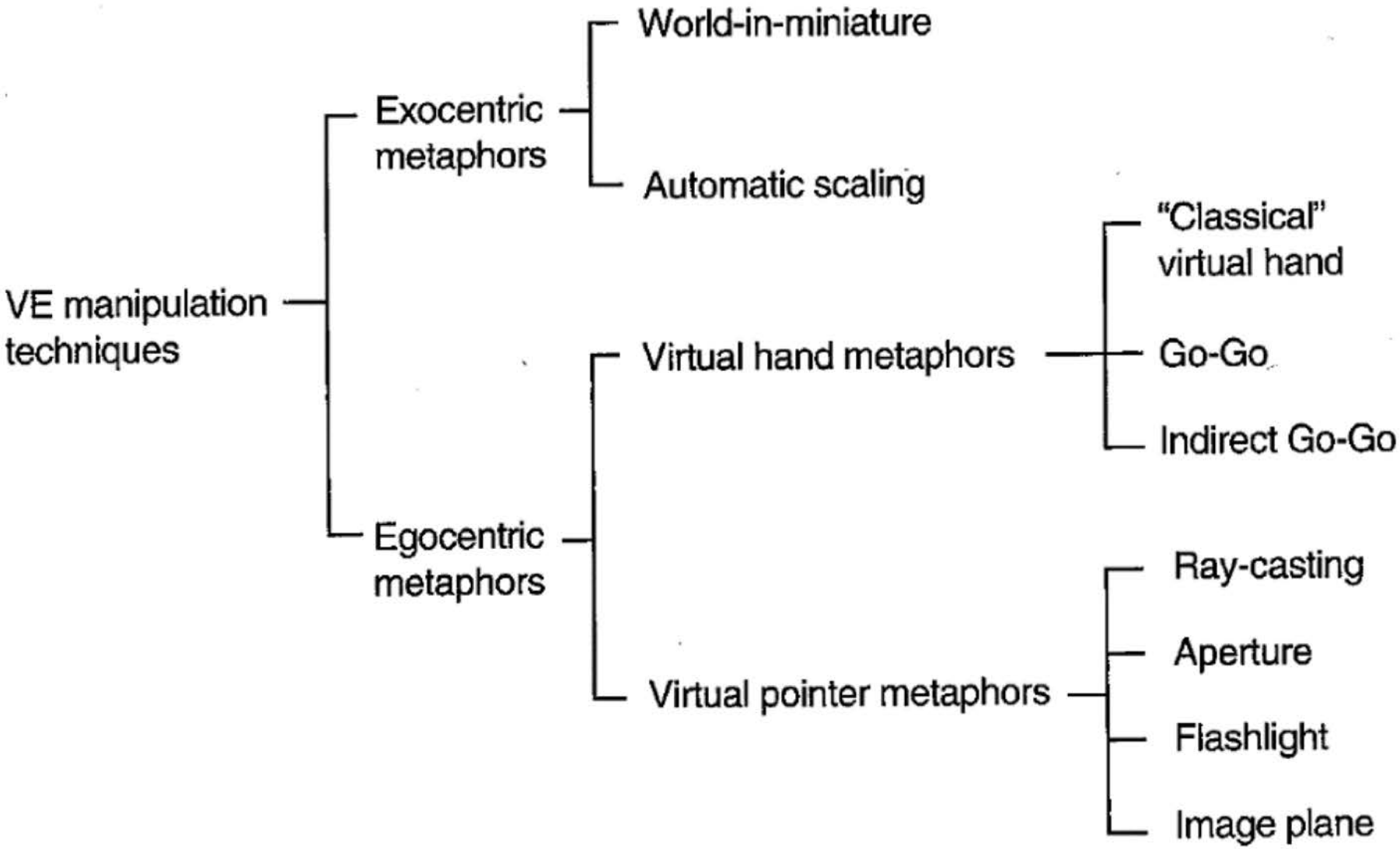


Goals of manipulation

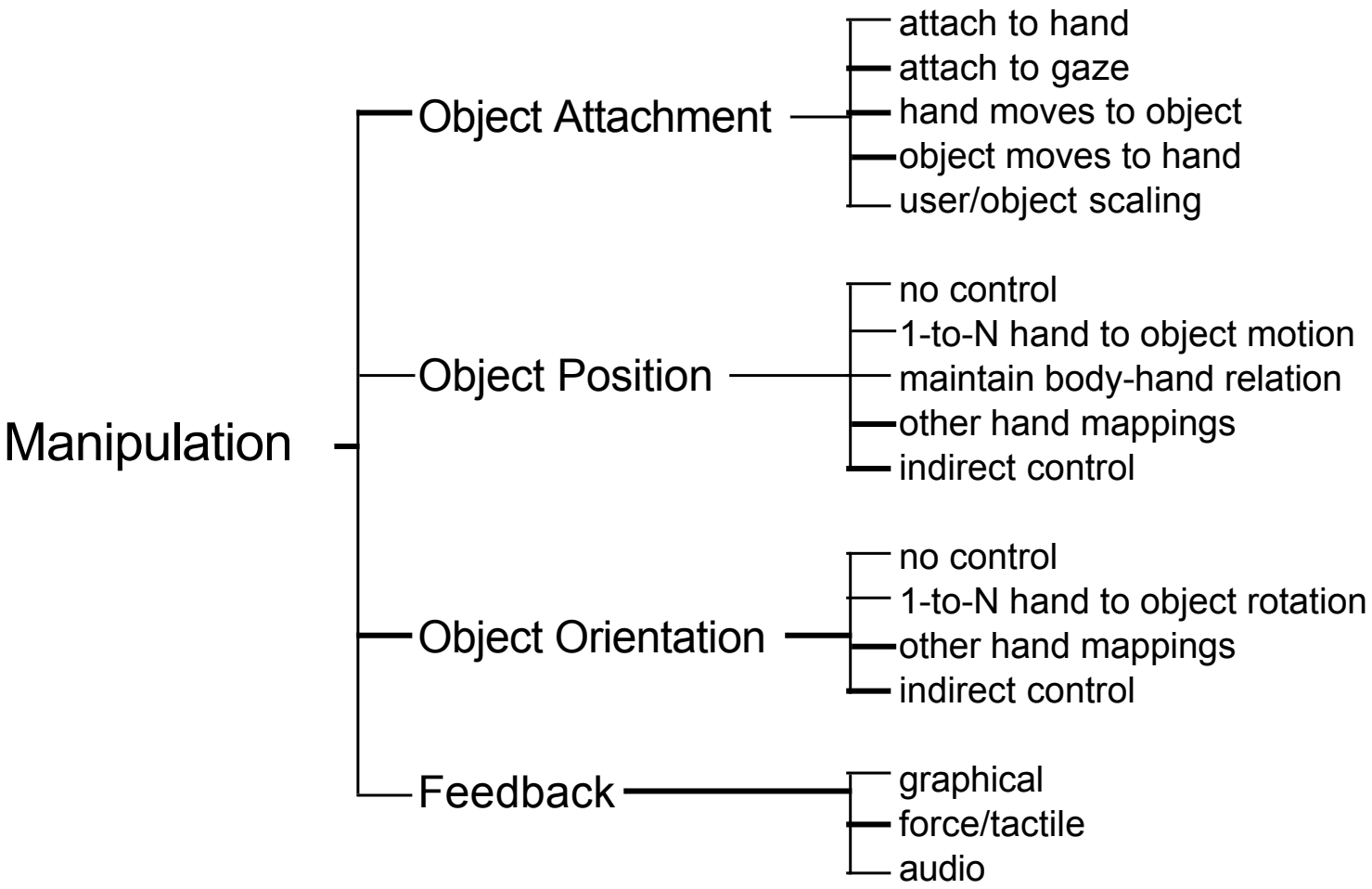
- Object placement
  - Design
  - Layout
  - Grouping
- Tool usage
- Travel



