CSC 2524, Fall 2019

XR Interaction Interfaces

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Adapted from and with thanks to Mark Billinghurst

Typical Virtual Reality System

HMD

User Interface

Input

Tracking

How can we Interact in VR?

Traditional UI design issues applicable in VR

- Input device
- Interaction style
- Feedback to the user

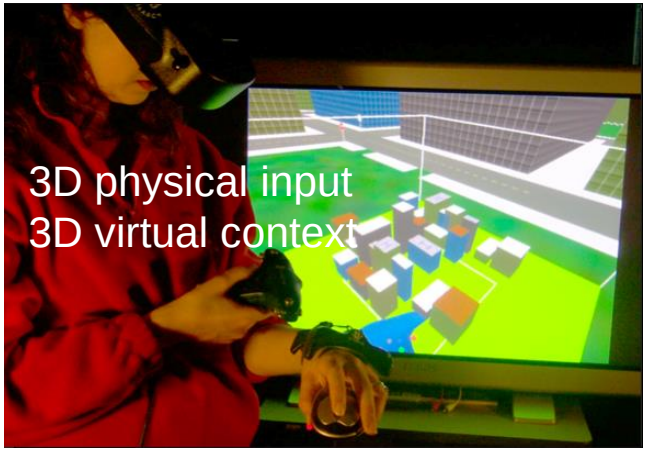
- Gulf of execution

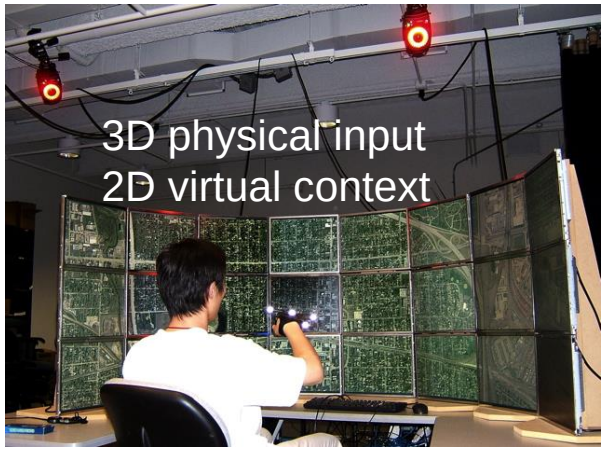
The difference between the user's perceived execution actions and the required actions.

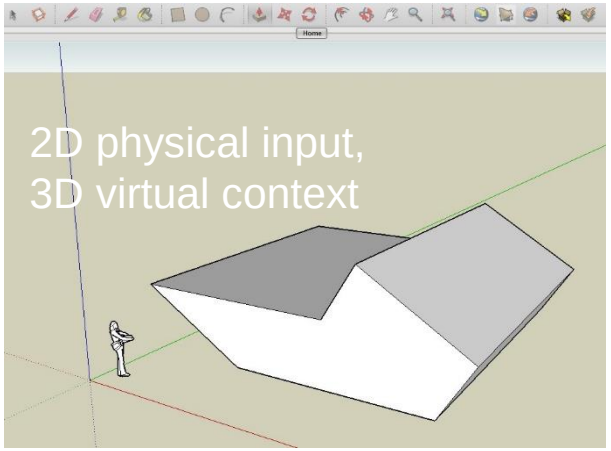
- Gulf of evaluation

The gap between the time of an external stimulus & when a user understands what it means: interface -> perception -> interpretation -> evaluation.

3D UI Examples







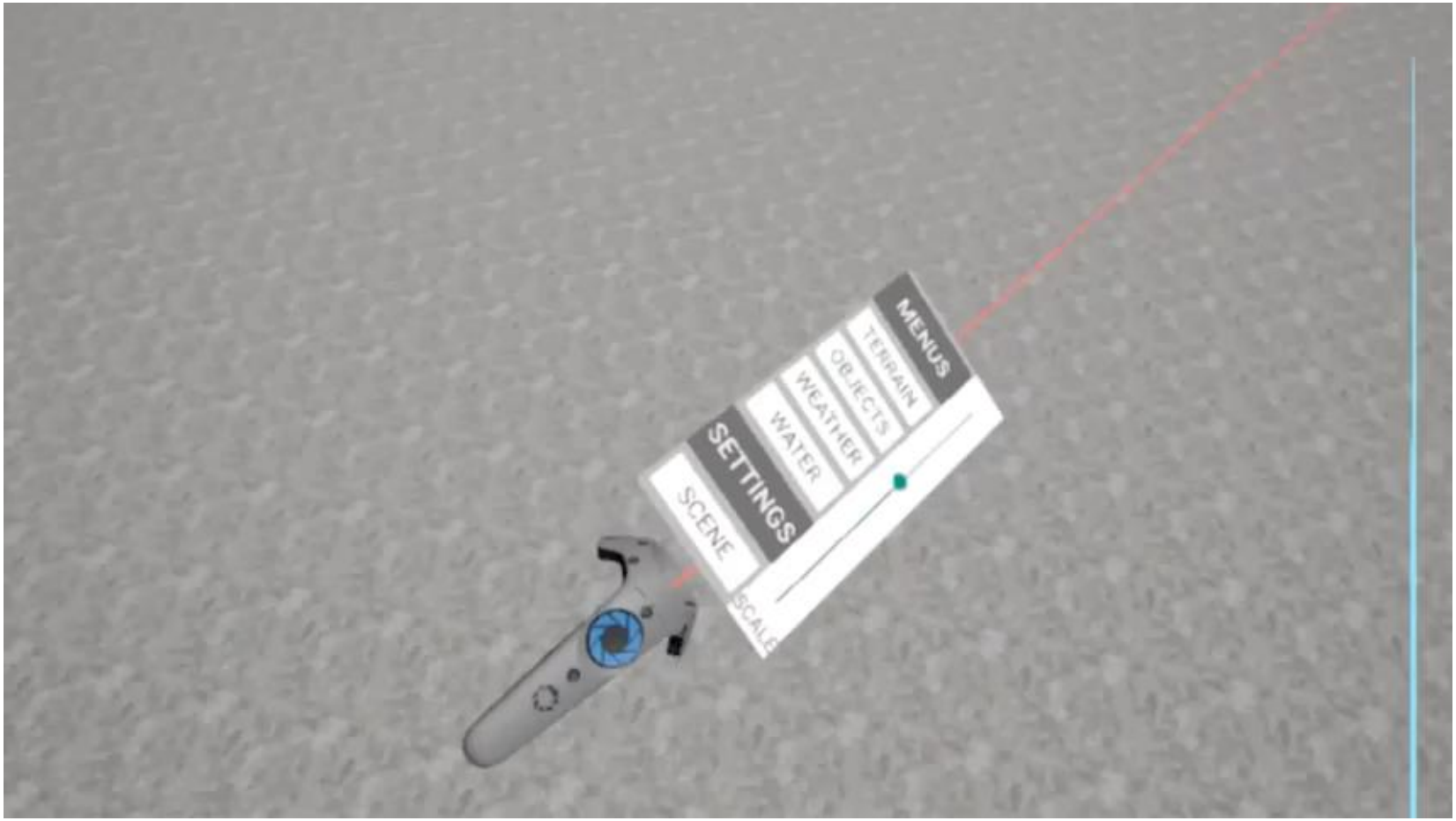
What makes 3D interaction difficult?

