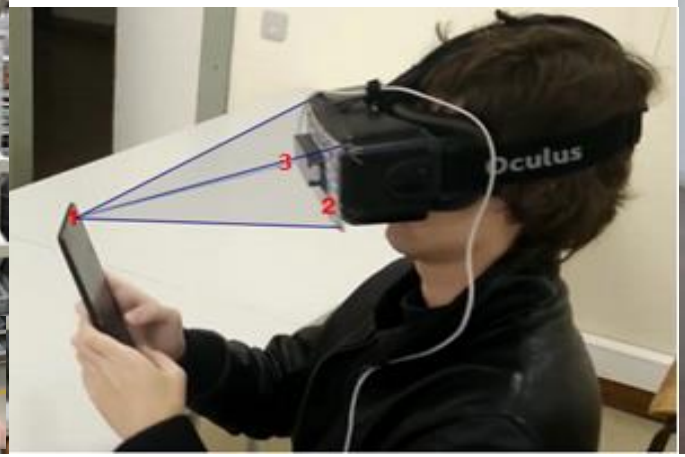
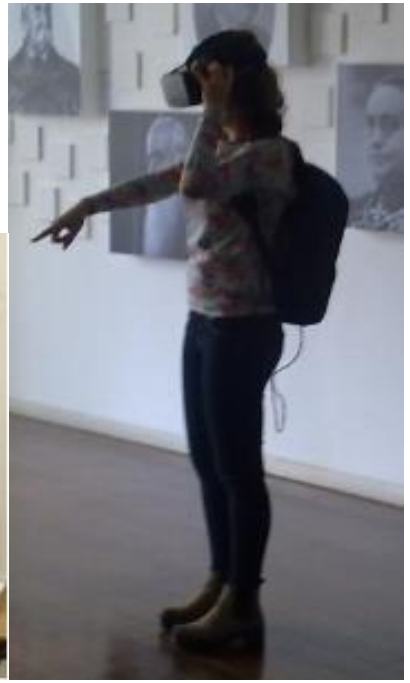
Universidade de Aveiro
Departamento de Electrónica,
Telecomunicações e Informática

Interaction in Extended Reality – 3DUIs





Realidade Virtual e Aumentada 2023

Beatriz Sousa Santos

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) application … mediated through the use of input and output devices...” (Jerald, 2016)

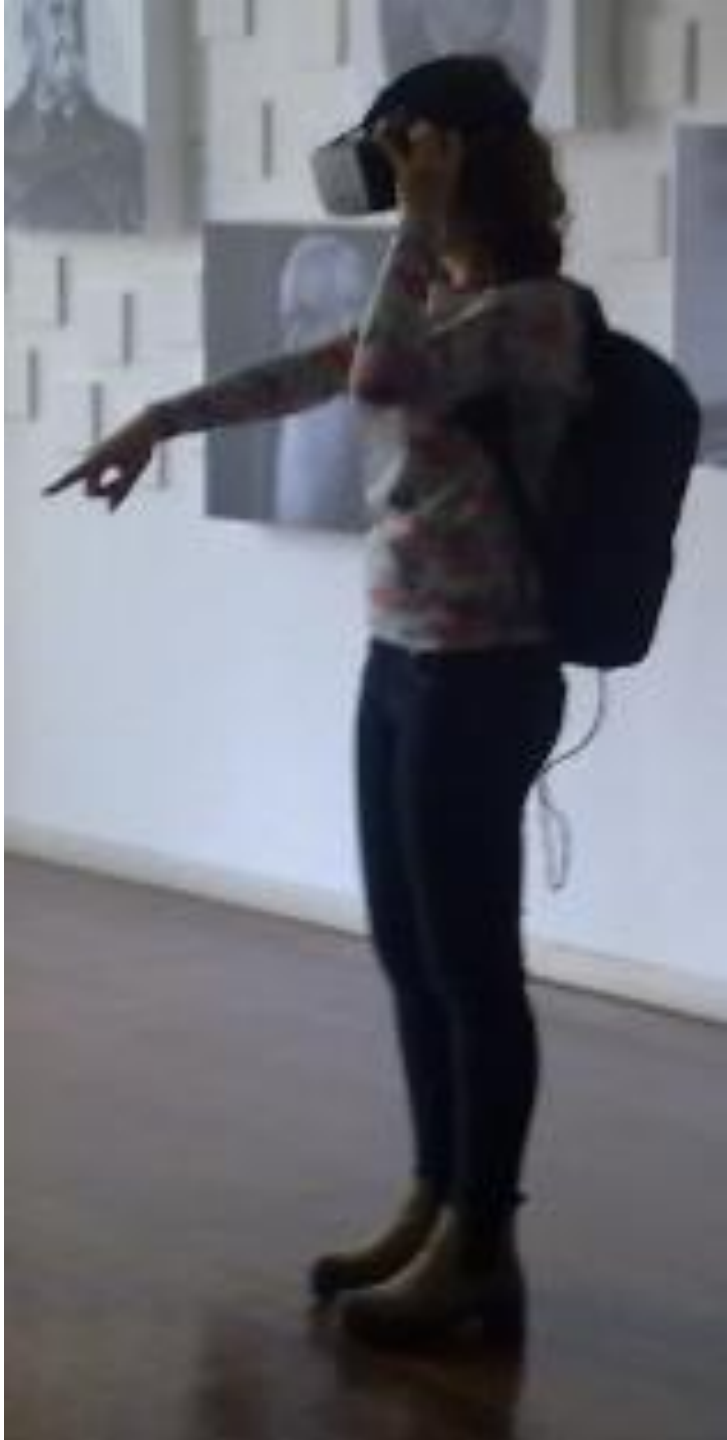
- Goals of **interaction design** in VR and AR (XR in general) applications:
  - **Usability and UX** (performance, ease of use, ease of learning, satisfaction, user comfort and safety)
  - **Usefulness** (users focus on tasks, interaction helps users meet goals)

