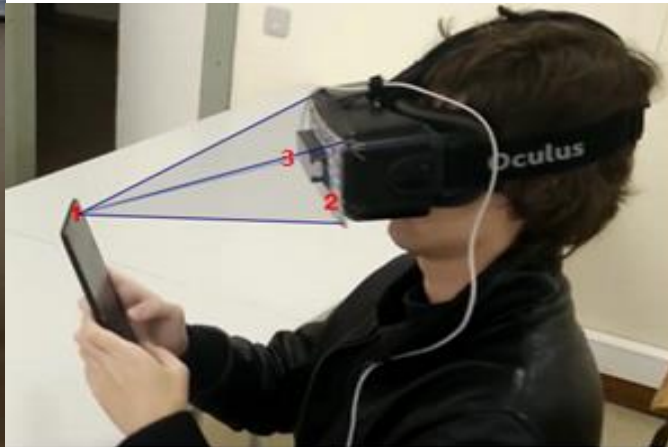




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Interaction in Virtual and Augmented Reality – 3DUIs



Challenges to wide adoption of VR

Design and technology:

- 3D user interfaces (3DUIs)
- Convenience and control (easy to use and affordable)

“The biggest barrier to wide adoption of immersive technologies is the lack of good user experience design”

(<https://www.gartner.com/smarterwithgartner/3-reasons-why-vr-and-ar-are-slow-to-take-off/>)

“ Interaction is the communication that occurs between a user and the VR (AR/MR) application ... mediated through the use of input and output devices...” (Jerald, 2016)

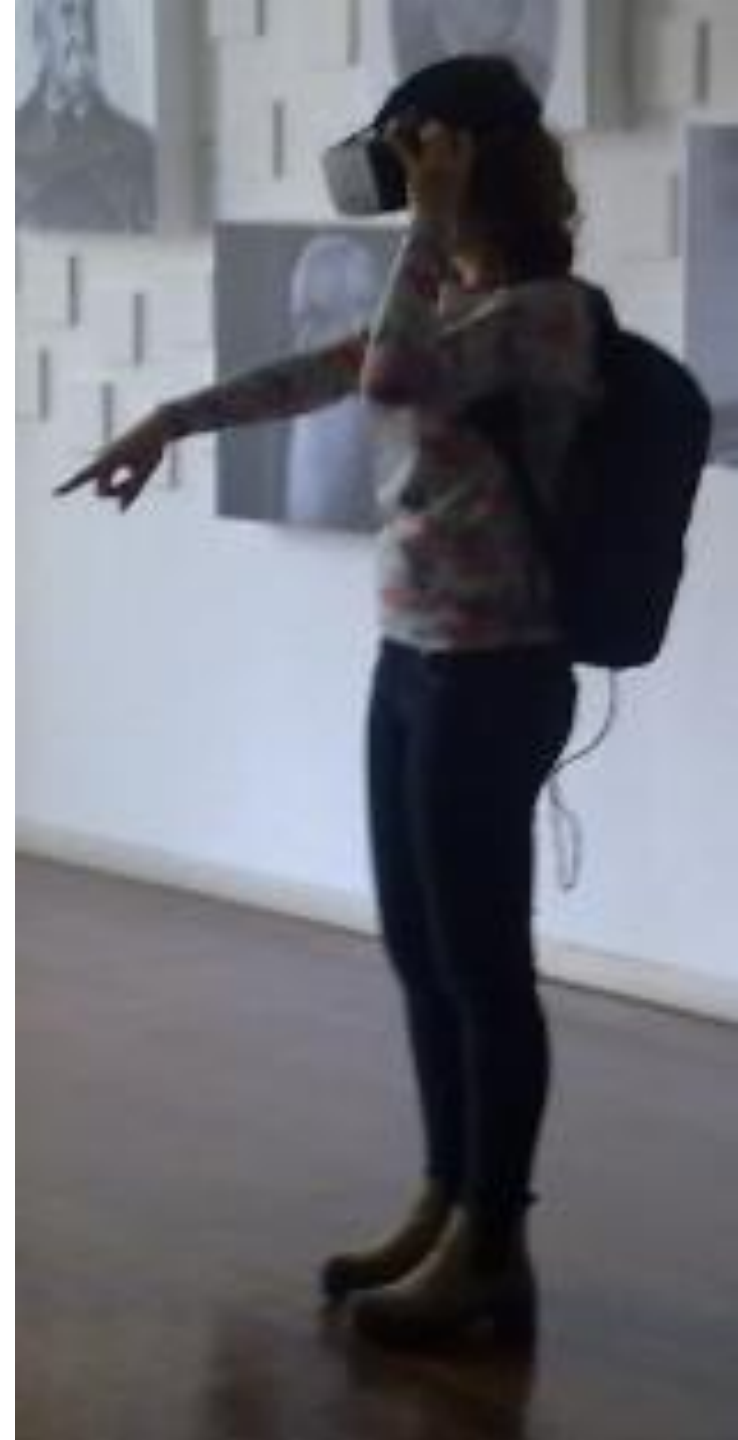
- Goals of **interaction design** in VR and AR (XR in general) applications:
 - **Usability and UX** (performance, ease of use, ease of learning, satisfaction, user comfort and safety)
 - **Usefulness** (users focus on tasks, interaction helps users meet goals)

as in any interactive system (3D or not)...

but comfort and safety are greater concerns in VR!

What is a 3D User Interface?