- Lack of precision
- Lack of constraints
- Fatigue
- Layout more complex
- Depth Perception
- Variations in Scale
- Lack of device standards

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..

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

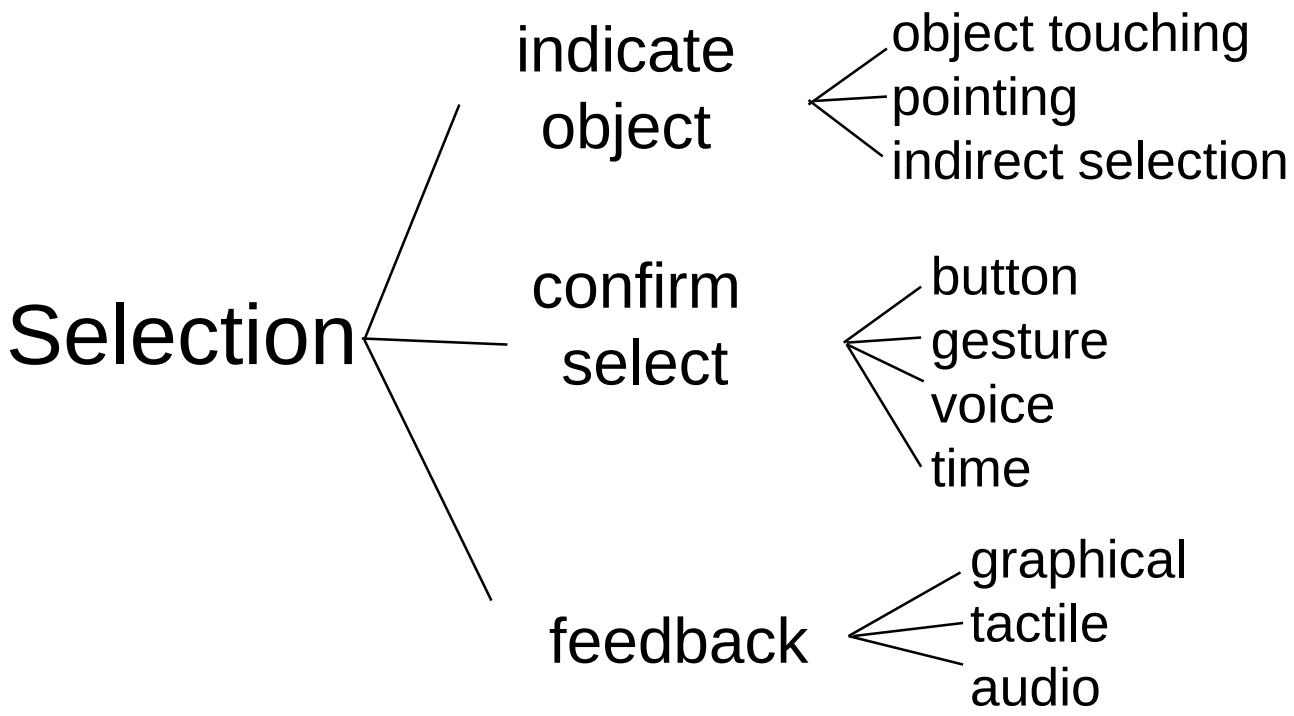
Selection and Manipulation

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

Variables affecting selection performance

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

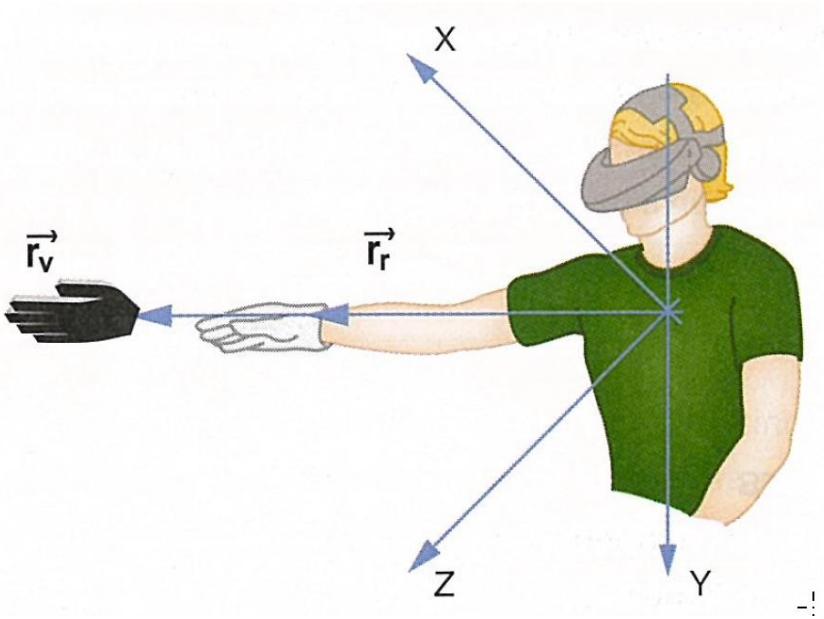
Selection breakdown

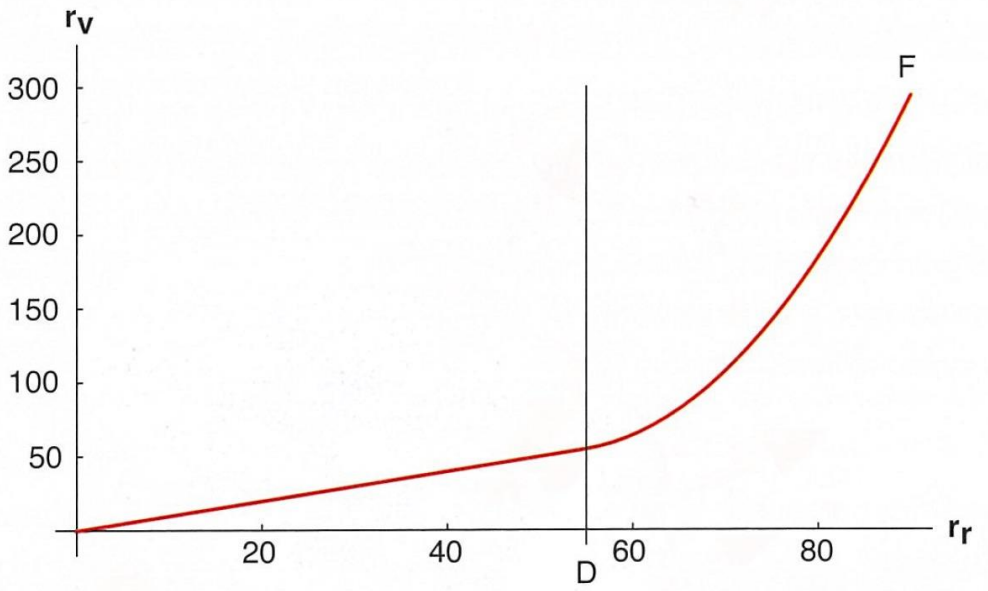


Common Selection Techniques

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

Go-Go Technique