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

but comfort and safety are greater concerns in VR!

What is a 3D User Interface?

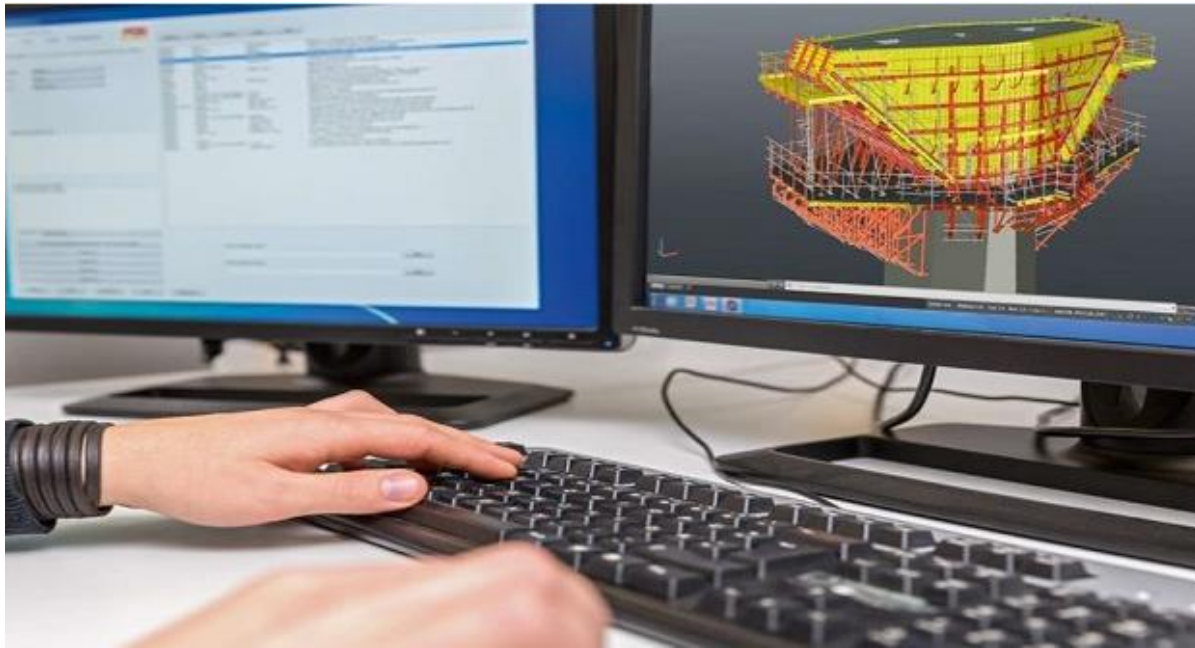
- Not easy to define …



Is this a 3D User Interface?