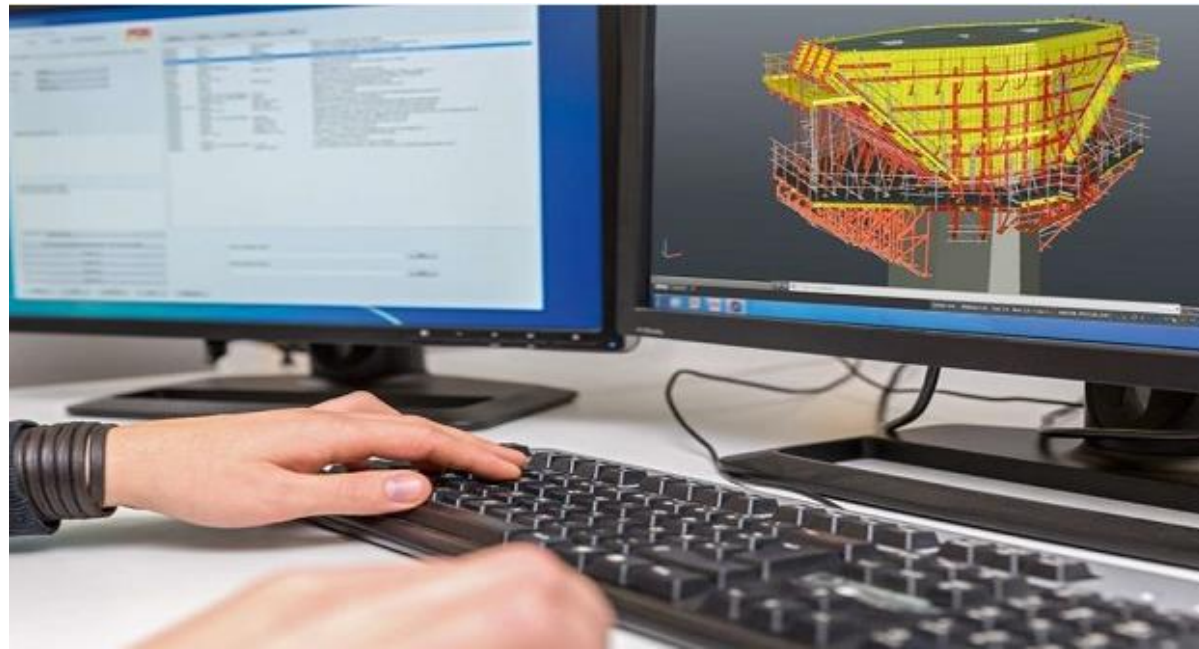
- Not easy to define ...



Is this a 3D User Interface?

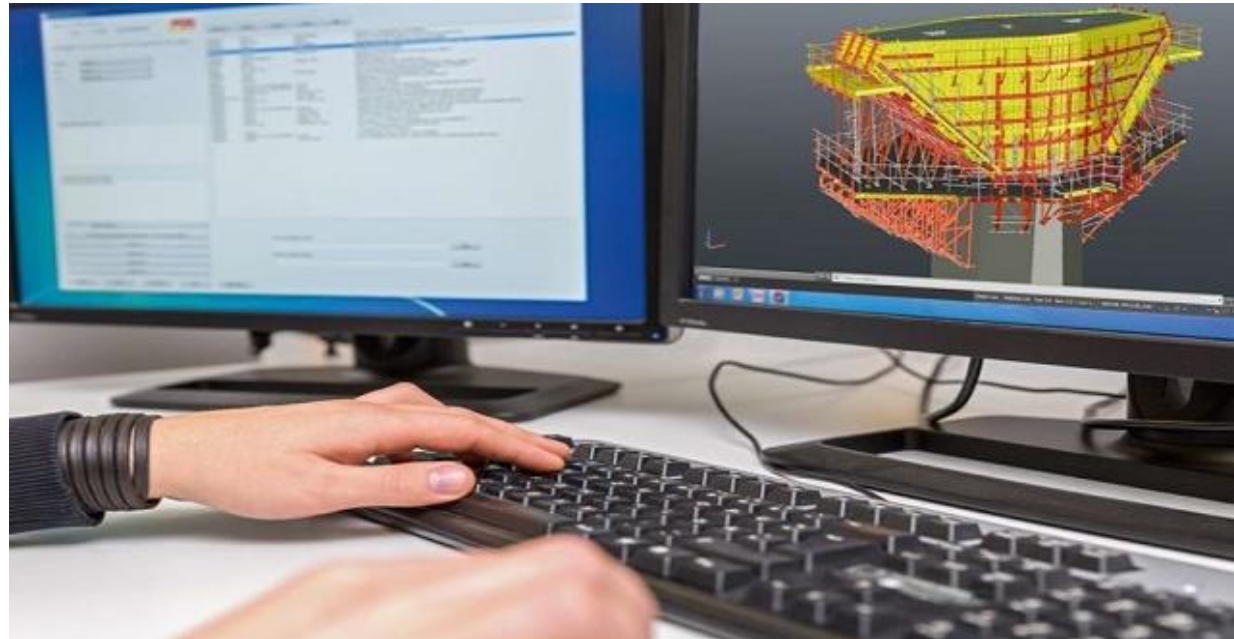
- A typical example:

Computer Aided Design (CAD) scenario



What is NOT a 3D User Interface

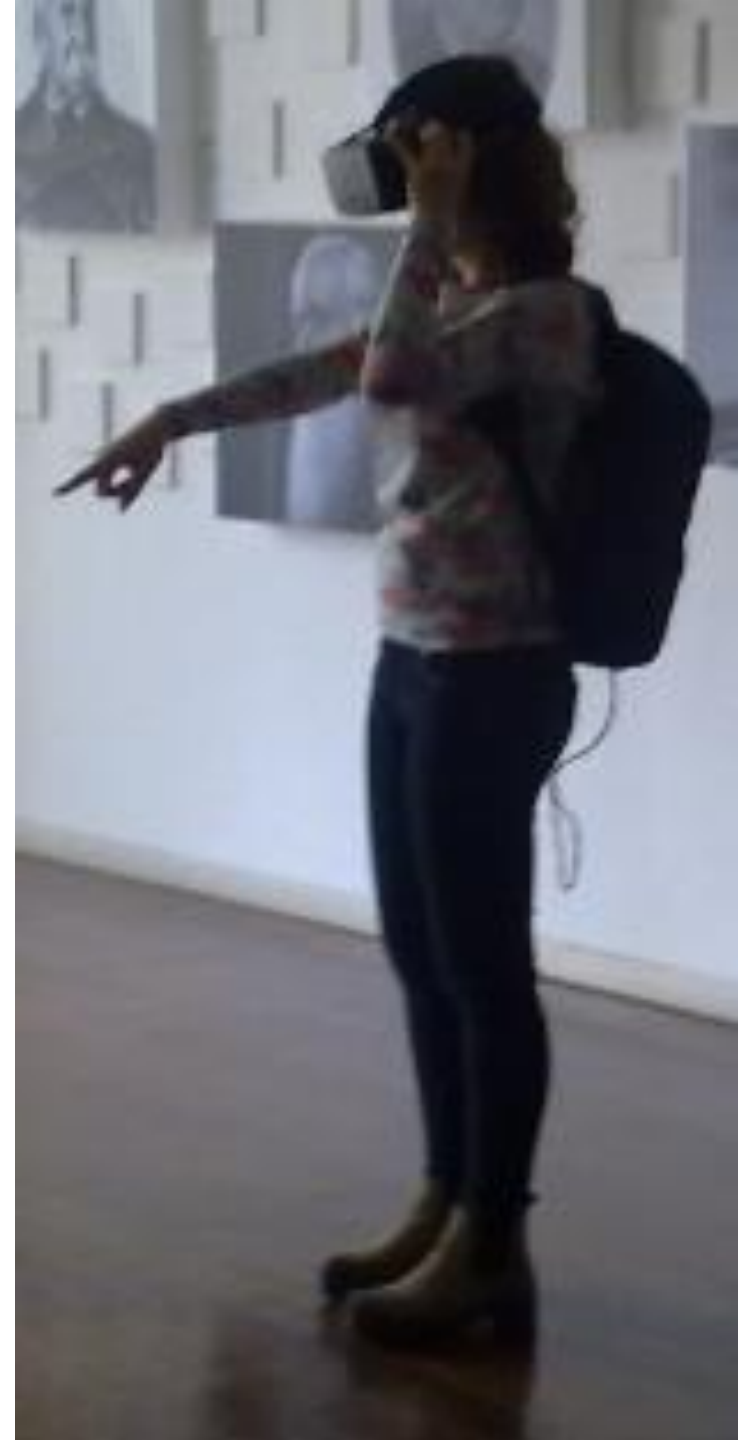
- If a system displays a virtual 3D space, but the user interacts indirectly with this space—e.g.,
 - by manipulating 2D widgets,
 - entering coordinates,
 - or choosing items from a menu
- **It is not a 3D UI !**