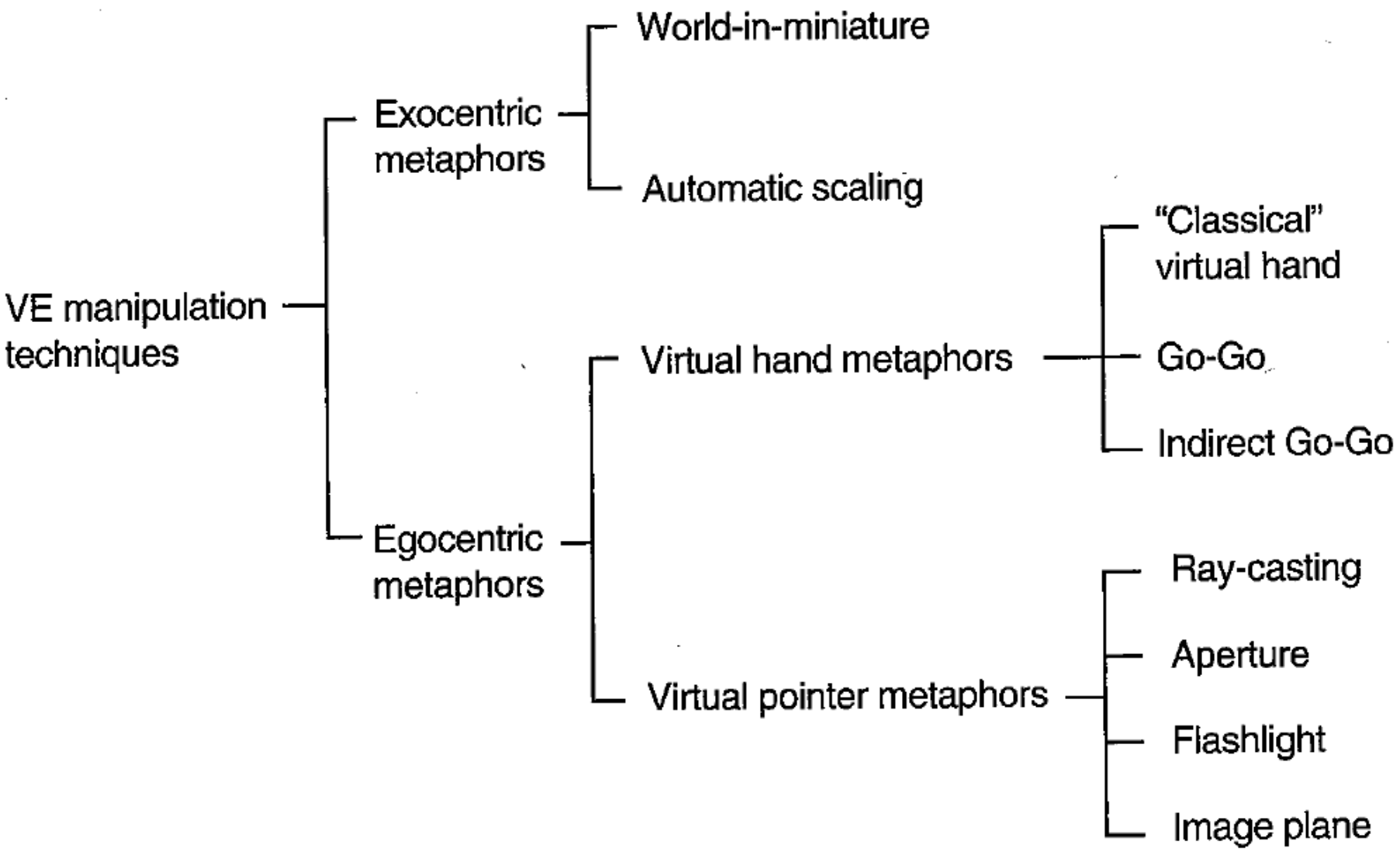
- Arm-extension technique
- Non-linear mapping between physical and virtual hand position
- Local and distant regions (linear < D, non-linear > D)

Poupyrev, I., Billinghurst, M., Weghorst, S., & Ichikawa, T. (1996). The Go-Go Interaction Technique: Non-linear Mapping for Direct Manipulation in VR. UIST, 79-80.

Precise 3D selection techniques

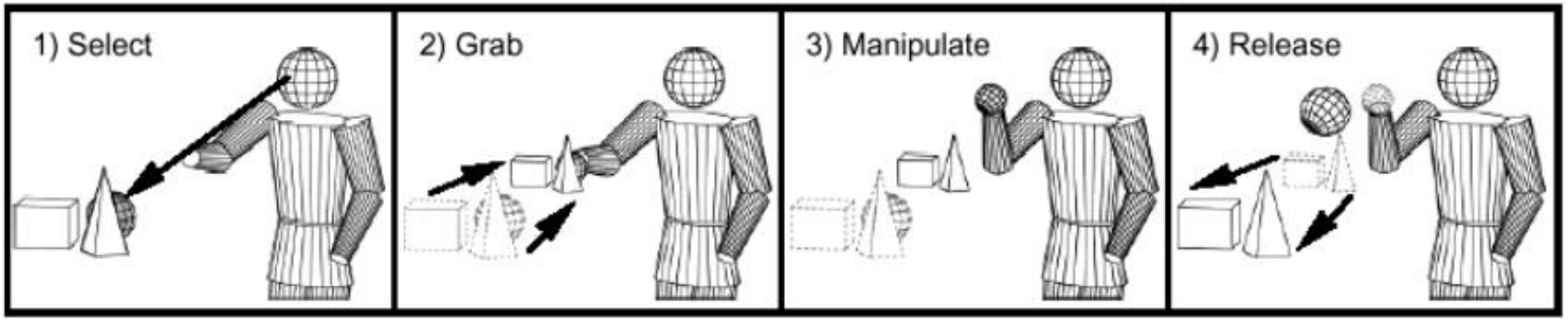
- Increase selection area
  - Cone-casting (Liang, 1993)
  - Snapping (de Haan, 2005)
  - 3D Bubble Cursor (Vanacken, 2007)
  - Sphere-casting (Kopper 2011)
- Increase control/display ratio
  - PRISM (Frees, 2007)
  - ARM (Kopper, 2010)