Classification of Manipulation Techniques



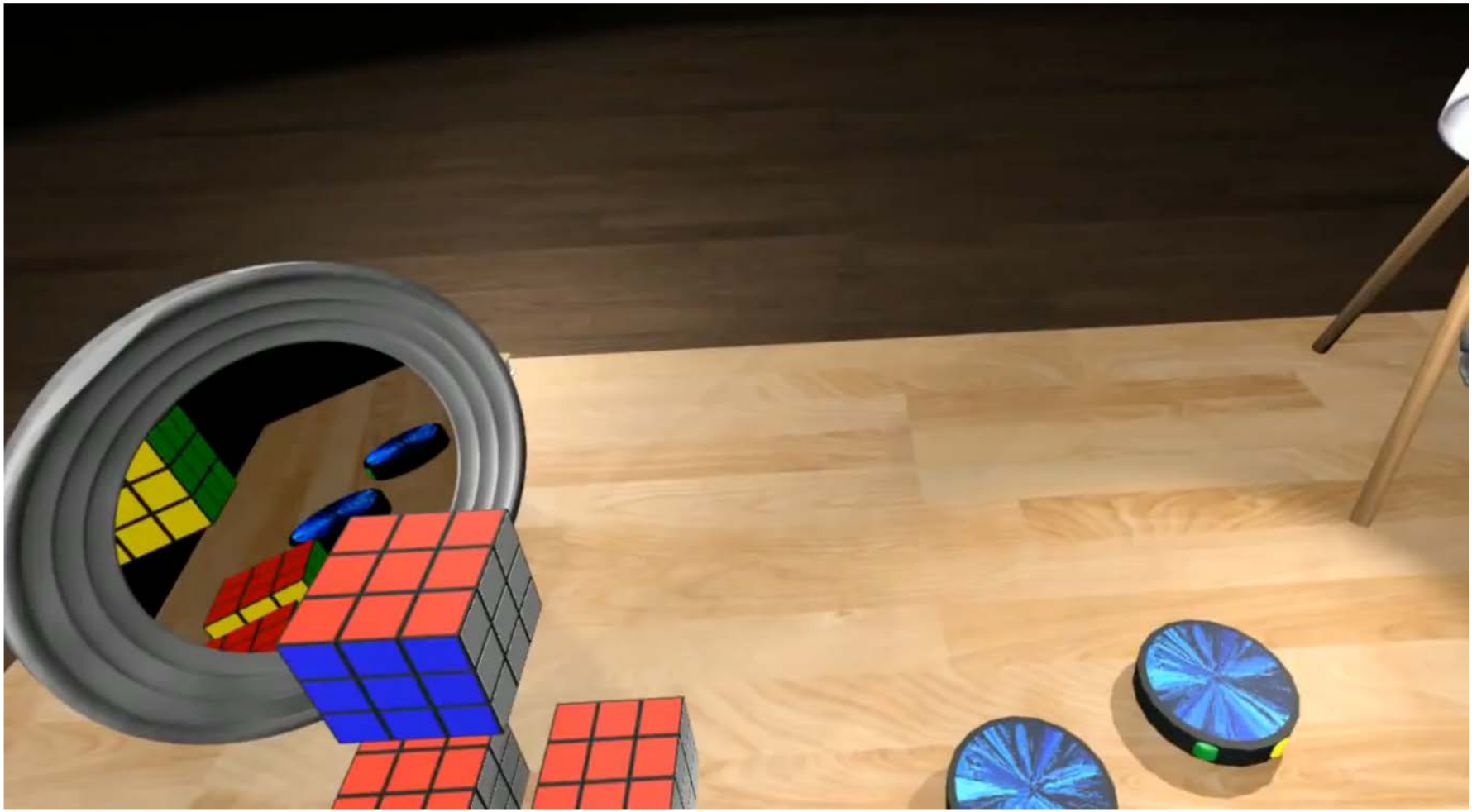
Technique Classification by Components



Common Manipulation Techniques

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

Simple Virtual Hand Manipulation



HOMER technique

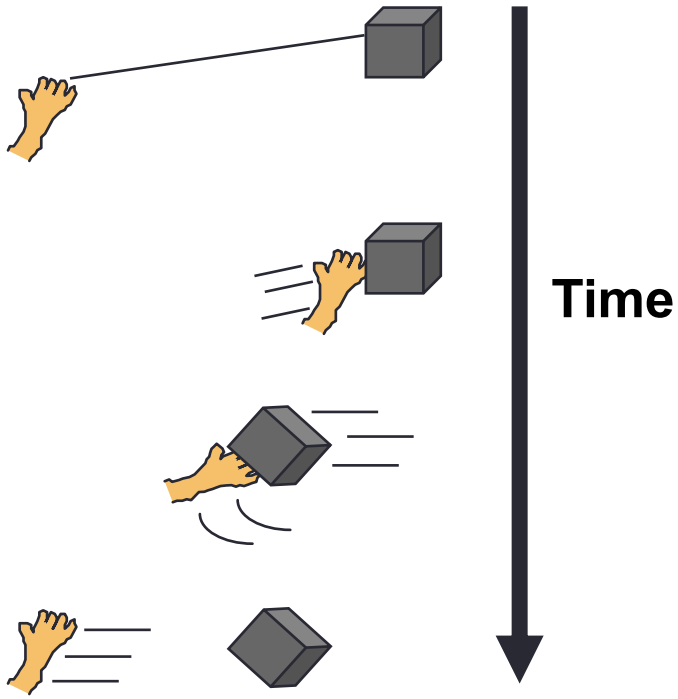
Hand-Centered

Object

Manipulation

Extending

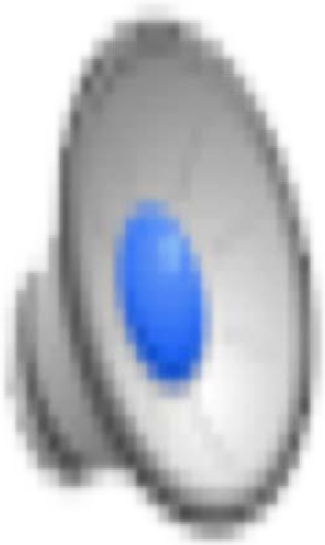
Ray-Casting



- 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.

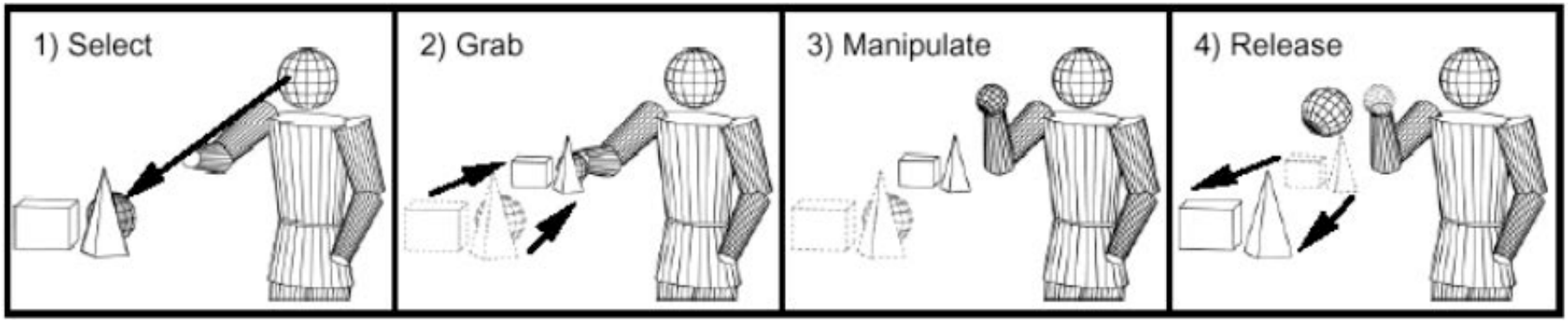
Example



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

Scaled-world Grab Technique

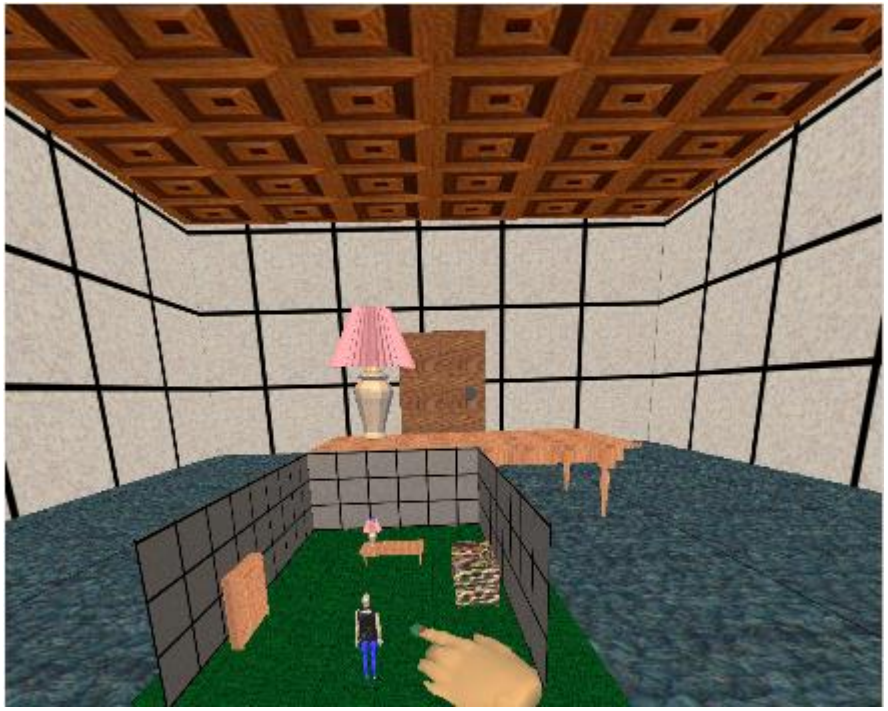
- Often used w/ occlusion
- At selection, scale user up (or world down) so that virtual hand is actually touching selected object
- User doesn‘t notice a change in the image until he moves



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.

Virtual Reality on a WIM:

Interactive Worlds in Miniature

Richard Stoakley
Matthew J. Conway
Randy Pausch
University of Virginia

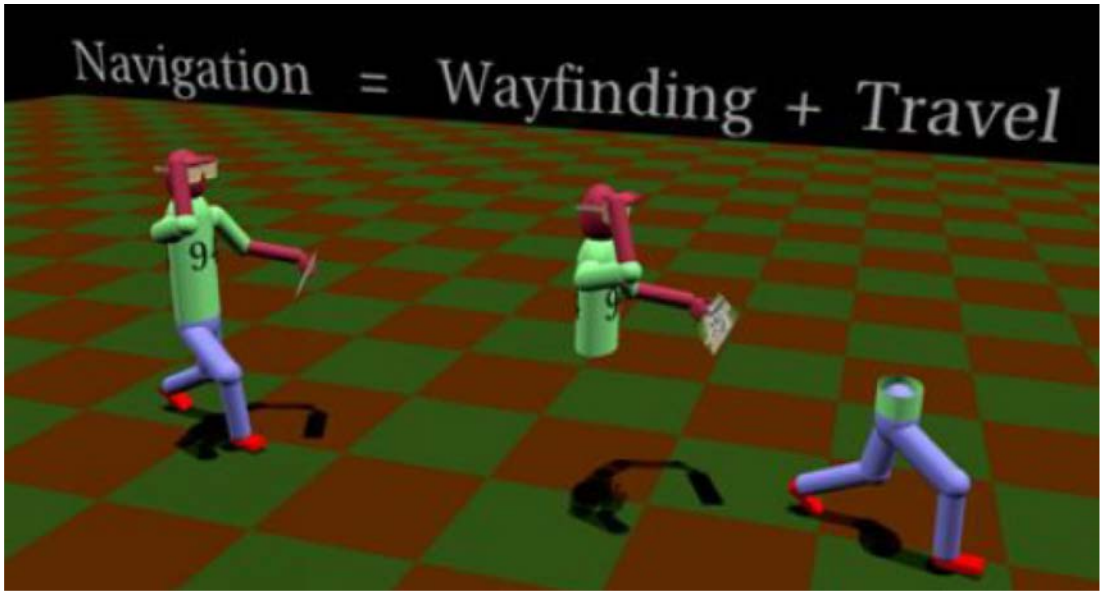
Two-Handed Interaction

- 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.