What is a 3D User Interface?

- Not easy to define...
- a UI that involves 3D interaction
- the user's tasks are performed **directly in a 3D spatial context**
- based on 3D spatial input ...

(Laviola et al., 2017),



- What makes 3D interaction difficult?
 - Spatial input
 - Lack of constraints
 - Lack of standards
 - Lack of tools
 - Lack of precision
 - Fatigue
 - Layout more complex
 - Perception, ...

- 3D User Interfaces (UIs) let users interact with virtual environments, objects, or information using direct 3D input in the physical and/or virtual world
- Isn't the 3D interface obvious?

Naturalism vs. Magic

- **Naturalism:** make the Virtual Environment work “exactly” like real world
- **Magic:** give user new abilities
 - Perceptual
 - Physical
 - ...

Naturalism vs Magic – a debate

- High levels of naturalism can enhance performance and the overall UX
- **Traditional interaction** styles can provide good performance,
but result in lower presence and engagement
- **Hyper-natural, magic** design approaches may improve performance and usability
- **All have to be carefully designed!**

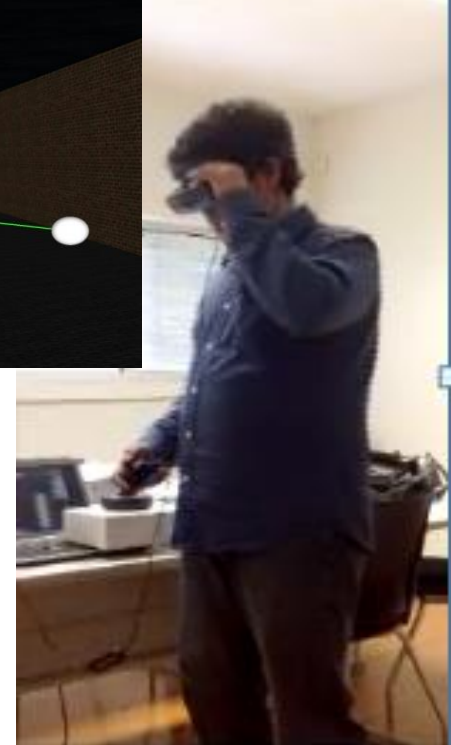
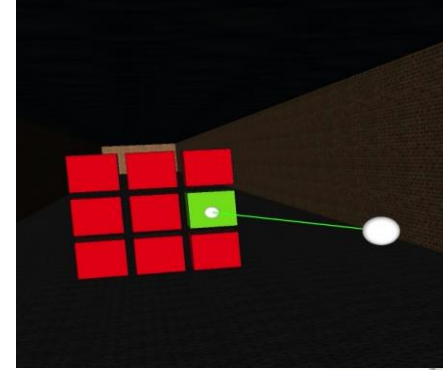
Bowman, D. A., McMahan, R. P., & Ragan, E. D., “Questioning naturalism in 3D user interfaces”. *Communications of the ACM*, 55(9), 78–88, 2012.

<http://doi.org/10.1145/2330667.2330687>

Universal interaction tasks for VEs

- Navigation
 - Travel – motor component
 - Wayfinding – cognitive component
- Selection
- Manipulation
- System control
- Symbolic input

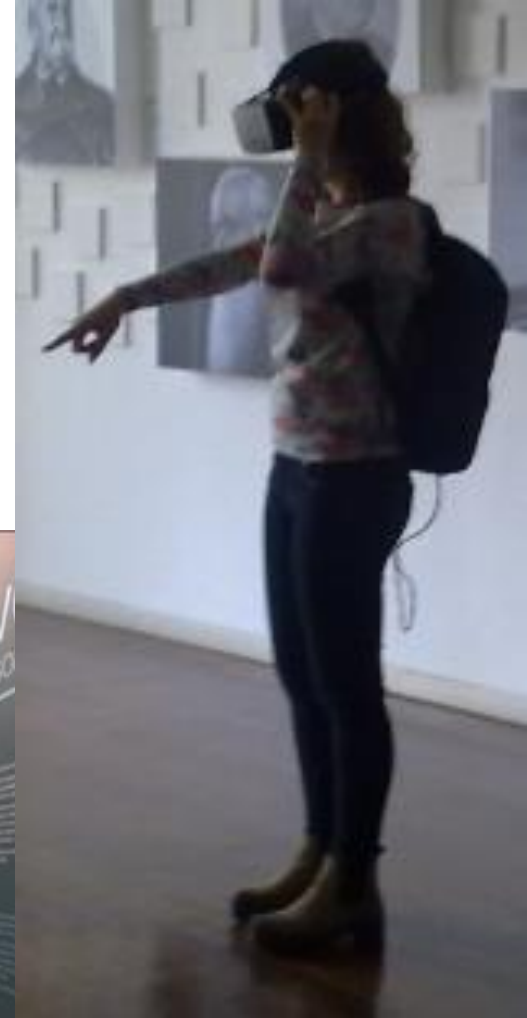
(Laviola *et al.*, 2017)