Classification of Manipulation Techniques



Scaled-world Grab Technique

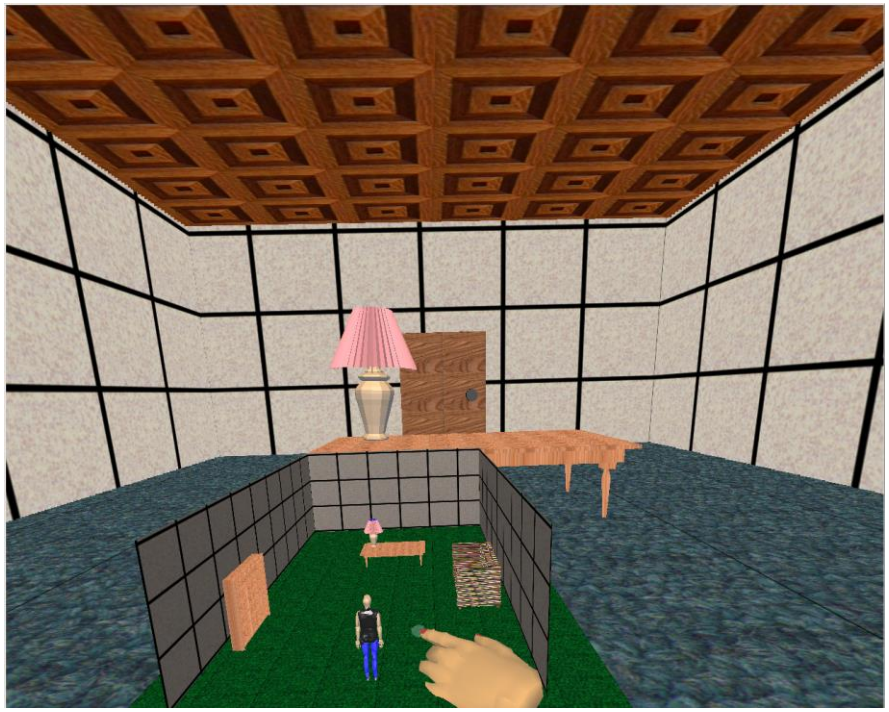
- Often used w/ occlusion
- At selection, scale user up (or world down) so that virtual hand is actually touching selected object
- User doesn‘t notice a change in the image until he moves



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

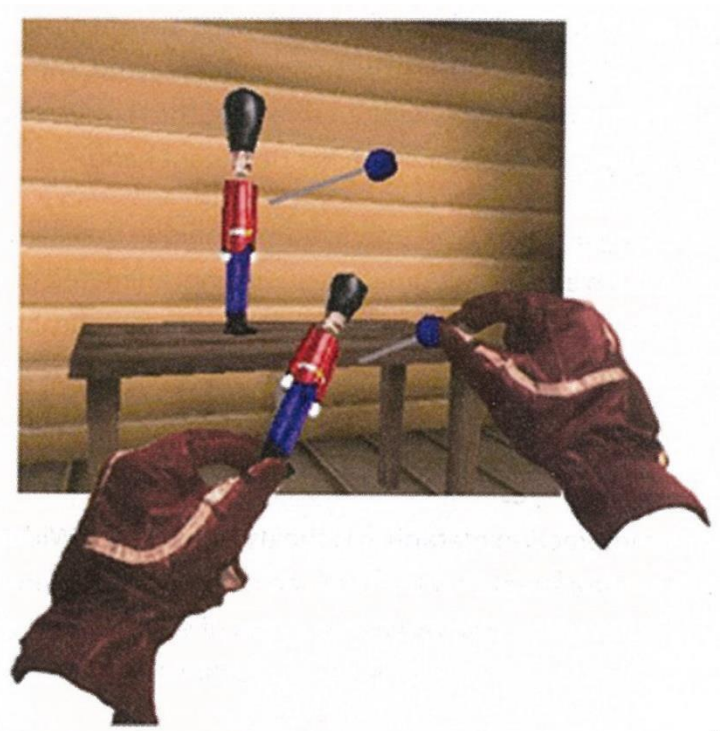
- "Dollhouse" world held in user's hand
- Miniature objects can be manipulated directly
- Moving miniature objects affects full-scale objects
- Can also be used for navigation



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.

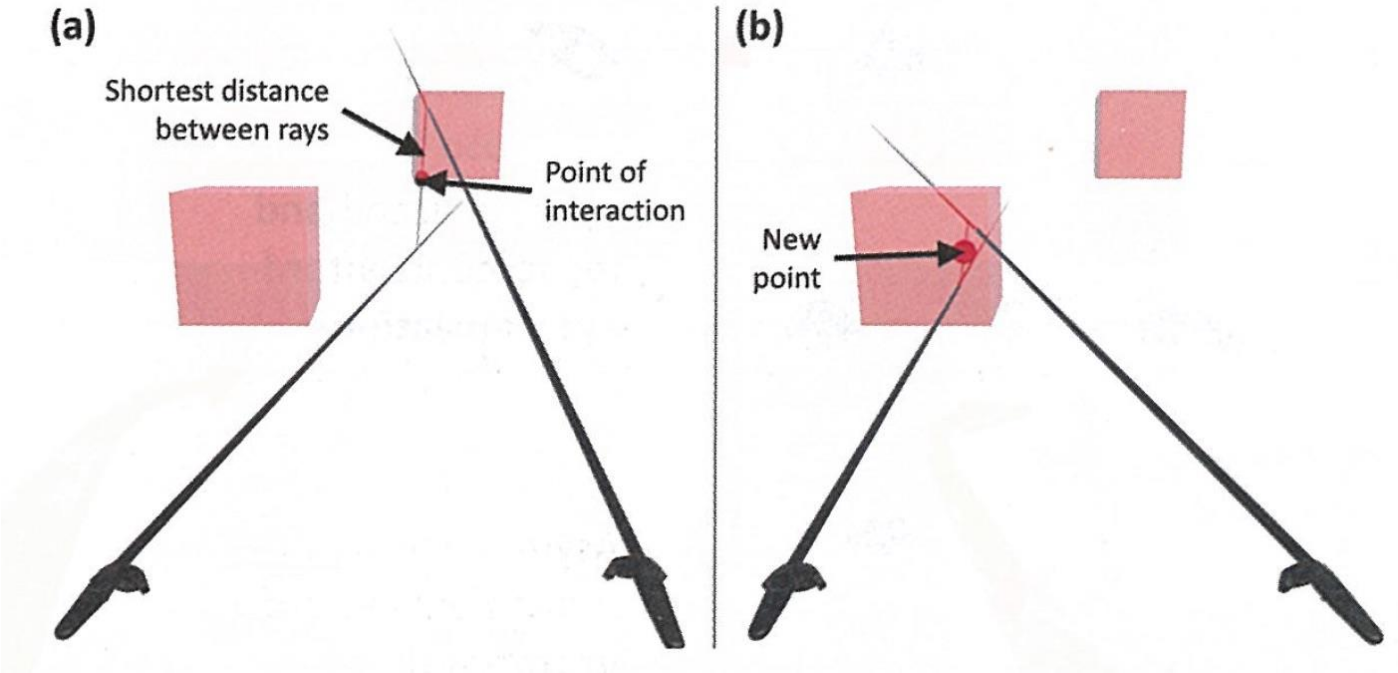
Voodoo Doll Interaction

- 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.