- A typical example:

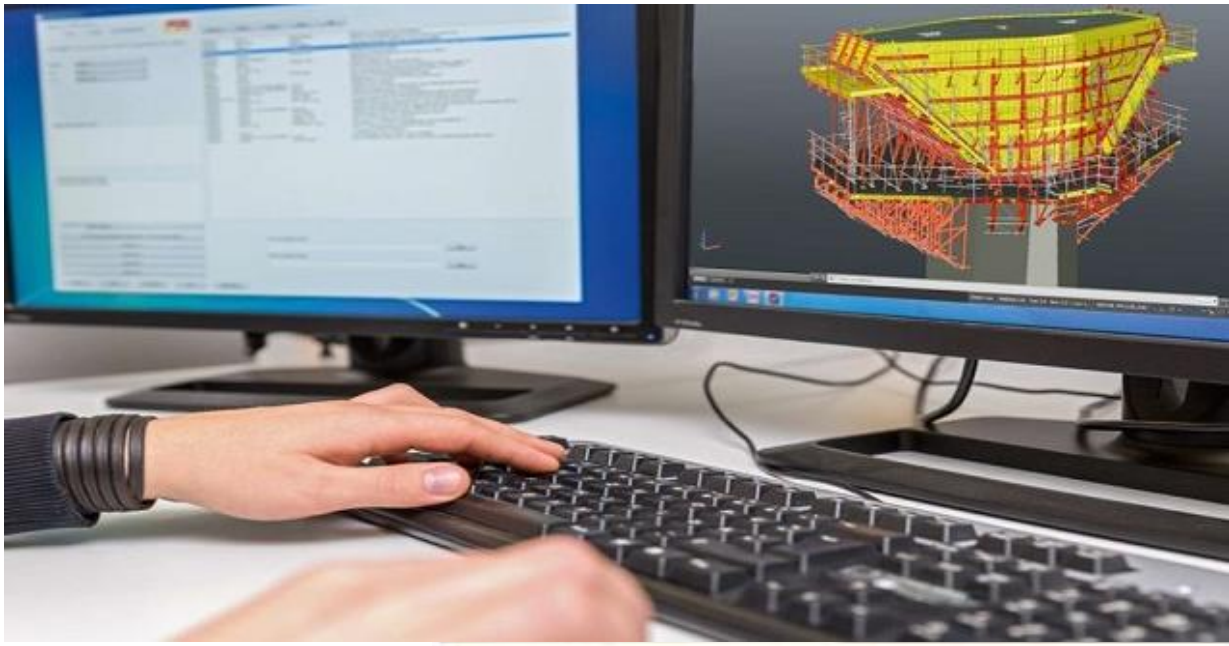
  Computer Aided Design (CAD) scenario



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

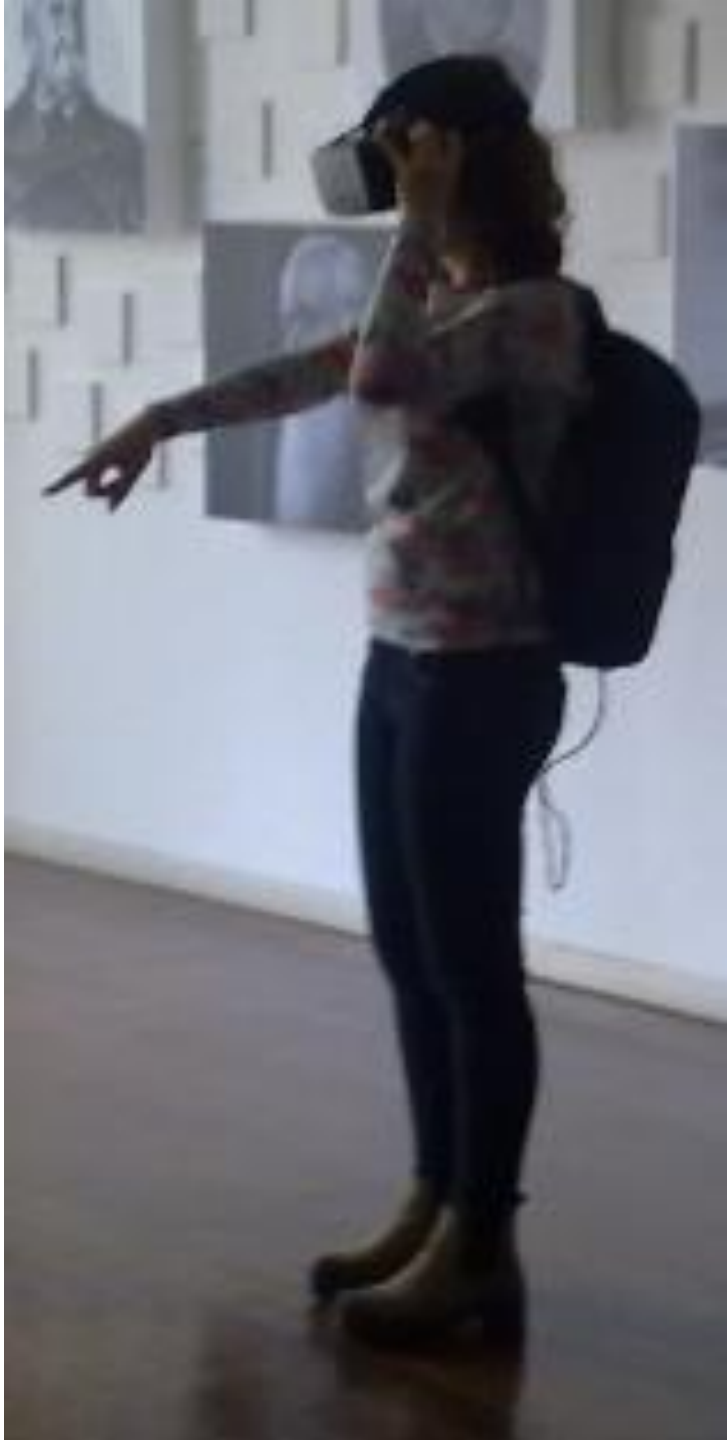
- **It is not a 3D UI !**



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 …

(Bowman et al., 2005),



- 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 still going on…

- 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!**