Examples with our work:

The Imaginary Museum an interactive exhibit

- The user was immersed in a virtual replica of a room
- Could explore virtual contents (text, videos, 3D models)
- And set their own virtual exhibits
- **Tasks:** navigation + selection + manipulation
- **Interaction methods:** walking + gestures

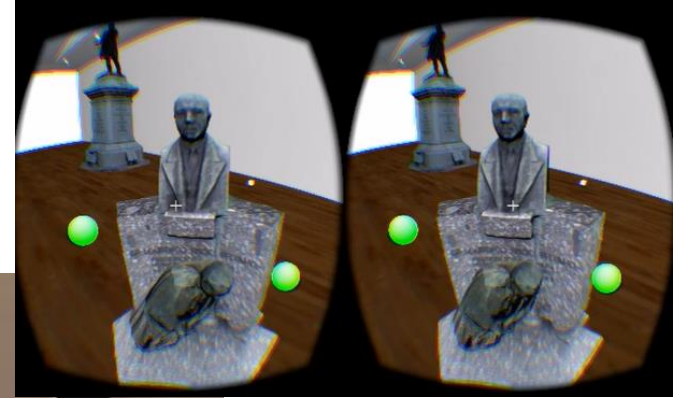


Imaginary museum



Imaginary Museum tasks and Interaction

- Placing 3D virtual objects in a virtual exhibit using spatial gestures



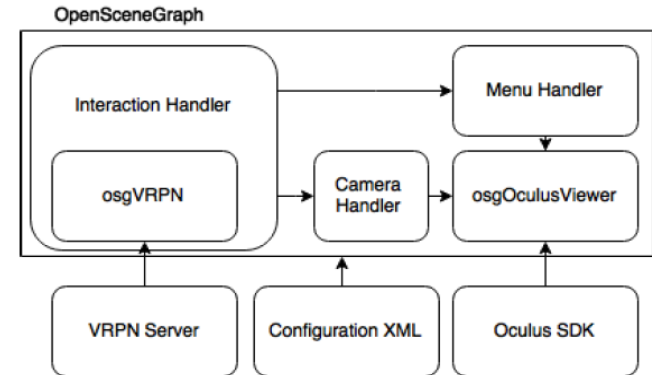
- While walking in the real/virtual worlds (1 : 1 mapping)

Example: Imaginary Museum setup

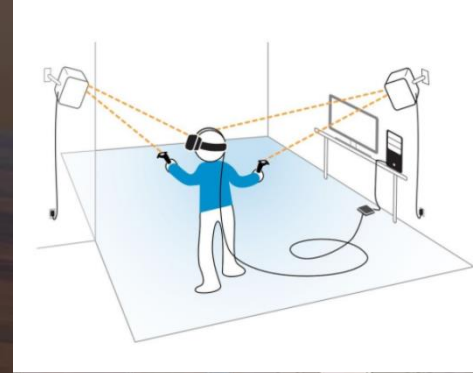


The user walks in a real room and navigates in the virtual room (similar to the real one)

Paulo Dias, João Pinto, Sérgio Eliseu, Beatriz Sousa Santos, "Gesture interactions for Virtual Immersive Environments: navigation, selection and manipulation", N. Streitz and P. Markopoulos (Eds.), *Distributed, Ambient, and Pervasive Interactions DAPI 2016, Lecture Notes in Computer Science*, LNCS 9740, pp. 211-221



Another example: Virtual escape room



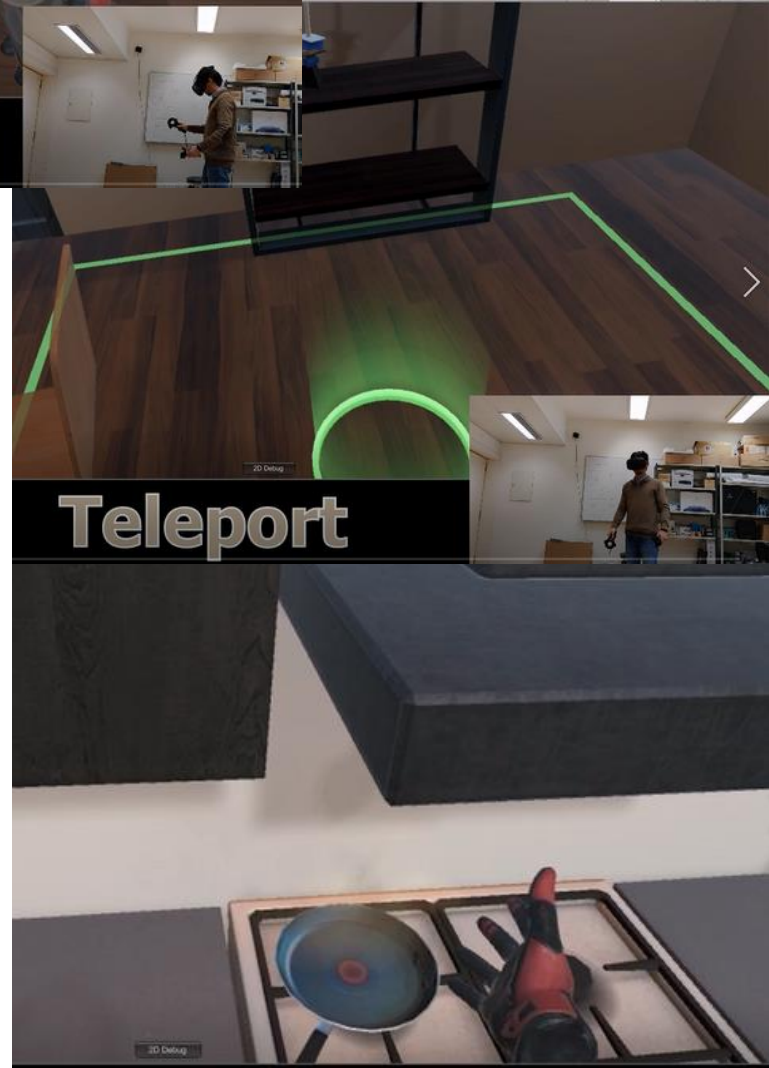
Same tasks

different interaction techniques

Navigation – Walking + Teleport

Manipulation

input devices:
(HTC Vive)
controllers



Another example:
Virtual escape room



Yet another example:

Same tasks; different interaction techniques

Navigation

Selection



input devices:
controllers
(Razer Hydra)



- System control – involves changing the mode or de state of the VE
 - Often done through commands (gesture/voice) or menus
- Symbolic input
 - Entering or editing text, numbers, or other symbols
- These tasks have not been as much researched as the previous ones
- Another task may be important: 3D modeling

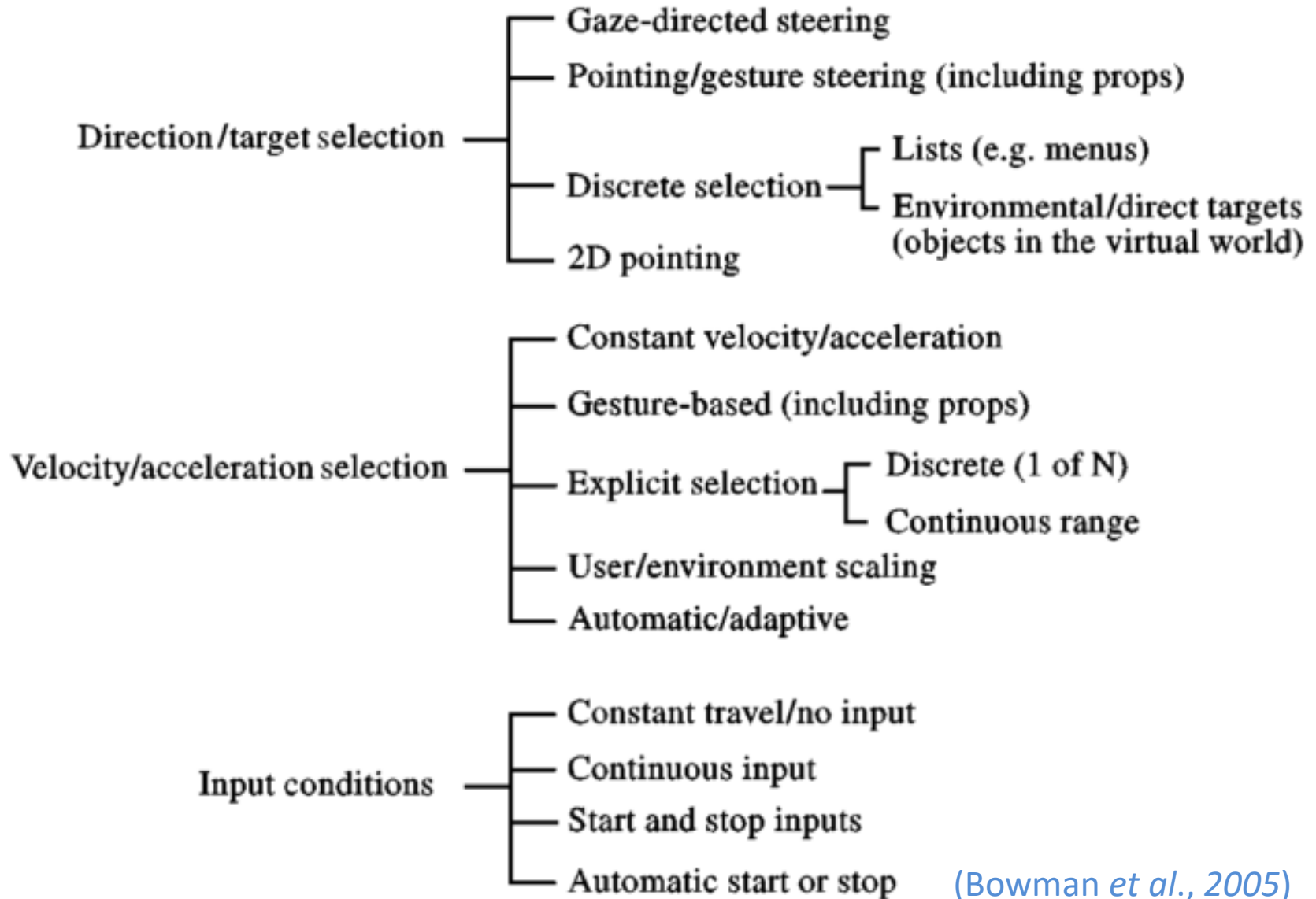
- There are many techniques to perform a task
- And several taxonomies of techniques
- **Why are taxonomies relevant?**

Example: Travel tasks

- 3D travel tasks according the user goal:
 - Exploration
 - Search
 - Maneuvering
- Other relevant characteristics:
 - distance to be traveled, curvature or turns, target visibility from the starting point