Symmetric Bimanual Technique

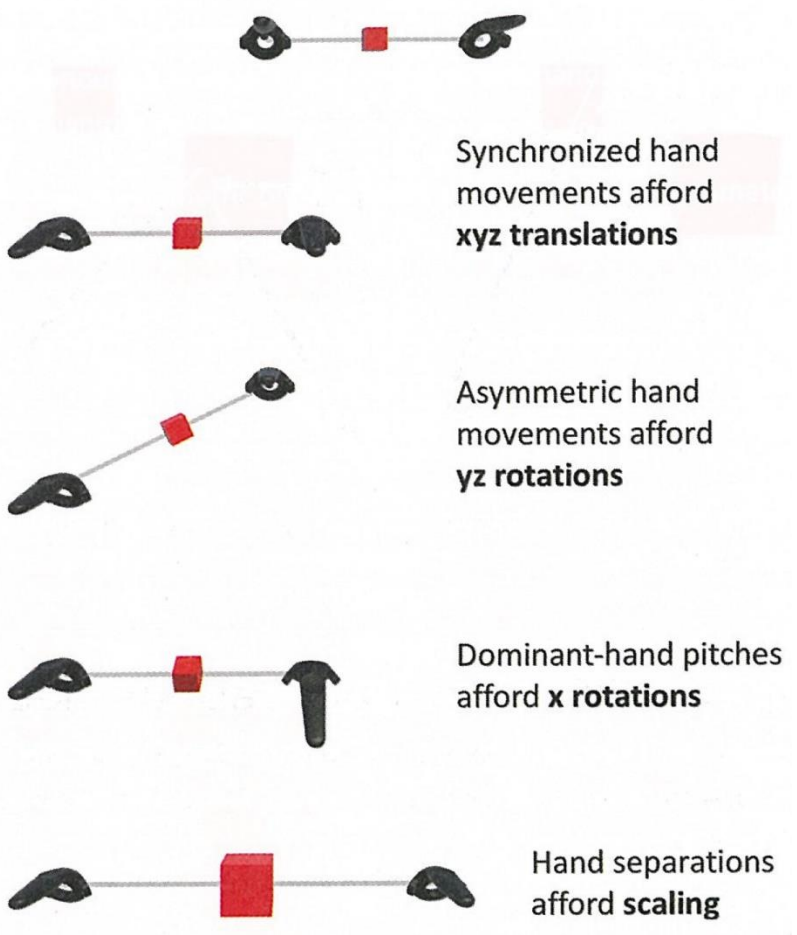


- iSith (Wyss 2006)
- Using two 6 DOF controllers each ray casting
- Intersection point of two rays determines interaction point

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

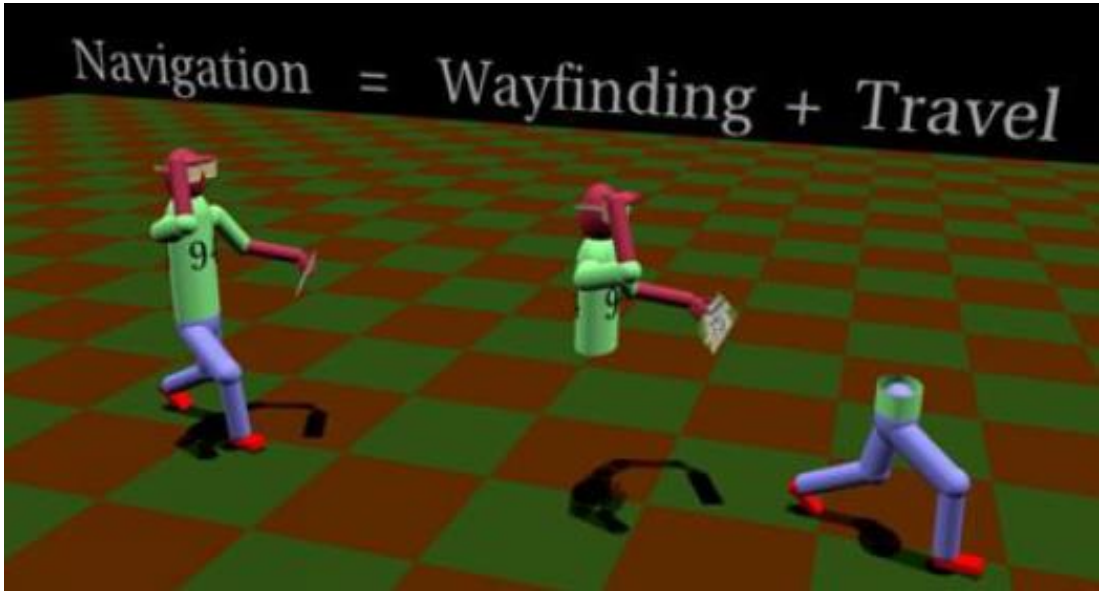


Cho, I., & Wartell, Z. (2015). Evaluation of a bimanual simultaneous 7DOF interaction technique in virtual environments. In *3D User Interfaces, 2015 IEEE Symposium on* (pp. 133-136). IEEE.

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
- Explore existing techniques before designing a new application-specific method
- Consider the trade-off between technique design and environmental design

Navigation



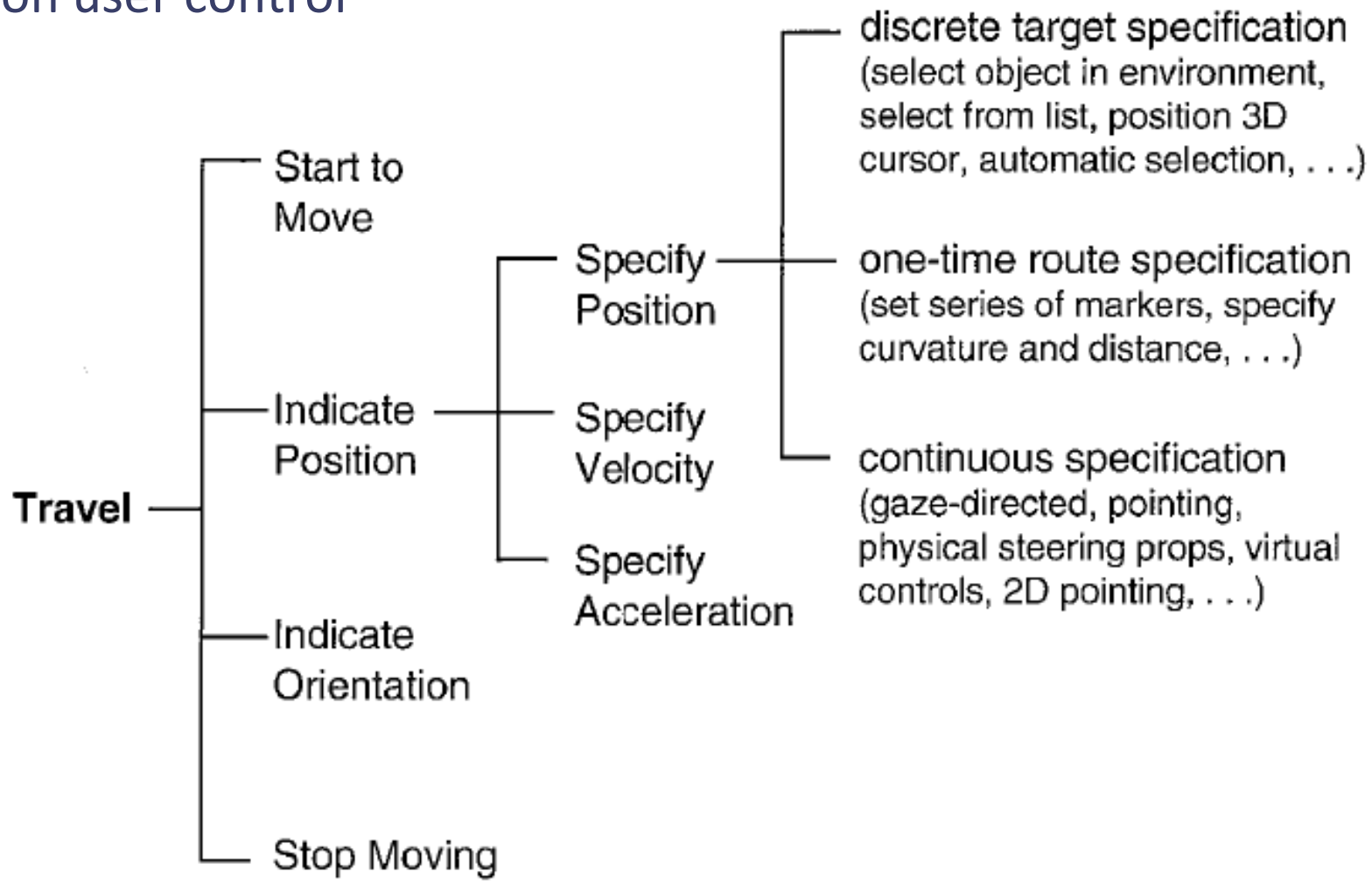
- How we move from place to place within an environment
- The combination of travel with wayfinding
  - *Wayfinding*: cognitive component of navigation
  - *Travel:* motor component of navigation
- Travel without wayfinding: "exploring", "wandering”