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

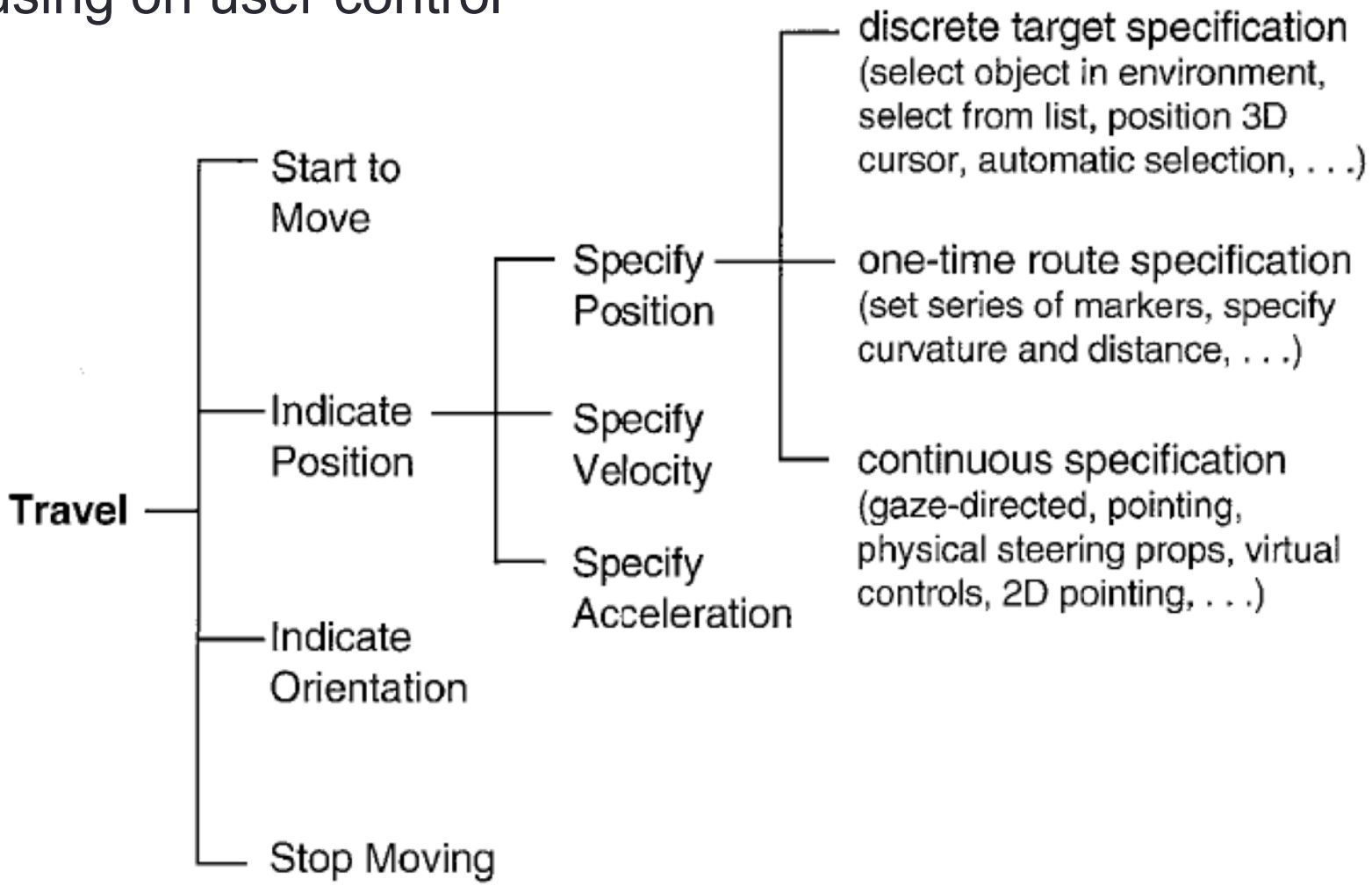
- The motor component of navigation
- Movement between 2 locations, setting the position (and orientation) of the user's viewpoint
- The most basic and common VE interaction technique, used in almost any large-scale VE

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



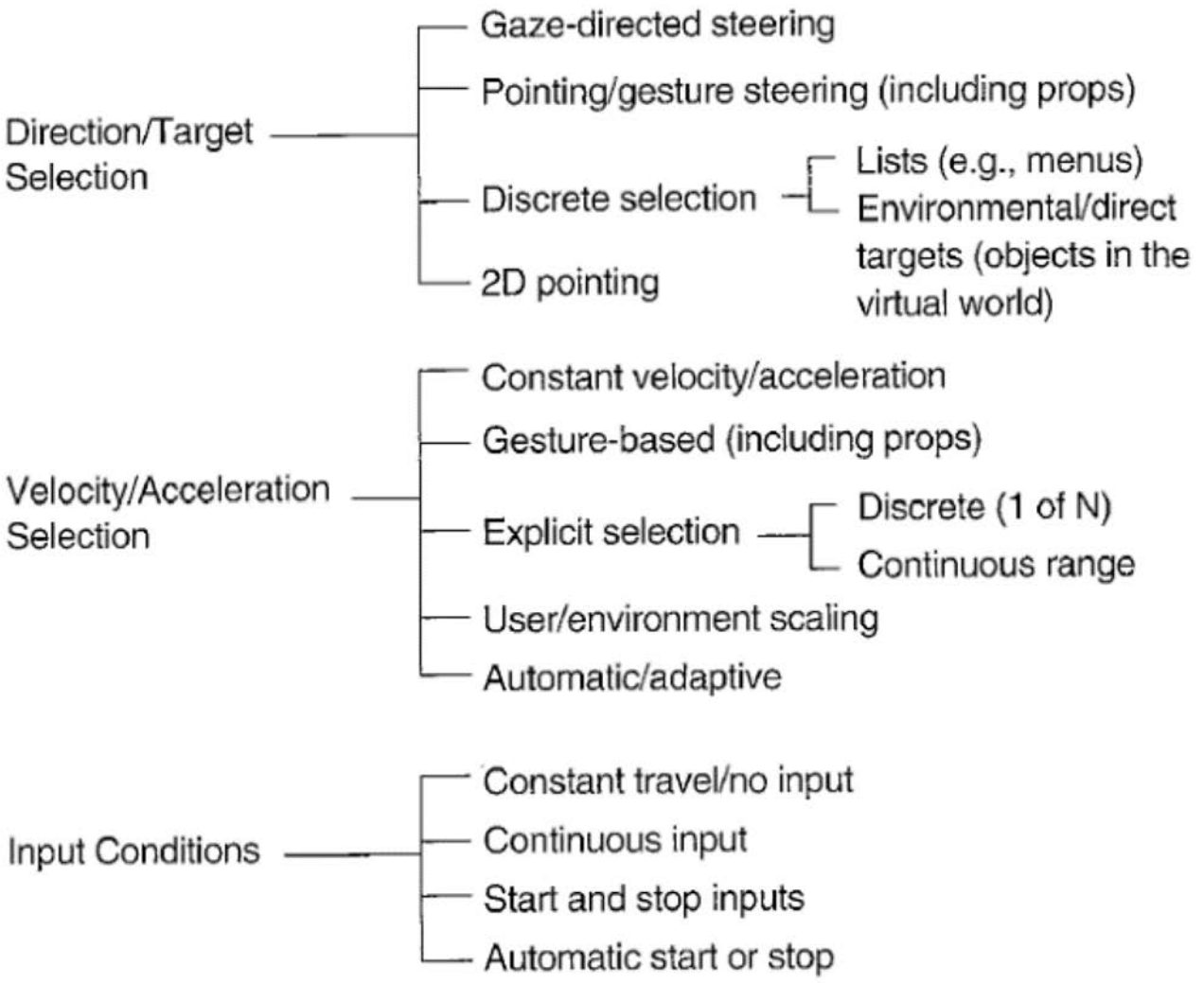
Technique classification

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

Different Locomotion Devices

Taxonomy of Travel Techniques

- Focusing on sub-task of travel

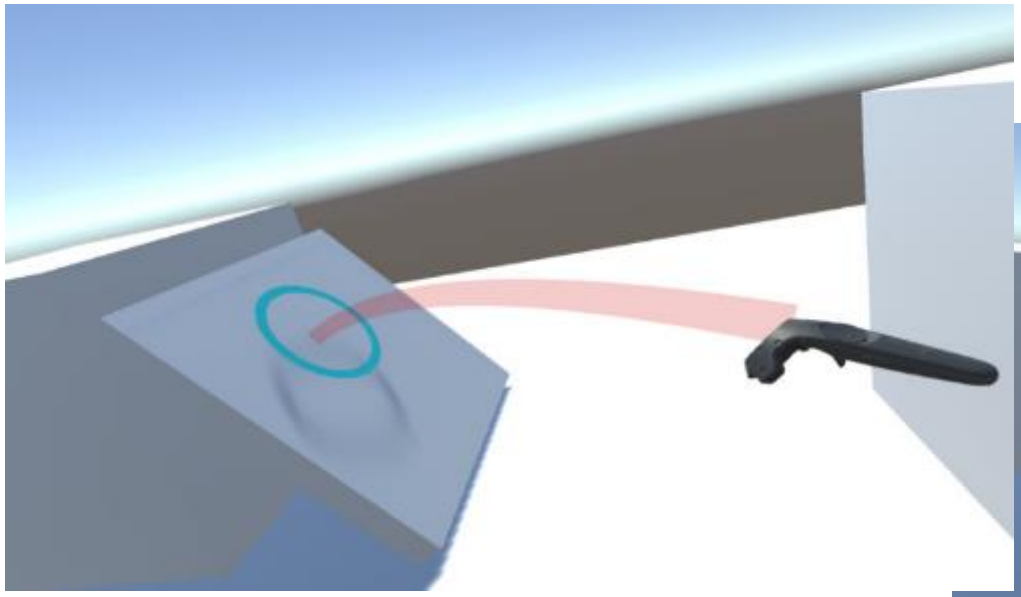


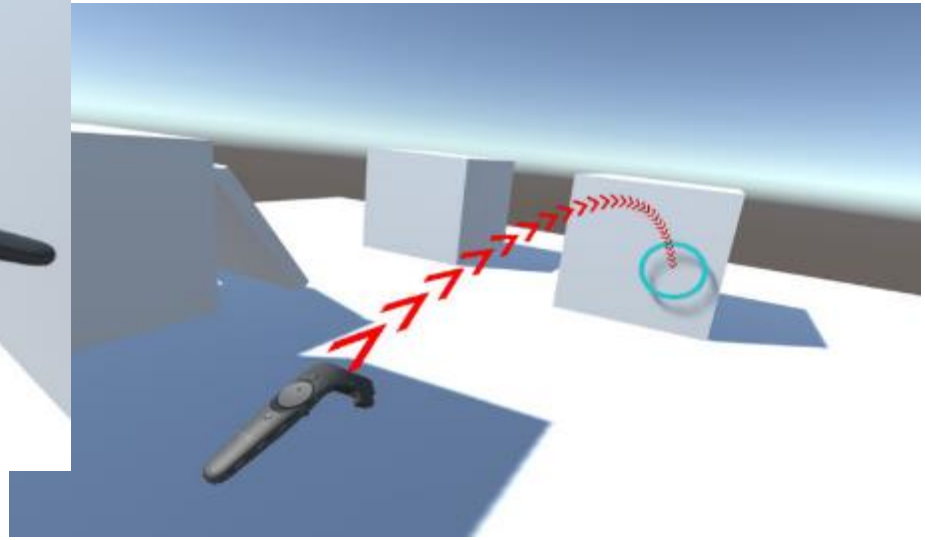
Bowman, D. A., Koller, D., & Hodges, L. F. (1997, March). Travel in immersive virtual environments: An evaluation of viewpoint motion control techniques. In *Virtual Reality Annual International Symposium, 1997., IEEE 1997* (pp. 45-52). IEEE.