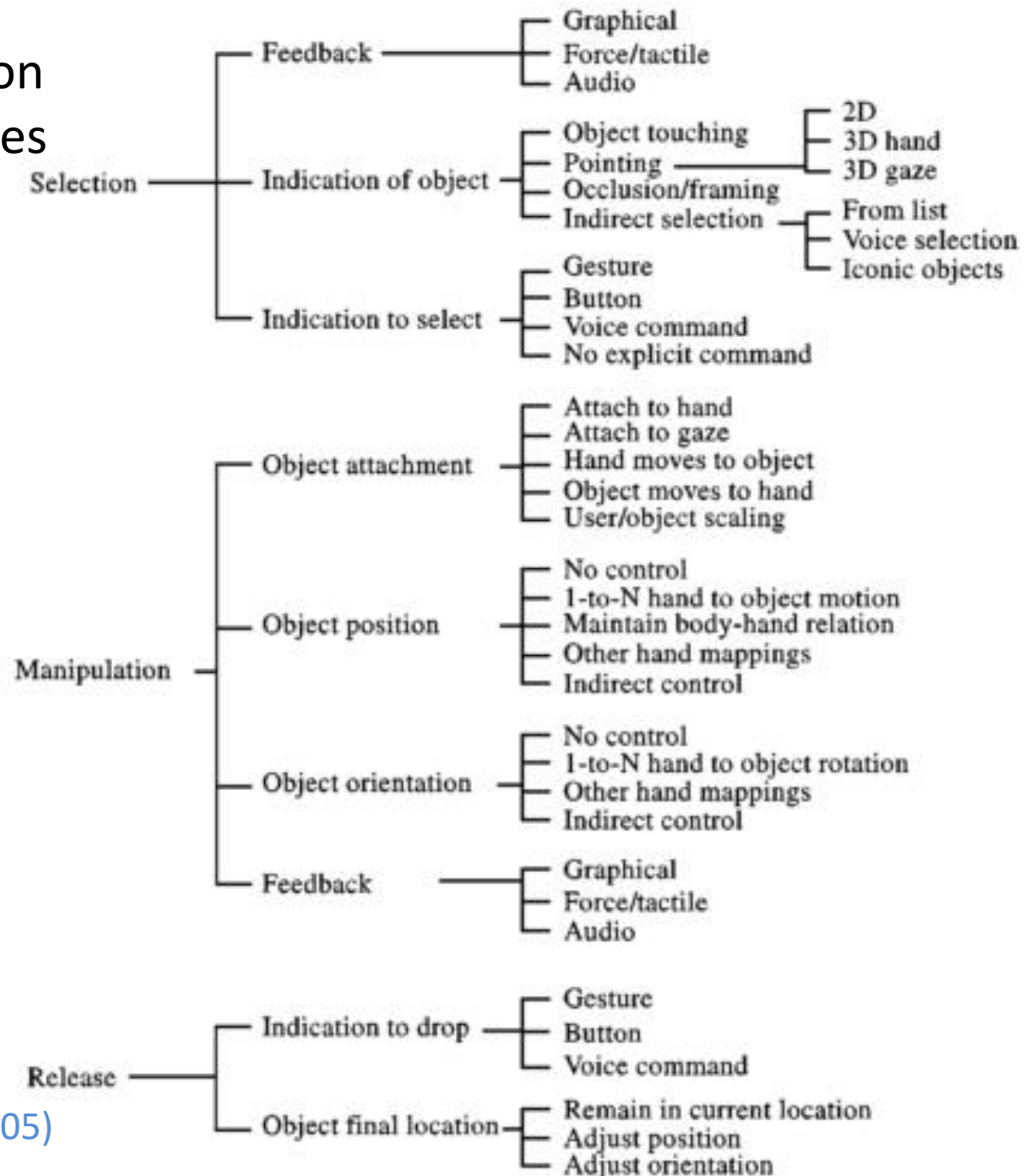
- Different taxonomies of travel techniques :
 - Active vs passive
 - Physical vs virtual
 - Metaphor
 - Subtasks

Travel – taxonomy of techniques concerning subtasks



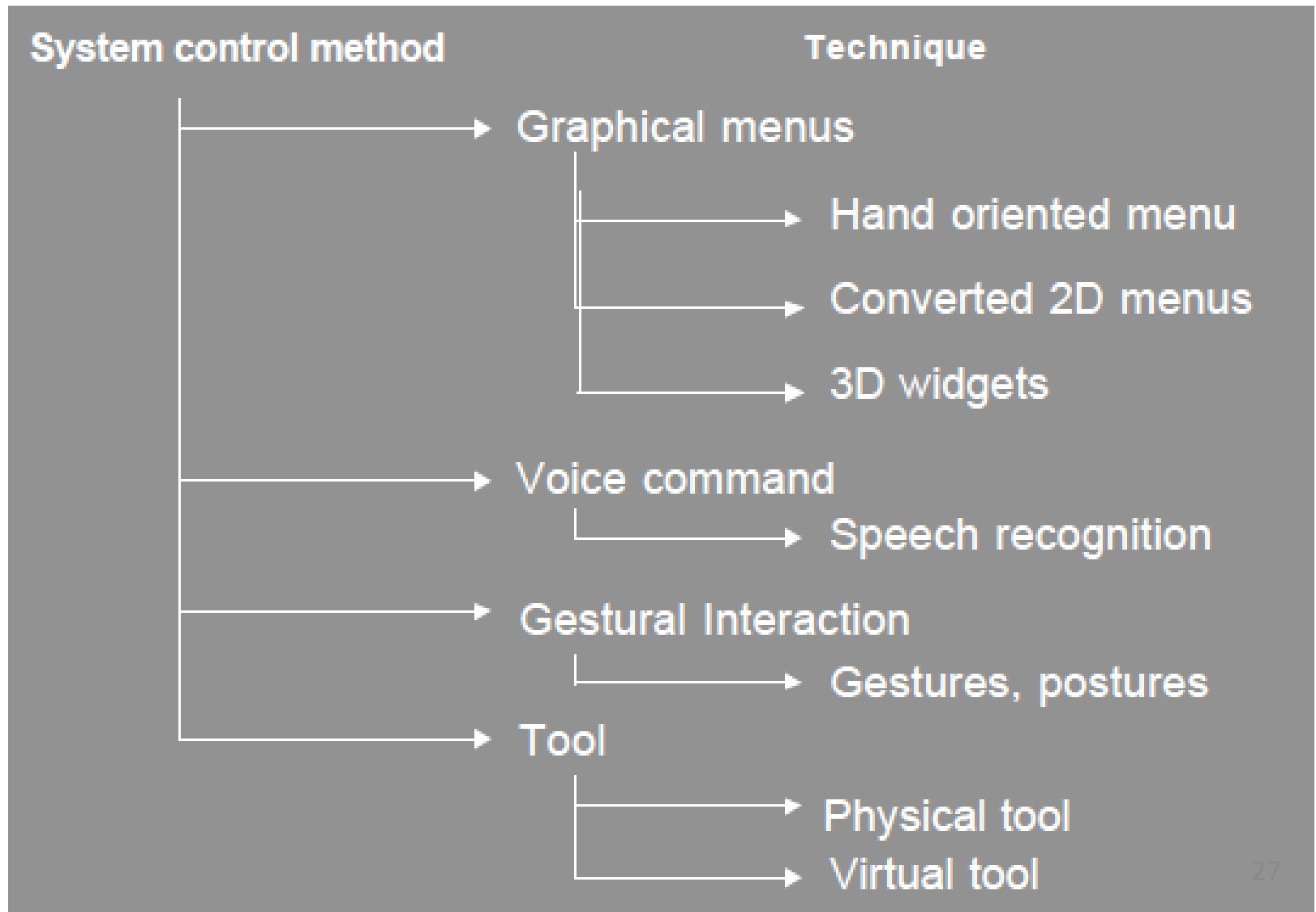
(Bowman *et al.*, 2005)