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

Focus on user control

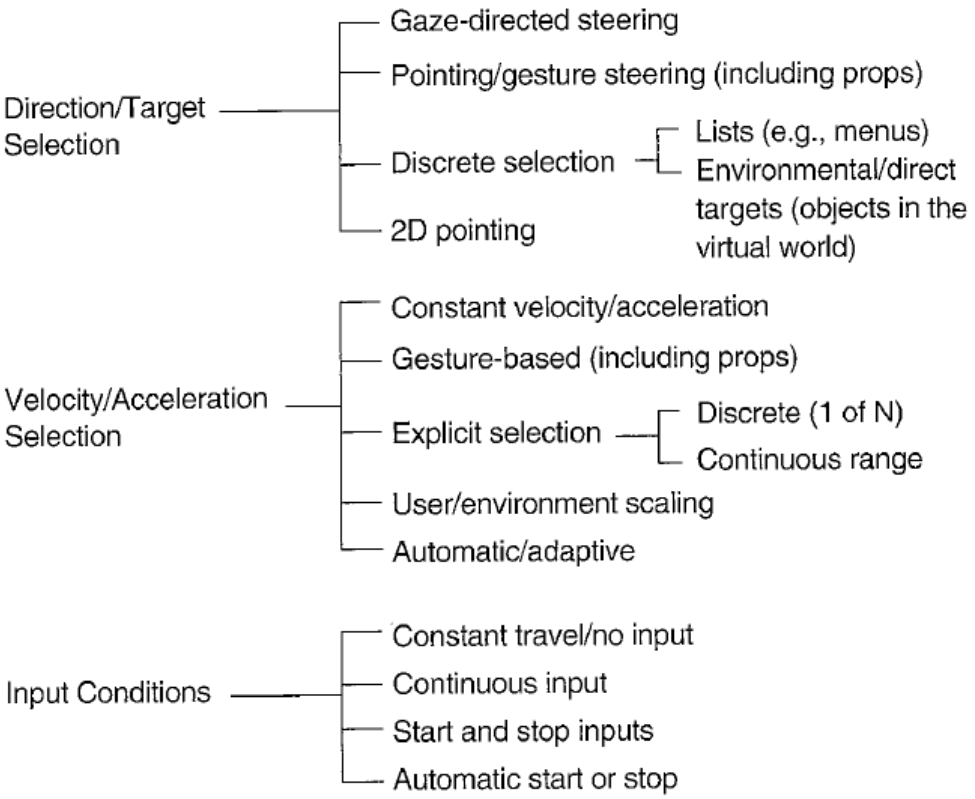


Technique classification

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

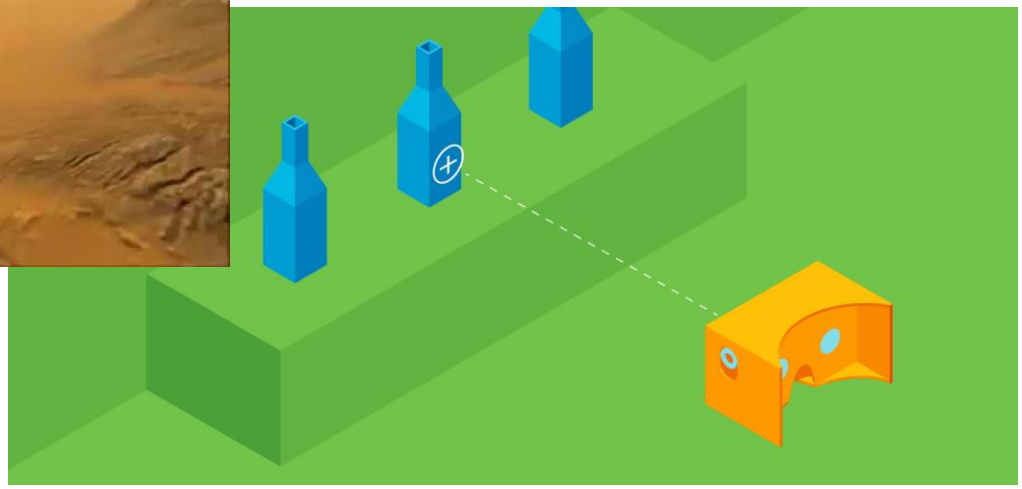
Different Locomotion Devices

Taxonomy of Travel Techniques



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

Pointing to Steer

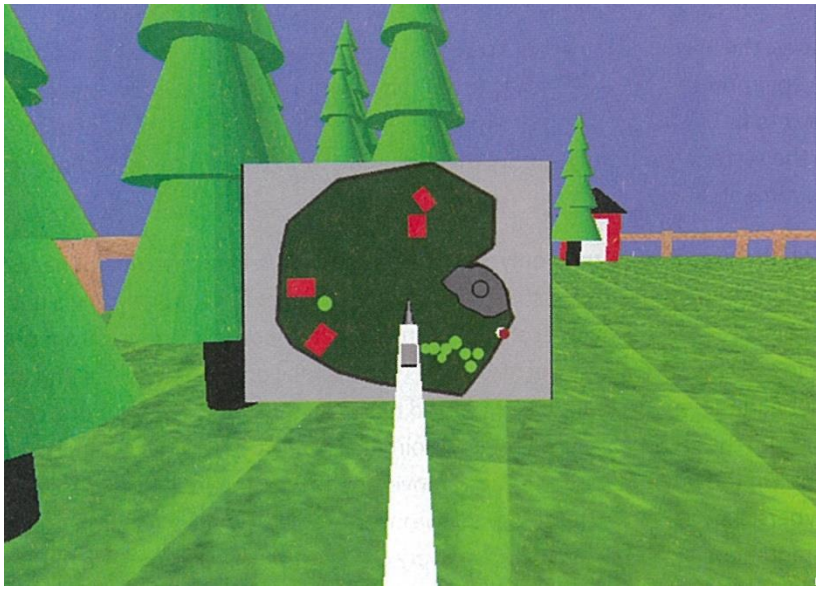
- Use hand tracker instead of head tracker
  - Point in direction you want to go
- Allows travel and gaze in different directions
  - good for relative motion, look one way, move another