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

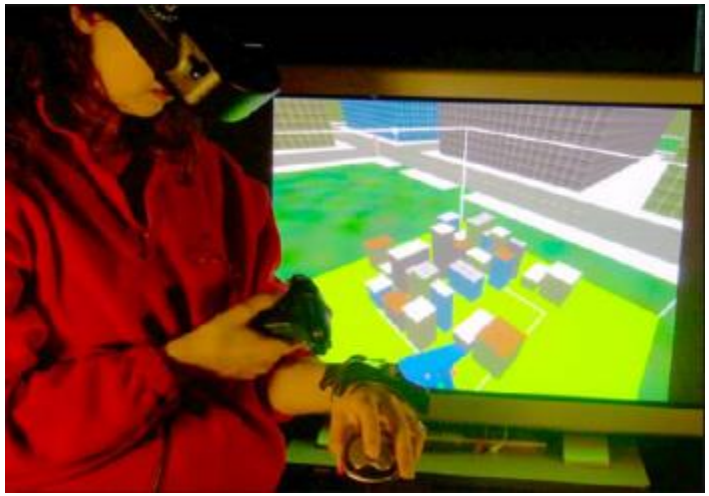
TelePortation

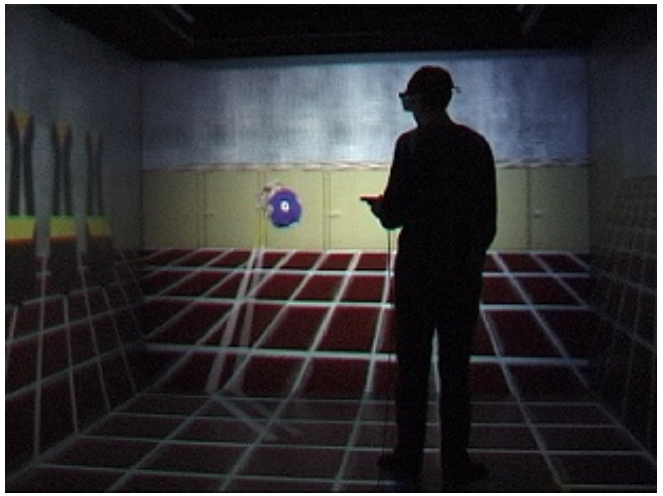




- Use controller to select end point
  - Usable with 3DOF contoller
- Jump to a fixed point in VR
- Discrete motion can be confusing/cause sickness

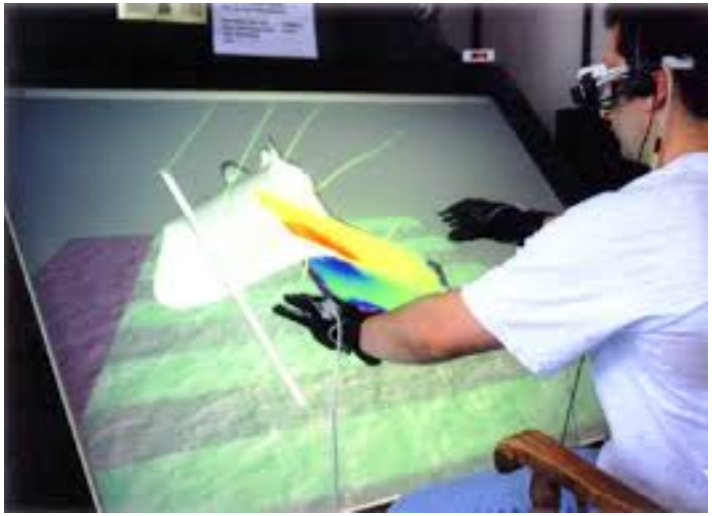
Pointing Technique





- 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

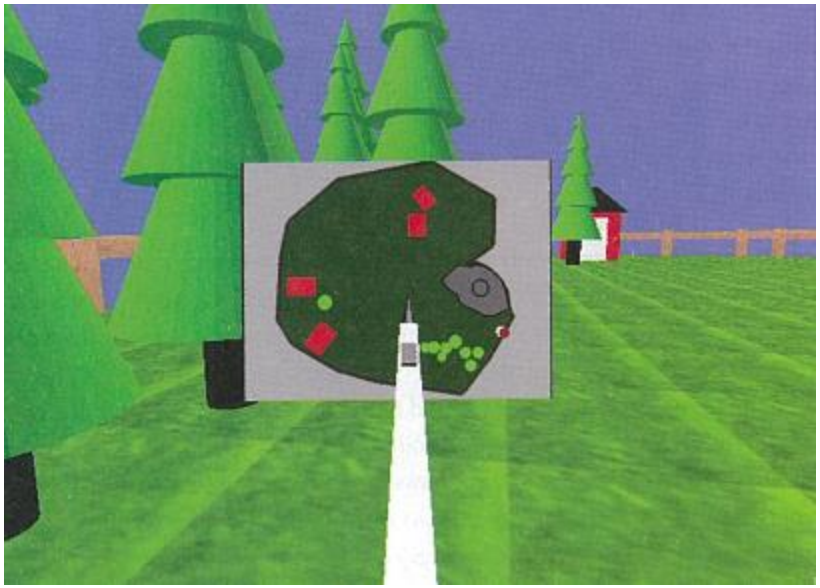
Grabbing the Air Technique



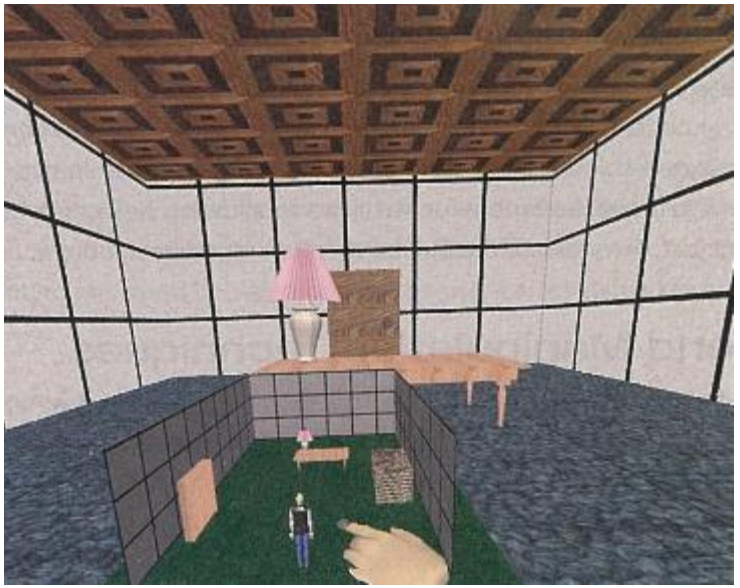
- Use hand gestures to move yourself through the world
- Metaphor of pulling a rope
- Often a two-handed technique
- May be implemented using Pinch Gloves