Selection/ Manipulation Taxonomy of techniques



(Bowman et al. , 2005)

Classification of system control techniques (Bowman *et al.*, 2008)



- System control – involves changing the mode or de state of the VE
- Some design guidelines:
 - Don't disturb flow of action
 - Use consistent spatial reference
 - Allow multimodal input
 - Structure available functions
 - Prevent mode errors by giving feedback

Symbolic input techniques

- Keyboard-based
(Miniature, Chord, Soft keyboards, ...)
- Gesture-based
(Sign language gestures, other gestures)
- Speech-based
(word/command recognition)
- ...



Strategies in Designing 3D User Interfaces for VEs

- There are some general high-level strategies and principles
 - Can be used in a wide variety of 3D tasks and applications
 - Some are based on the characteristics of human psychology and physiology
 - Others are based on common sense and cultural metaphors
- Examples:
 - Feedback
 - Constraints
 - Two hand interaction

Constraints

- Artificial limitations designed to help users interact more precisely or efficiently
- Examples:
 - Snap-to grid
 - Intelligent objects
 - Single DOF controls

Passive haptic Feedback

- Props or “near-field” haptics
- Examples:
 - Flight simulator controls
 - Steering wheel
- Increase presence, improve interaction

J. C. McClelland, R. J. Teather, “HaptoBend : Shape-Changing Passive Haptic Feedback in Virtual Reality,” in *ACM Symp. on Spatial User Interaction SUI’17*, 2017, pp. 82–90.

<https://dl.acm.org/doi/pdf/10.1145/3131277.3132179>



Passive haptic Feedback another example:

Haptic feedback in immersive VEs in a simple and cost-effective way

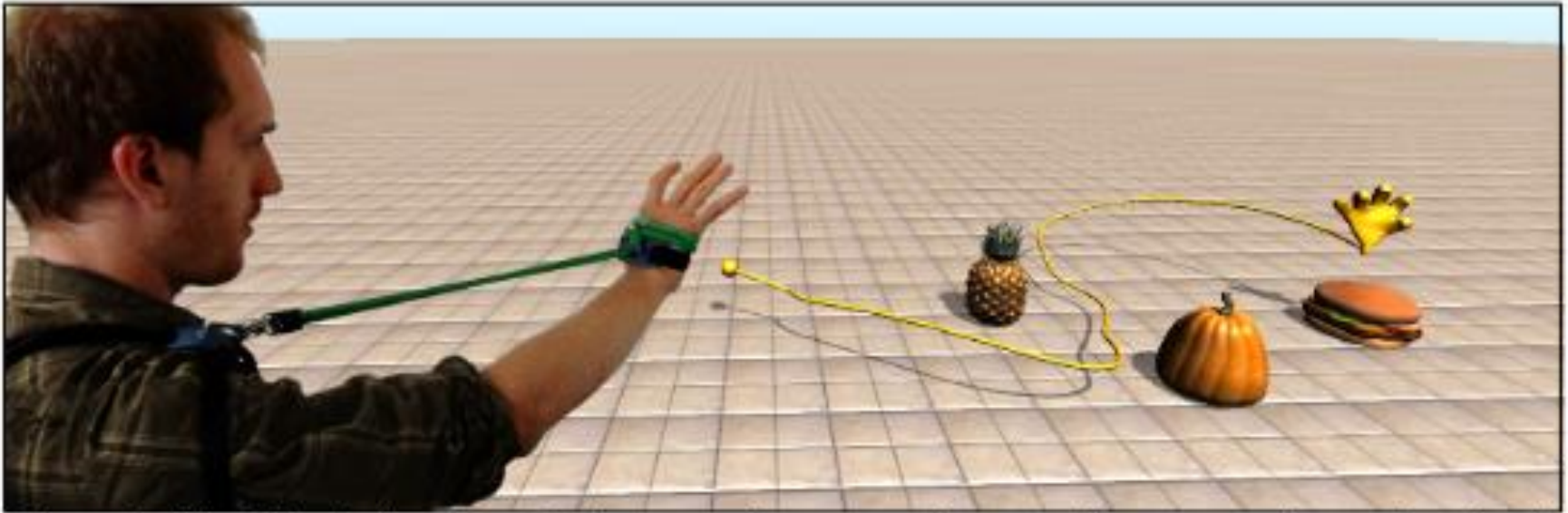


Figure 1. The Elastic-Arm is a body-mounted armature that provides egocentric passive haptic

M. Achibet *et al.*, “Leveraging Passive Haptic Feedback in Virtual Environments with the Elastic-Arm Approach,” *Presence Teleoperators Virtual Environ.*, vol. 25, no. 1, pp. 17–32, 2016. https://doi.org/10.1162/PRES_a_00243

Two-handed interaction

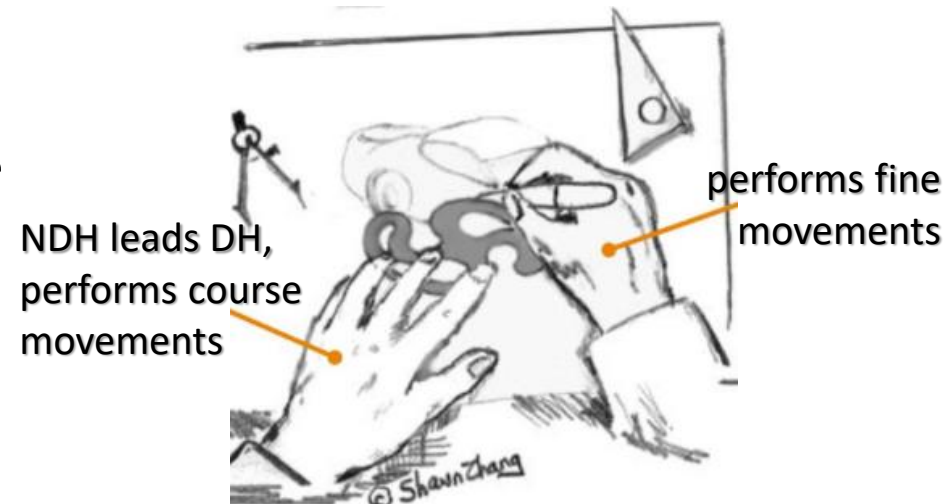
- Symmetric vs. Asymmetric
- Dominant vs. non-dominant hand
- Manipulation initiated by ND hand
- Guiard's principles
 - ND hand provides frame of reference
 - ND hand used for coarse tasks,
D hand for fine grained tasks