Grabbing the Air Technique

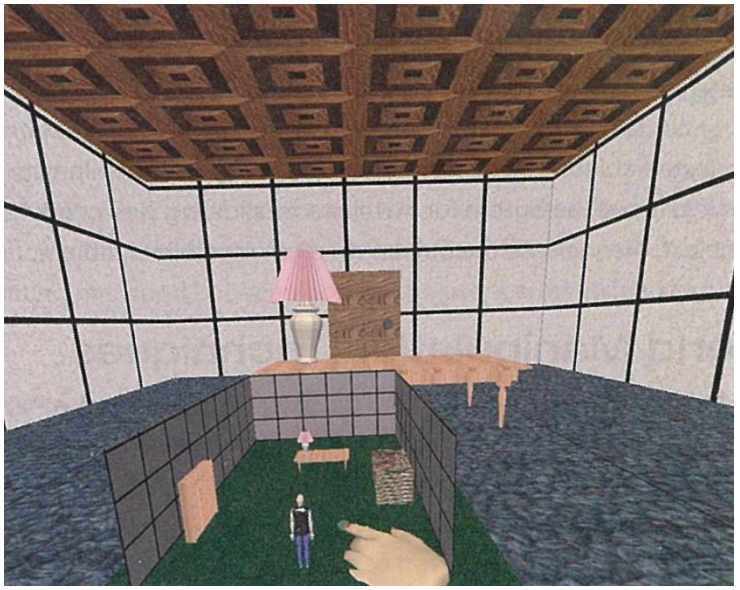
- Use hand gestures to move yourself through the world
- Metaphor of pulling a rope
- Often a two-handed technique
- May be implemented using Pinch Gloves

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

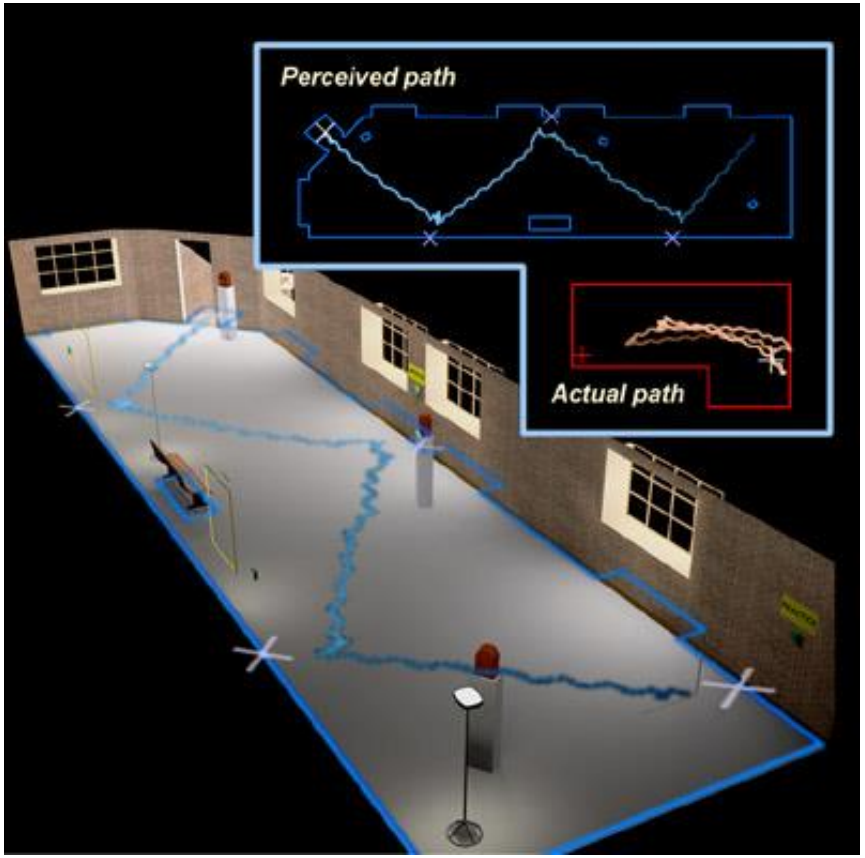


Moving avatar in WIM view

- 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

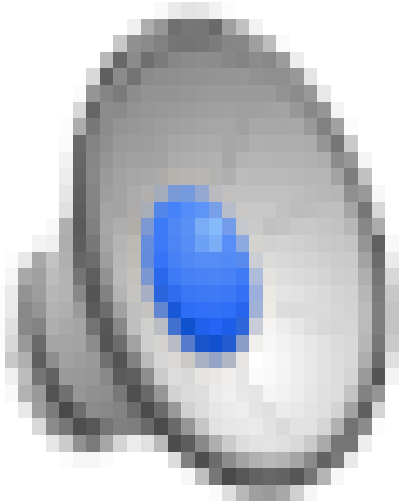
Redirected Walking

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



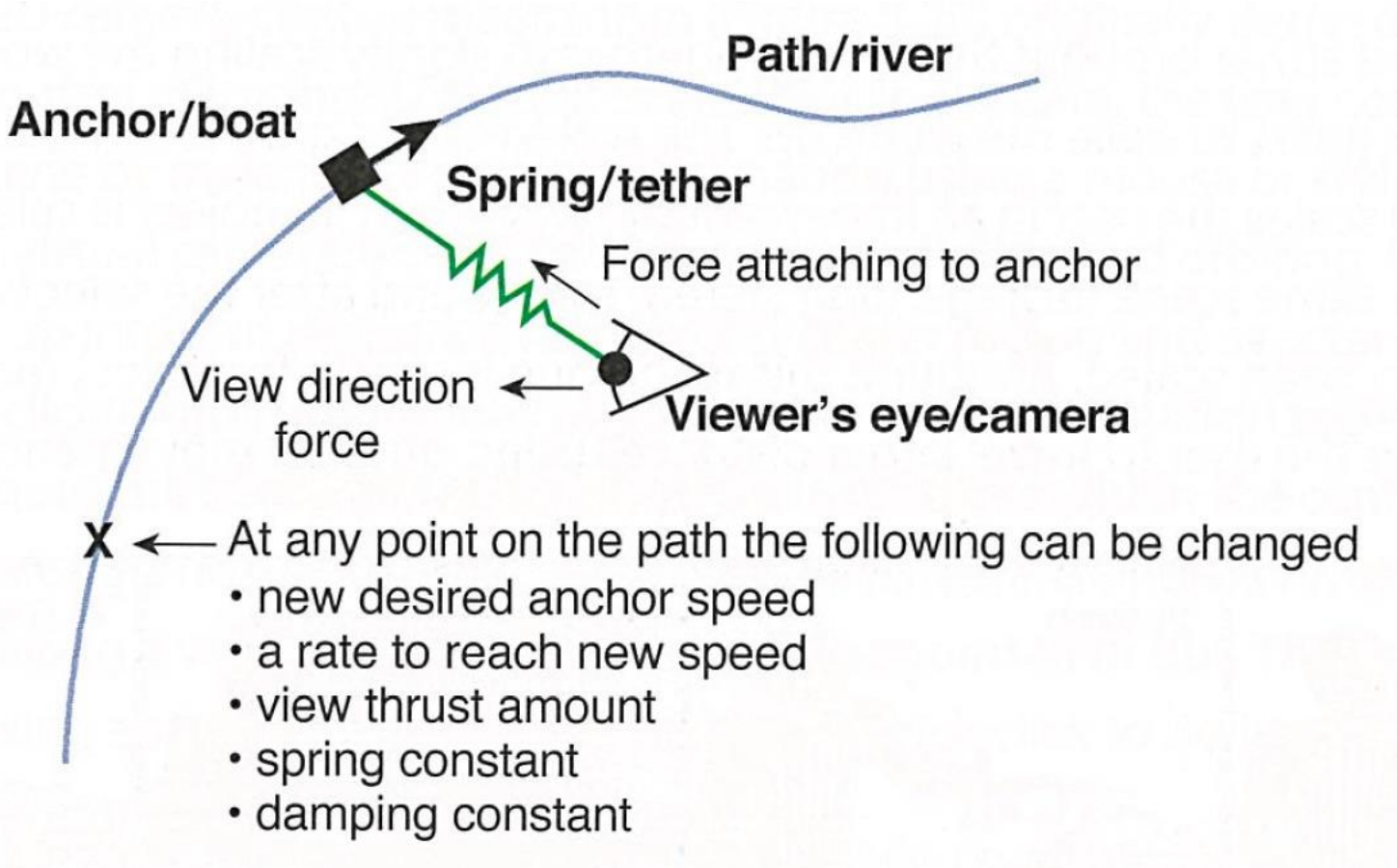
Razzaque, S., Kohn, Z., & Whitton, M. C. (2001, September). Redirected walking. In *Proceedings of EUROGRAPHICS* (Vol. 9, pp. 105-106).