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

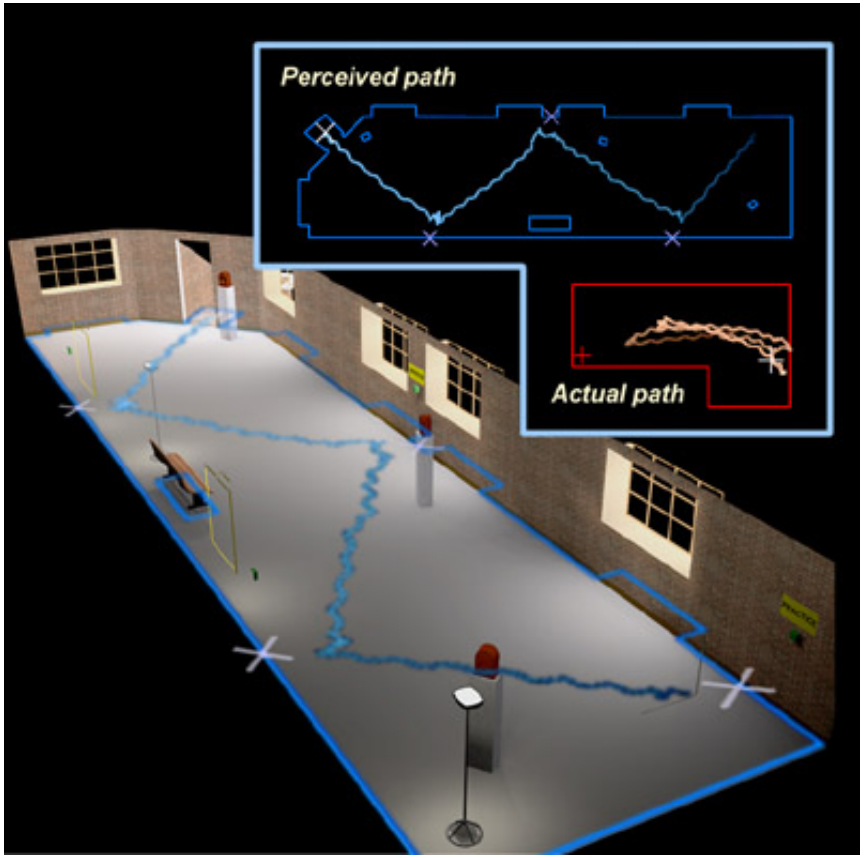


Moving avatar in WIM view

- 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

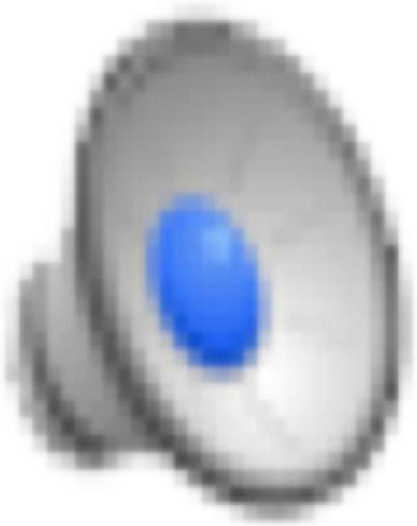
Redirected Walking

- 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

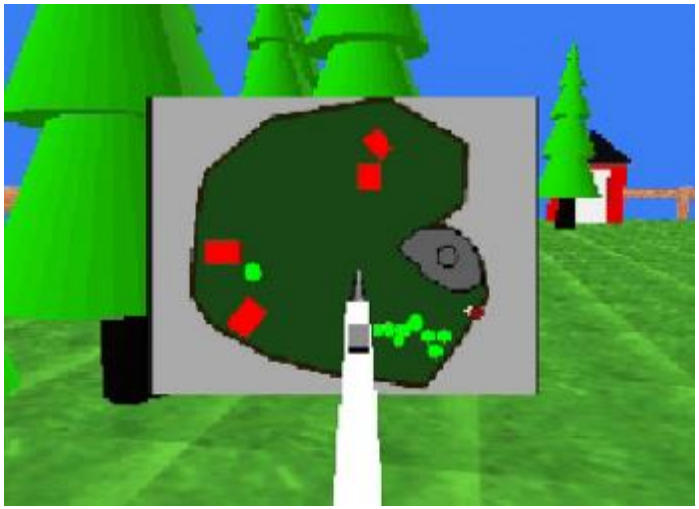
Wayfinding

- 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

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

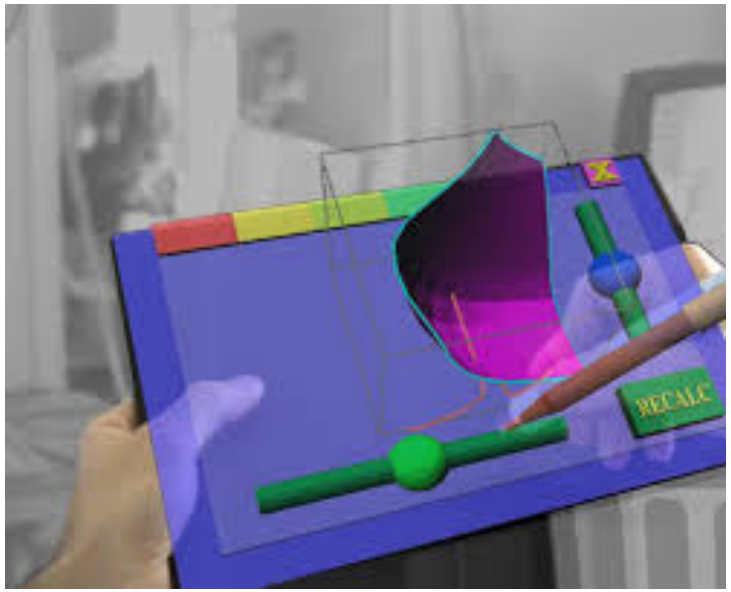
- Path following
  - Easy method of wayfinding
  - Multiple paths through a single space may be denoted by colors
    - For example, hospitals that use colored lines to indicate how to get to certain locations.
- Bread crumbs (leaving a trail)
  - leaving a trail of markers - like Hänsel and Gretel
  - 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

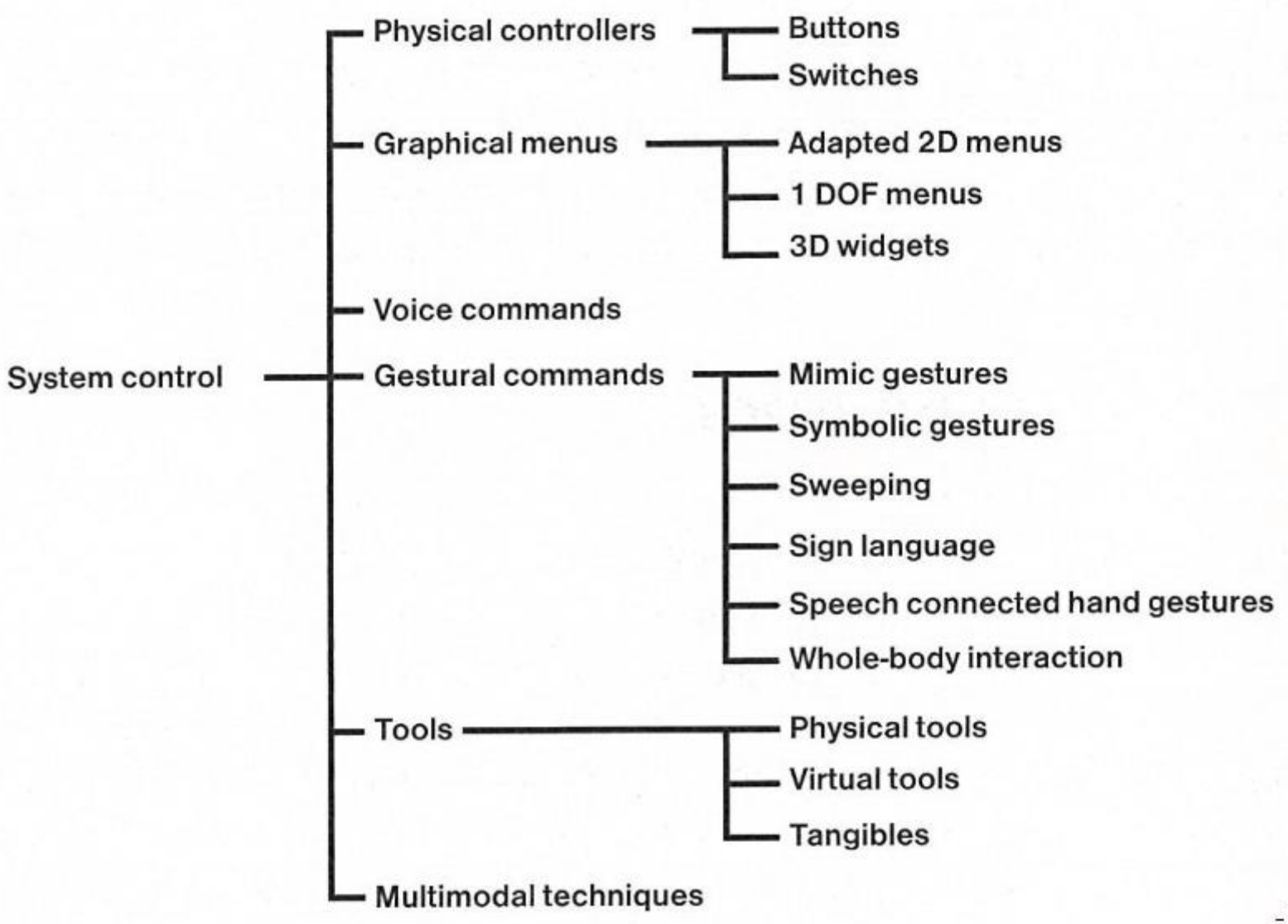
SYSTEM CONTROL

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



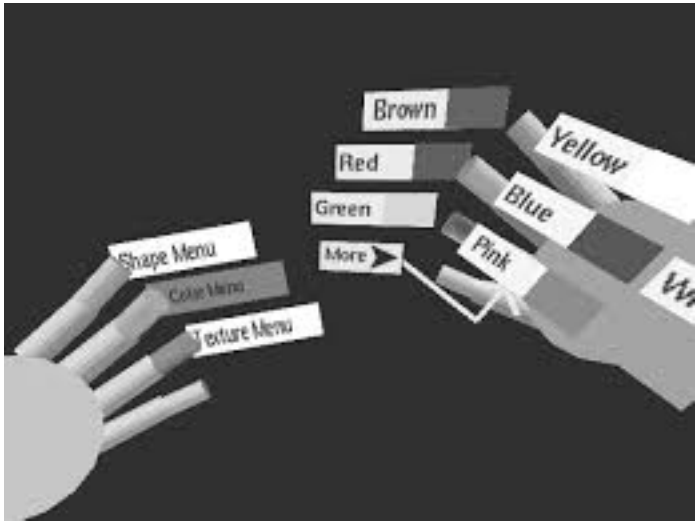
System Control Options

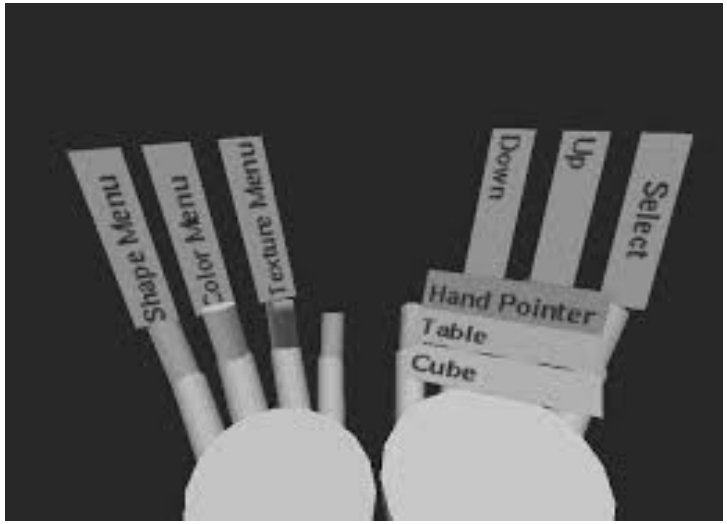


Example: GearVR Interface

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

TULIP Menu

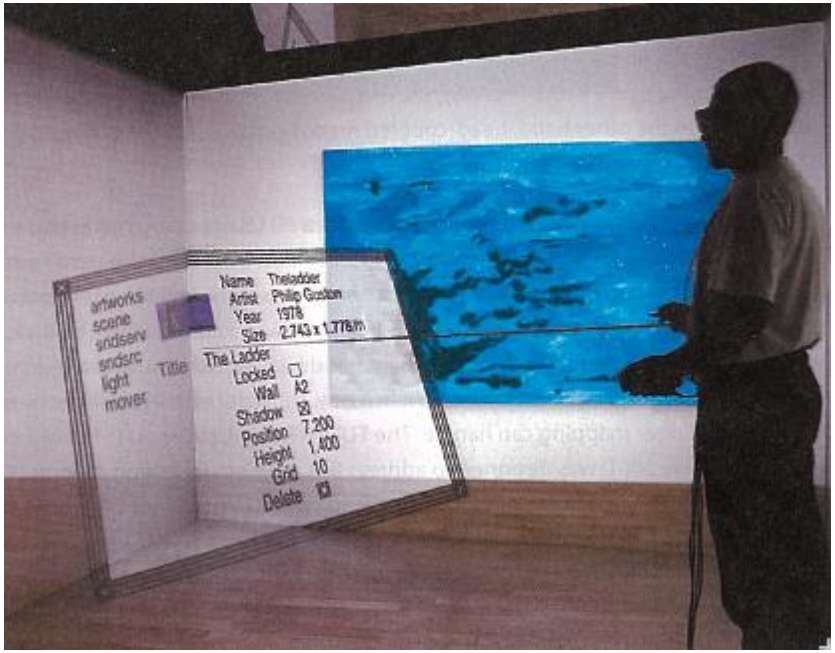




- Menu items attached to virtual finger tips
- Ideal for pinch glove interaction
- Use one finger to select menu option from another