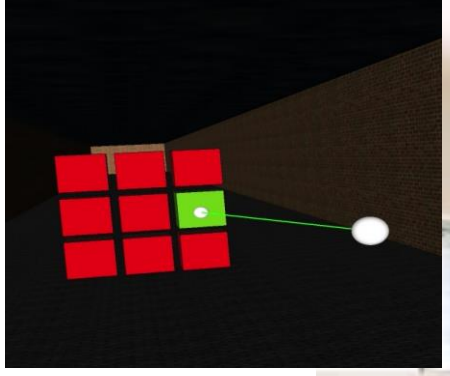
R. Neuhaus, et al., “To mimic reality or to go beyond? “Superpowers” in virtual reality, the experience of augmentation and its consequences”, International Journal of Human-Computer Studies, vol. 181, 2024. https://doi.org/10.1016/j.ijhcs.2023.103165

D. Bowman et al.,“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

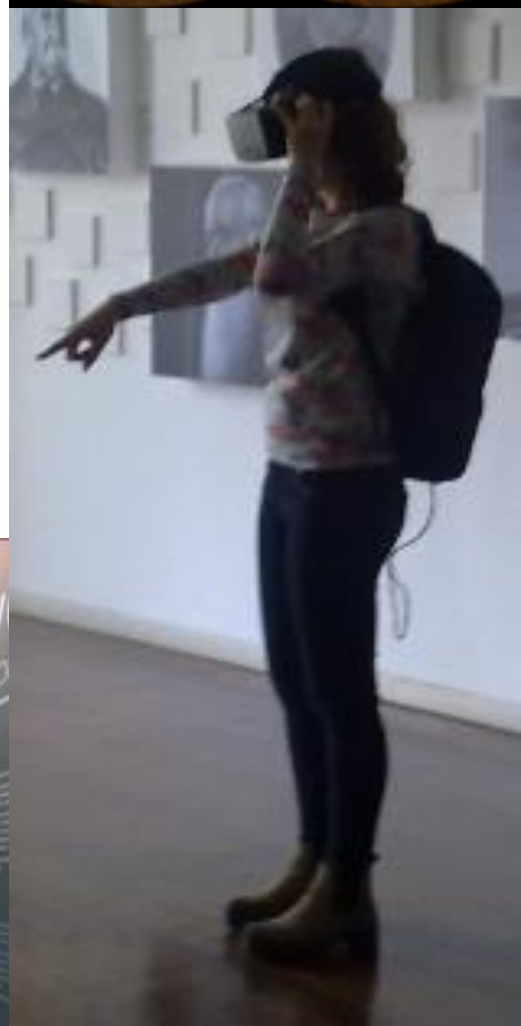
(Bowman *et al.*, 2005)