Redirected Walking



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

Guided Navigation Technique



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

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

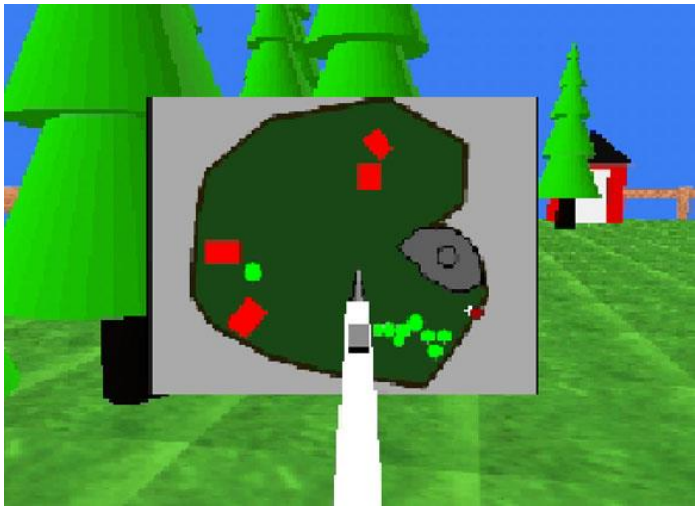
Wayfinding – Making Cognitive Maps

- 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

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



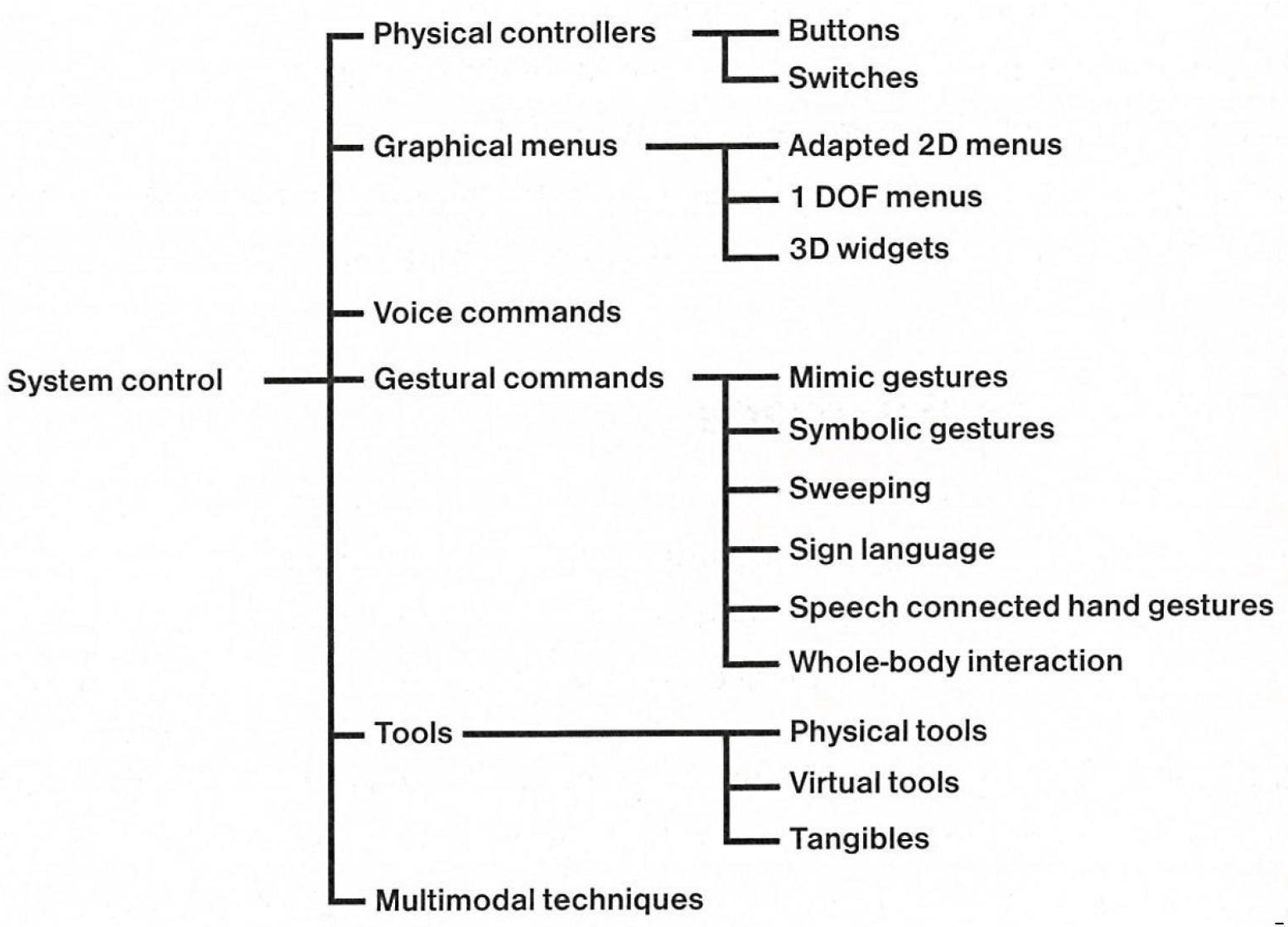
Design Guidelines for Navigation

- 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

- 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



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

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