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

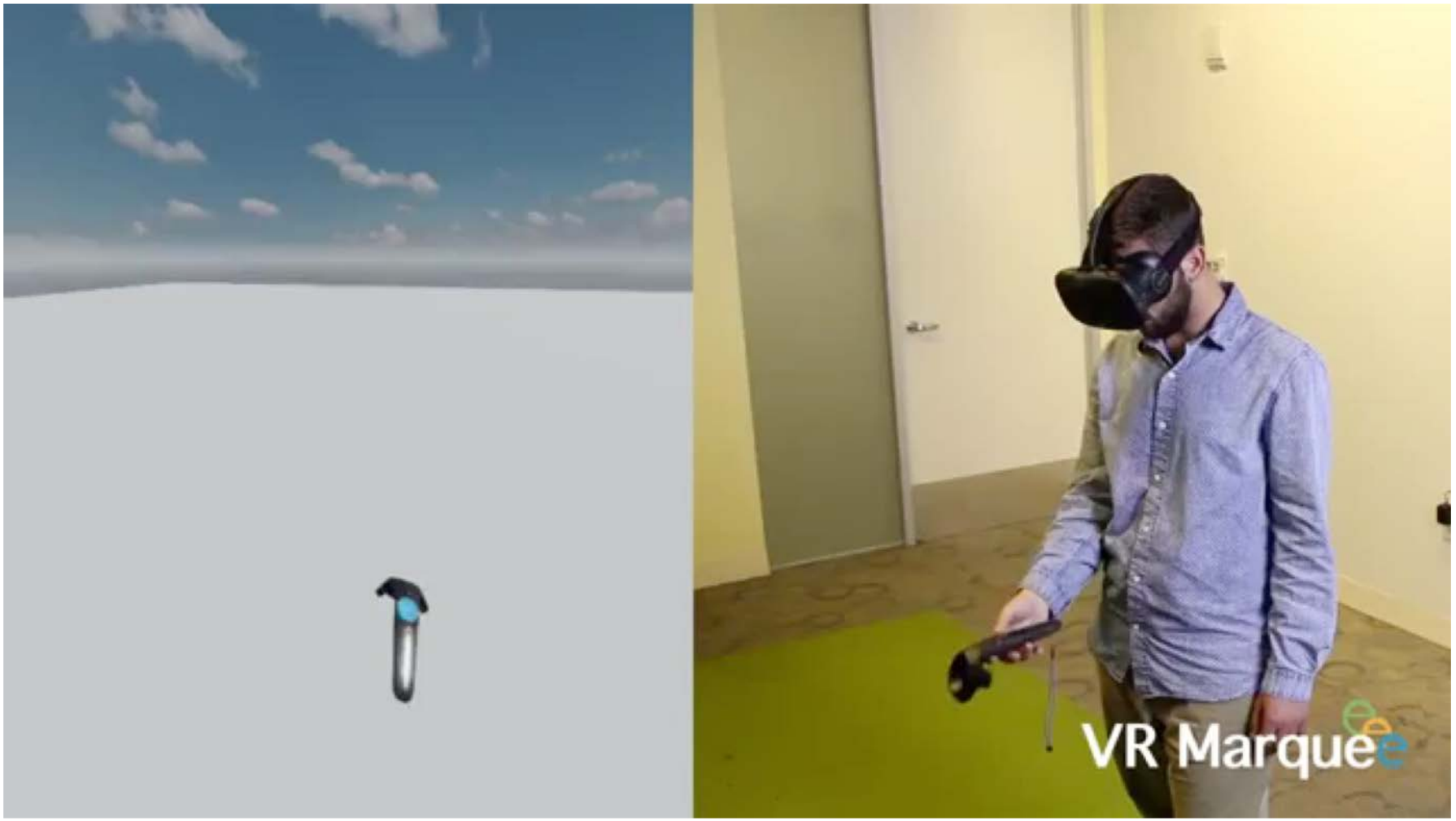


2D Menu in VR CAVE

Nested Pie Menu

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

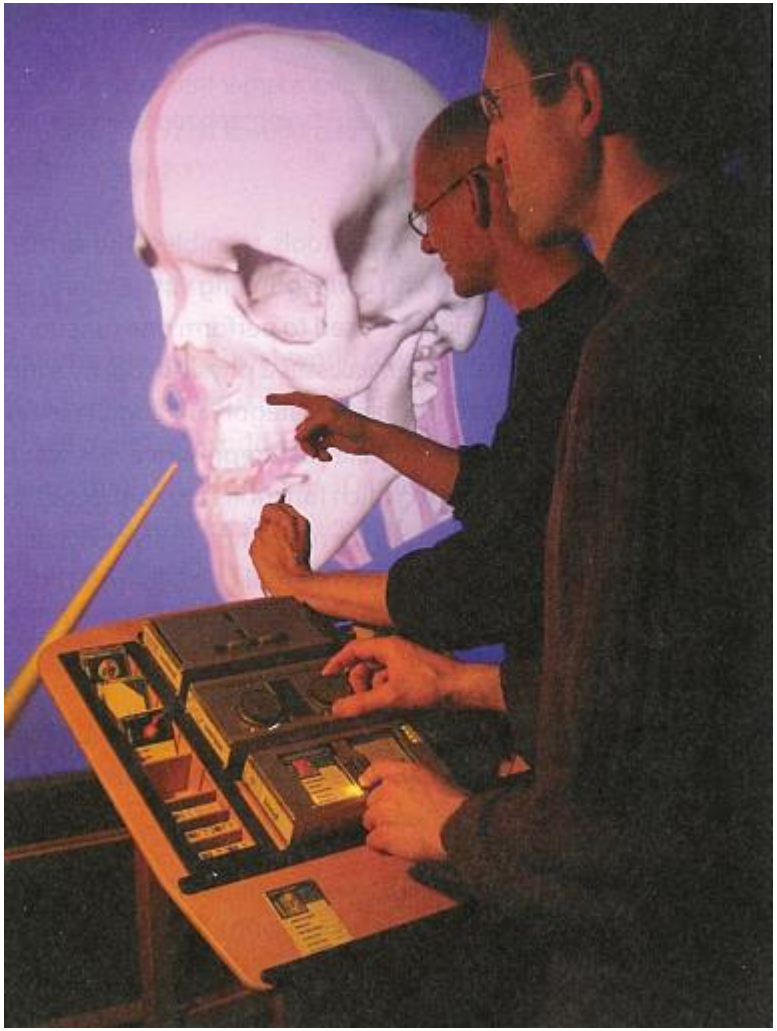
Example: Marking Menu in VR



- https://www.youtube.com/watch?v=BTTBgZ94IAc

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

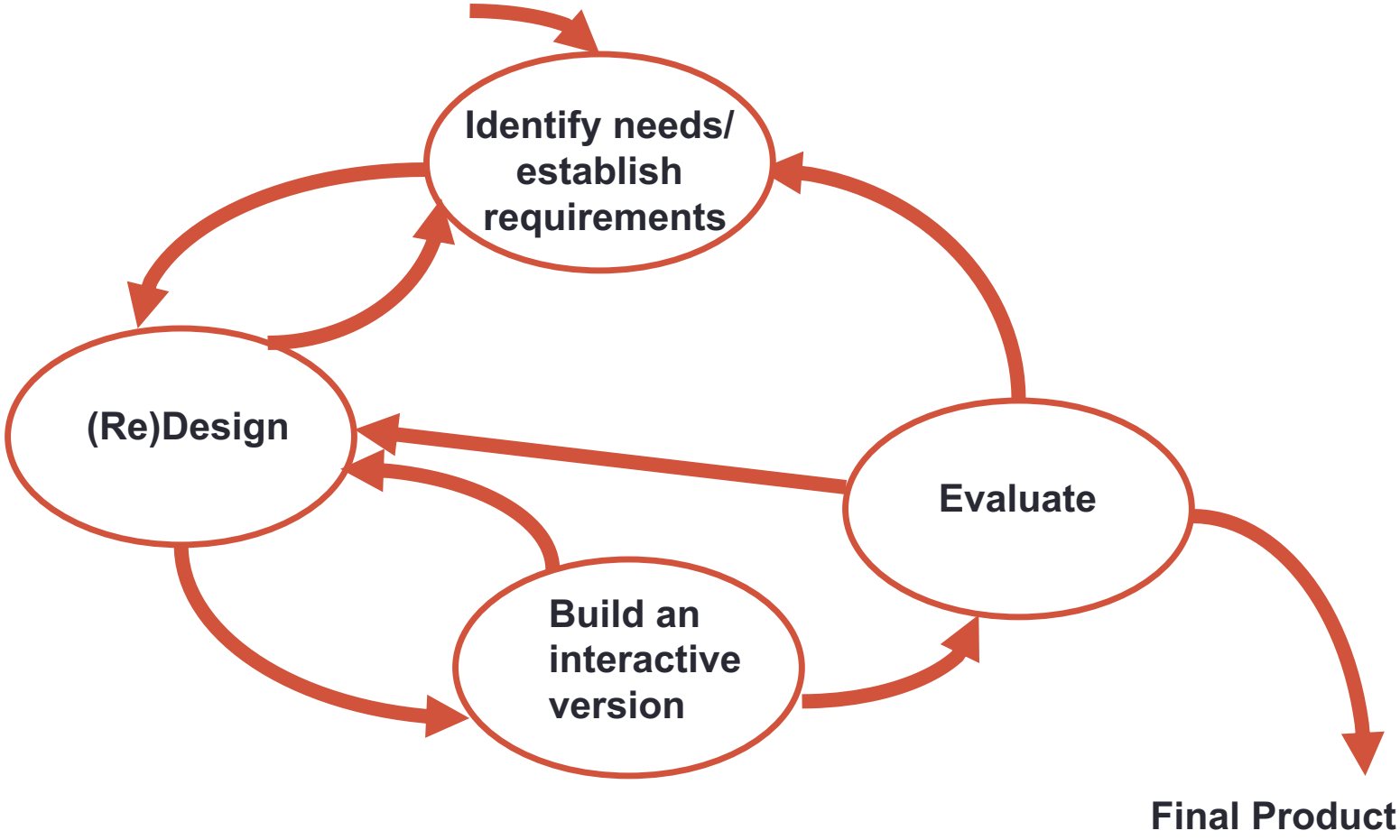
- Avoid mode errors
- Design for discoverability
- Consider using multimodal input
- Use an appropriate spatial reference frame
- Prevent unnecessary focus and context switching
- Avoid disturbing the flow of action of an interaction task
- Structure the functions in an application and guide the user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