(ND – Non-Dominant)



Simulator for training cataract surgery

<https://doi.org/10.1016/j.compbimed.2009.08.003>



(MacKenzie, 2003)

Interaction Patterns for VR

“Generalized **high interaction concept** that can be used over and over again across different applications to achieve common user goals” (Jerald , 2016)

- Common approaches to general problems:
 - described from the user’s point of view,
 - \approx implementation independent
- **Interaction techniques** are more specific and technology dependent
- Similar techniques may be grouped under the same interaction pattern
e.g. Walking pattern -> real walking and walking in place



Interaction Patterns for VR

- Interaction patterns and interaction techniques provide conceptual models to experiment with, and starting points for innovative designs ([Jerald , 2016](#))
- Designers should not fall into the trap that there is a single best interaction pattern or technique.
- Each pattern and technique has strengths and weaknesses depending on the users and application goals
- Understanding distinctions and managing trade-offs is essential to creating high-quality interactive experiences

Interaction Patterns for VR

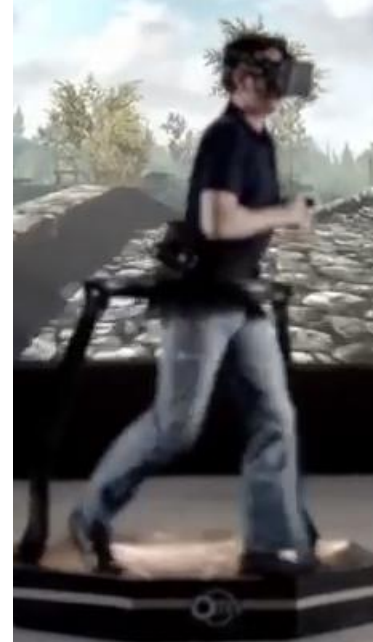
- Distinguishing between interaction patterns and techniques is useful:
 - There are many existing interaction techniques and many more will be developed
 - Higher-level groupings **enable easier systematic analysis and comparison**
 - ...
- Important interaction patterns:
 - Selection Patterns
 - Manipulation Patterns
 - Viewpoint Control Patterns
 - Indirect Control Patterns
 - Compound Patterns

- **Selection** - specification of one or more objects from a set in order to state an object to which a command will be applied, to denote the beginning of a manipulation task, or to specify a target to travel toward
 - Hand Selection Pattern,
 - Pointing Pattern,
 - Image-Plane Selection Pattern,
 - Volume-Based Selection Pattern
- **Manipulation** - modification of attributes for one or more objects such as position, orientation, scale, shape, color, and texture
 - Direct Hand Manipulation Pattern,
 - Proxy Pattern,
 - 3D Tool Pattern

- **Viewpoint control** - task of manipulating one's perspective and can include translation, orientation, and scale (equivalent to moving, rotating, scaling the world)
 - Walking Pattern,
 - Steering Pattern,
 - 3D Multi-Touch Pattern,
 - Automated Pattern
- **Indirect Control** - provides control through an intermediary to modify an object, the environment, or the system. Is more abstract than previous patterns
 - Widgets and Panels Pattern and Non-Spatial
 - Control Pattern
- **Compound Patterns** - combines two or more patterns into more complicated patterns
 - Pointing Hand Pattern,
 - World-in-Miniature Pattern,
 - Multimodal Pattern.

Example of a Pattern: The Walking Pattern

- **Uses motion of the feet to control the viewpoint**
- Includes everything from real to mimicking walking
- Advantages:
 - provides a high degree of interaction fidelity
 - enhances presence and ease of navigation
 - spatial orientation and movement understanding
 - ideal for navigating small to medium-size spaces
 - results in no motion sickness if implemented adequately
- Limitations:
 - not appropriate for rapid or distant navigation
 - may require a large tracked space
 - cable can be a tripping hazard



What future to 3DUI?

- The design domain of 3D UI is rapidly expanding due to recent technology advancements and new interaction techniques
- **No single configuration is right for all conditions**
- **3D UX crucial**
- **Excellent opportunities to 3DUI:**
 - Simulators
 - Games
- **Emerging topic: Hybrid User Interfaces**

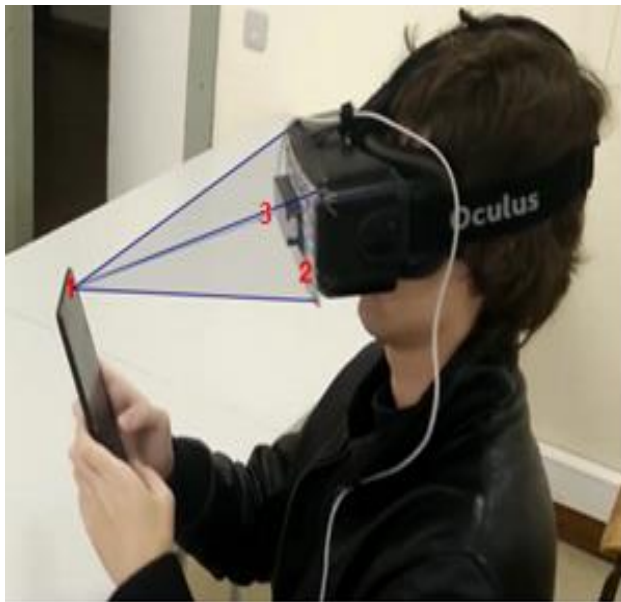
[Opportunities and Challenges of HUIs for Optimization of MR Interfaces | IEEE \(2023\)](#)



Hybrid User Interfaces

- Combine the visual and interaction spaces of complementary device technologies (such as augmented reality headsets and handheld devices) to take advantage of the strong points of each

[ISMAR 2023 Workshop on Hybrid UIs](#)



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