INTERACTION DESIGN FOR VIRTUAL REALITY

How Can we Design Useful VR?

- Designing VR experiences that meet real needs

The Interaction Design Process

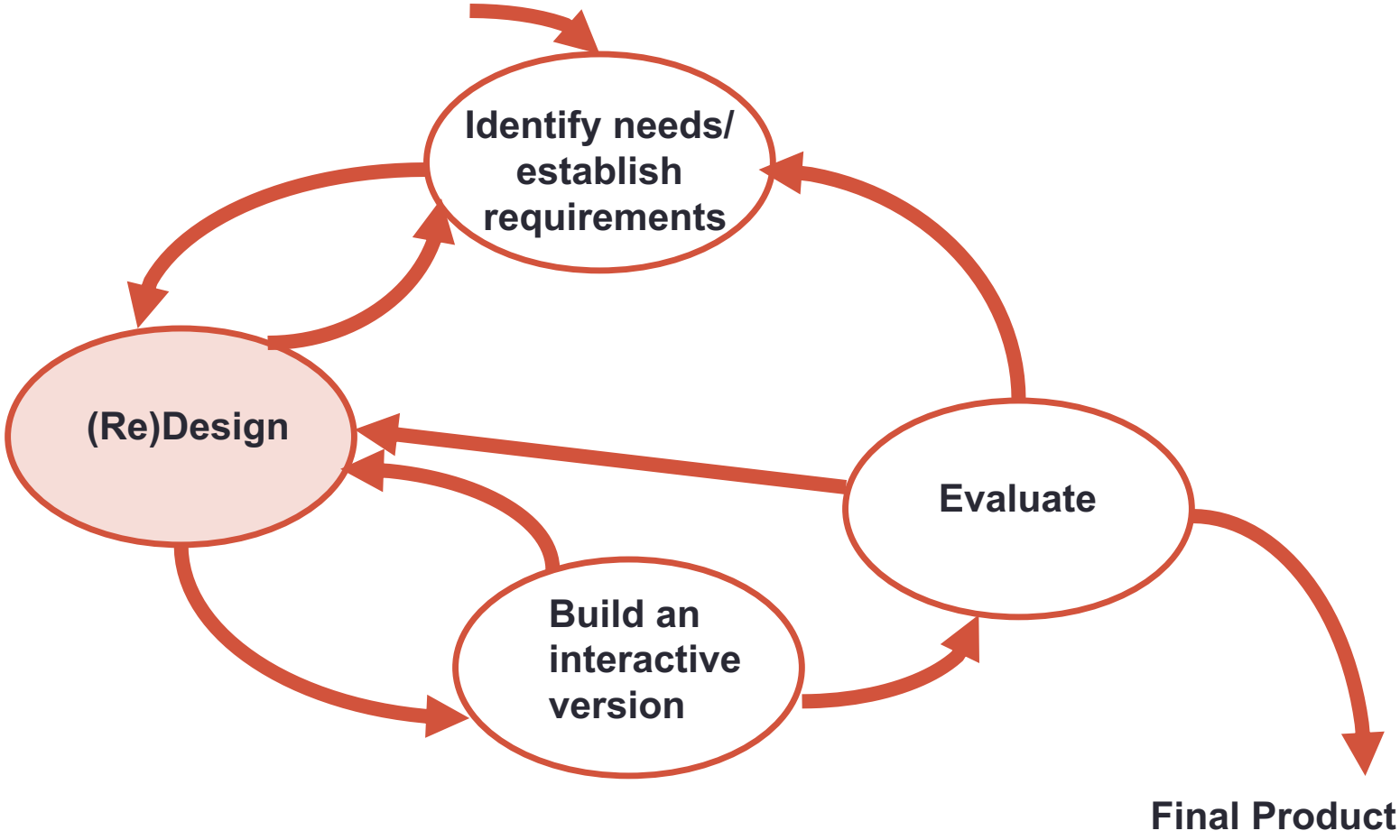


Develop alternative prototypes/concepts and compare them
And iterate, iterate, iterate....

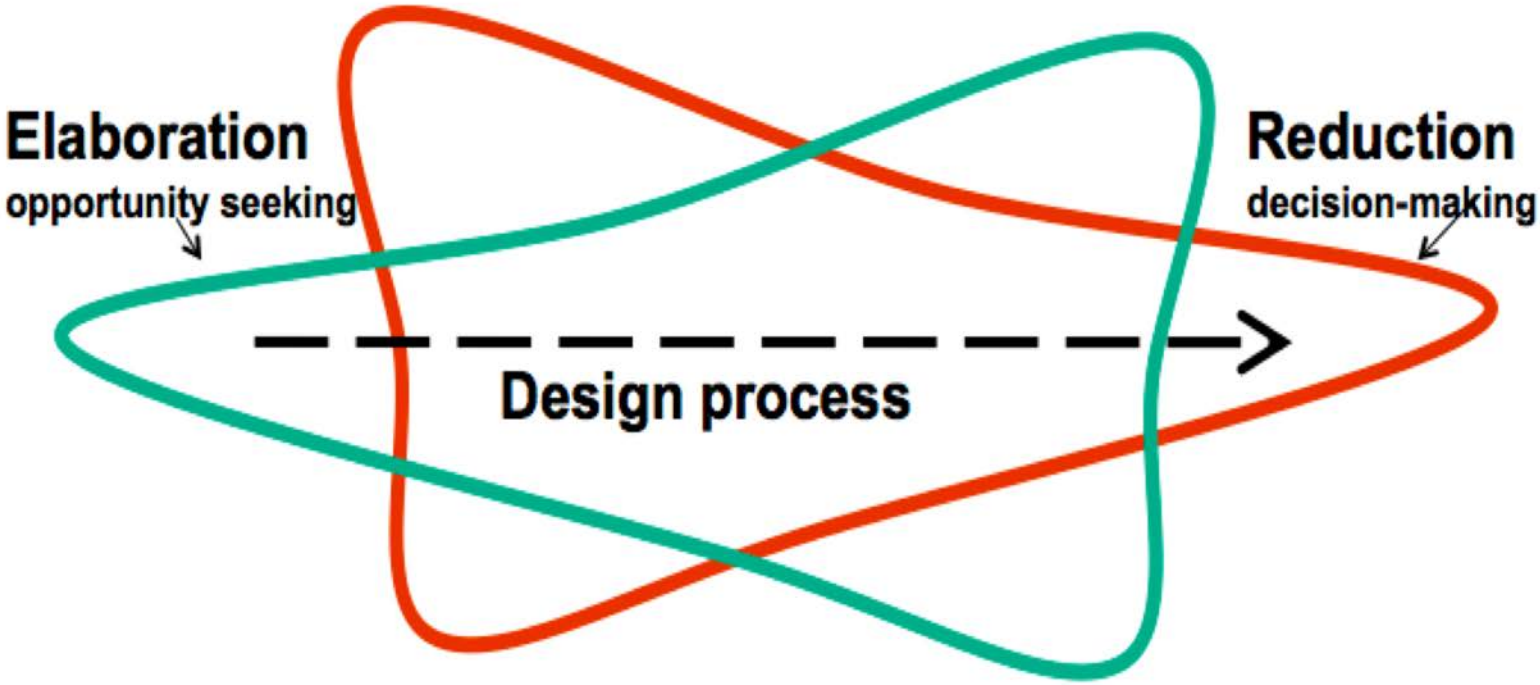
Key Questions

1. Who is the user?
   - Different types of users
2. What are the user needs?
   - Understand the user, look for insights
3. Can VR address those needs?
   - VR cannot solve all problems

The Interaction Design Process

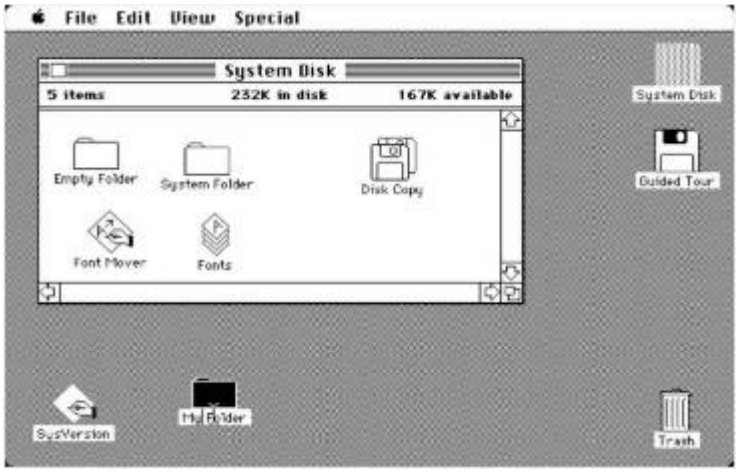


Elaboration and Reduction



- Elaborate on Ideas and Reduce to Final Design Direction
  - *Elaborate* - generate solutions. These are the opportunities
  - *Reduce* - decide on the ones worth pursuing
  - *Repeat* - elaborate and reduce again on those solutions

Use Interface Metaphors



- Design interface object to be similar to familiar physical object that the user knows how to use
  - E.g. Desktop metaphor, spreadsheet, calculator
- Benefits
  - Makes learning interface easier and more accessible
  - Users understand underlying conceptual model

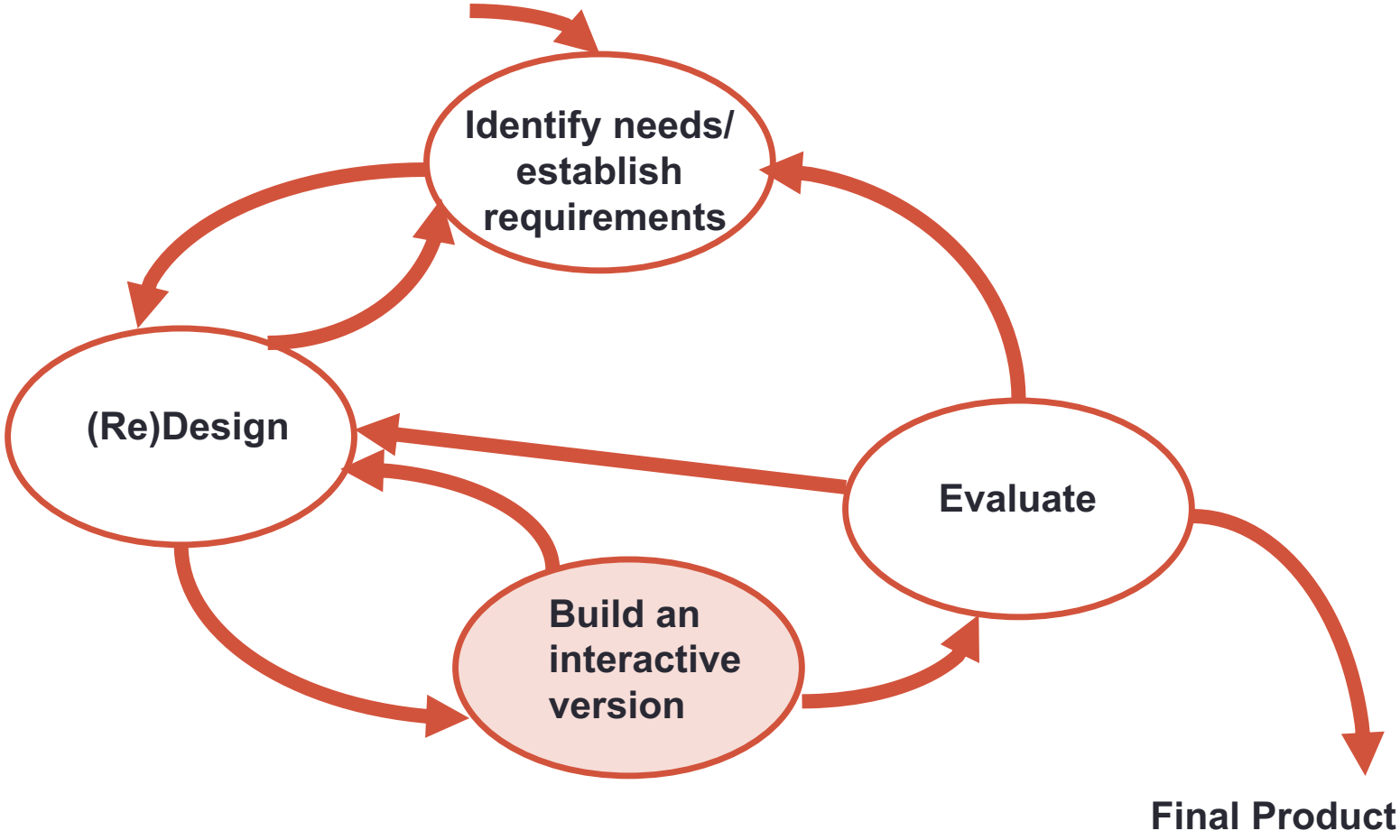
Affordances in VR

Familiar objects in Job Simulator

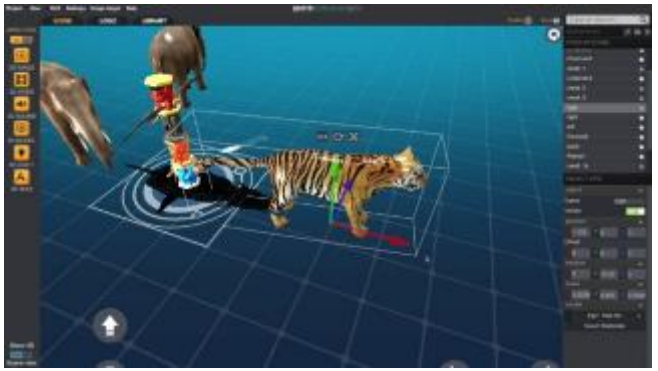
Object shape shows how to pick up

- 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 behavior to expected

Interaction Design Process

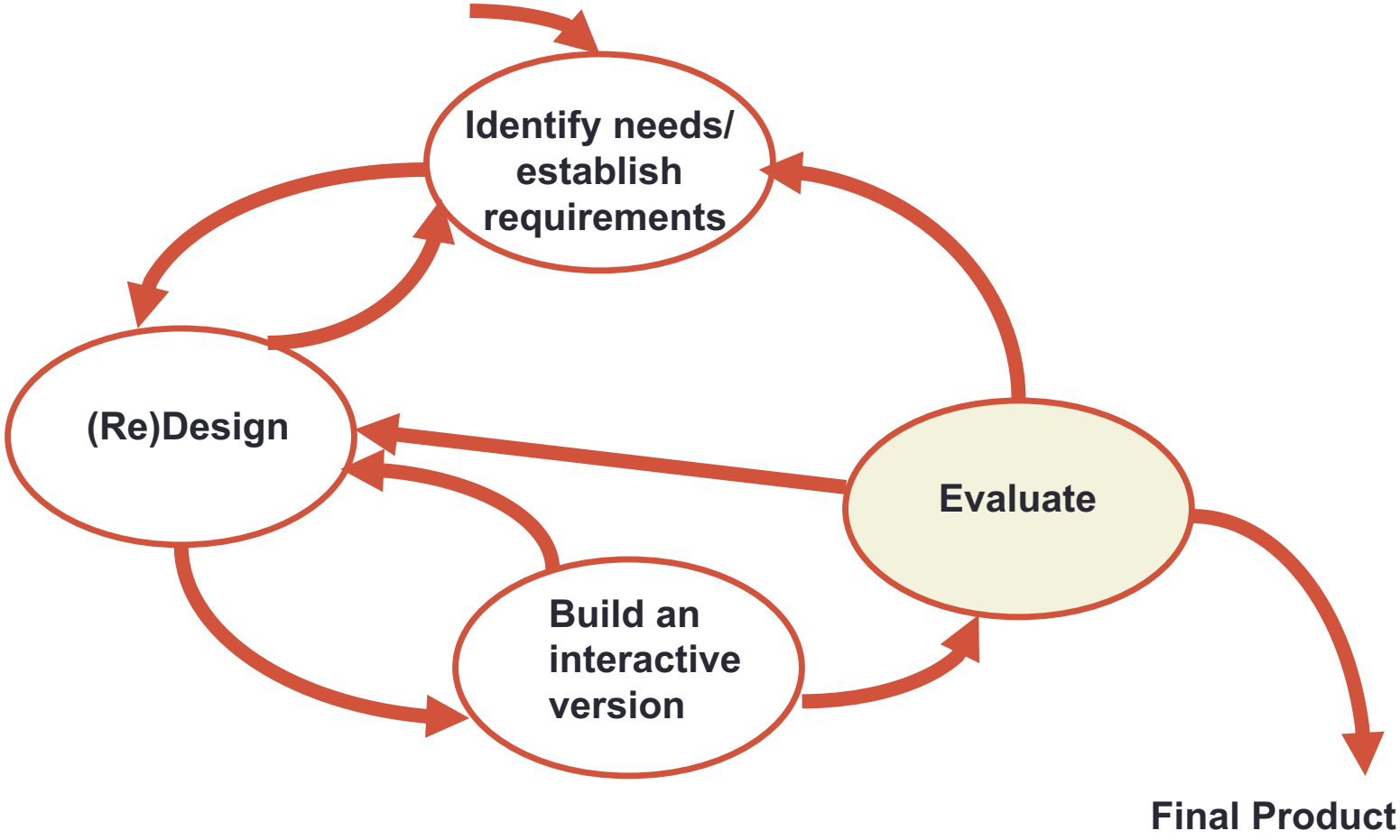


Why Prototype?



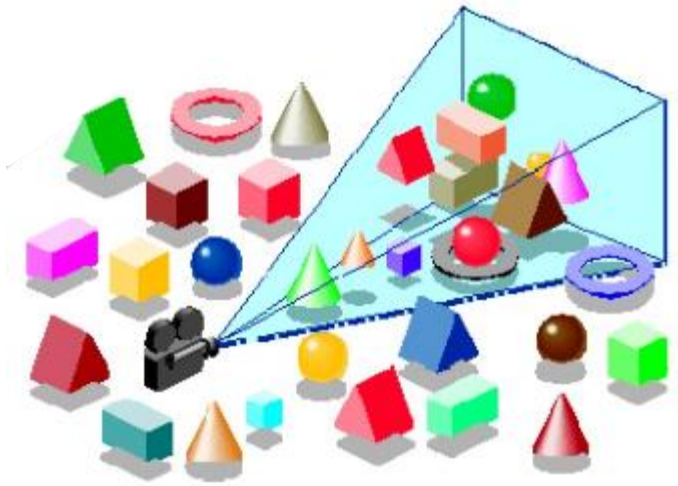
- Quick visual design
- Capture key interactions
- Focus on user experience
- Communicate design ideas
- “Learn by doing/experiencing”

Interaction Design Process



Four Evaluation Paradigms

- ‘quick and dirty’
- usability testing (lab studies)
- field studies
- predictive evaluation



CONCLUSION

Thank you

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