Example: 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

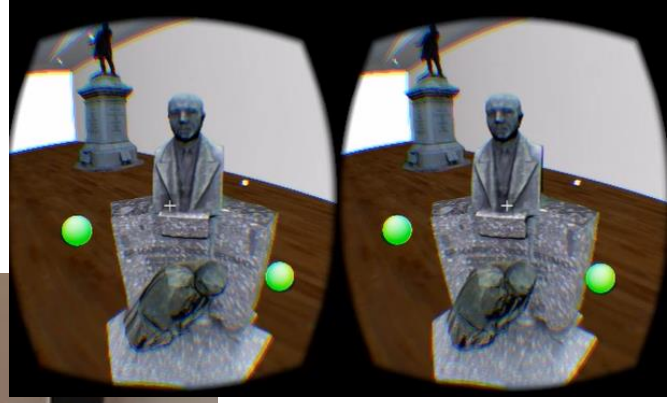
- **Tasks**: navigation + selection + manipulation
- **Interaction methods**: walking + gestures

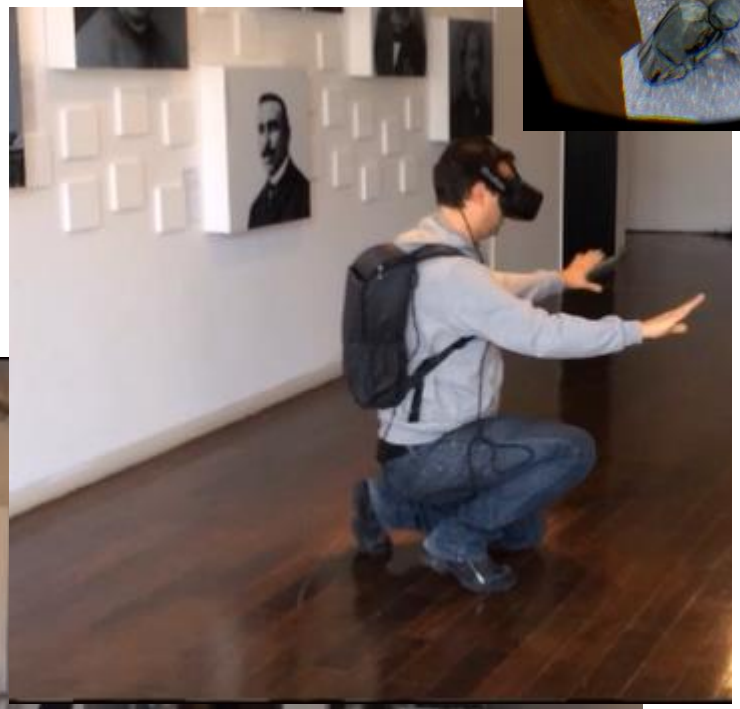


Imaginary museum

Imaginary Museum tasks and Interaction

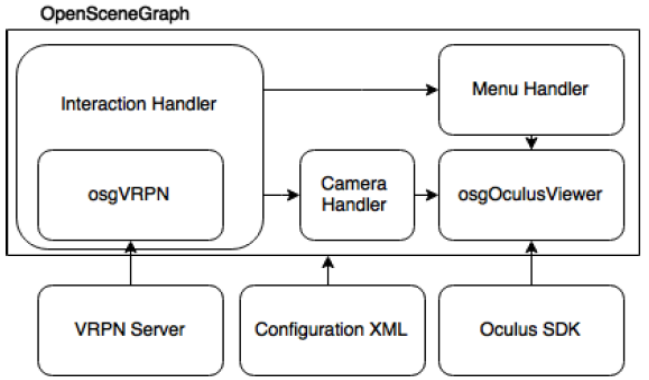
- Placing 3D virtual objects in a virtual exhibit using spatial gestures





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

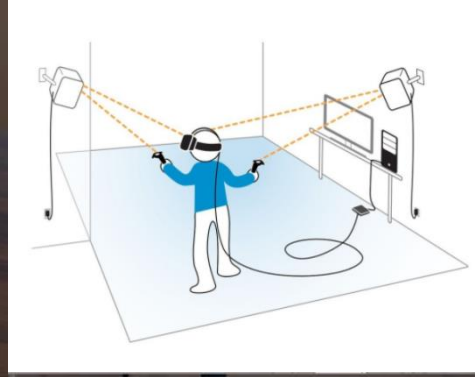
Example: Imaginary Museum setup

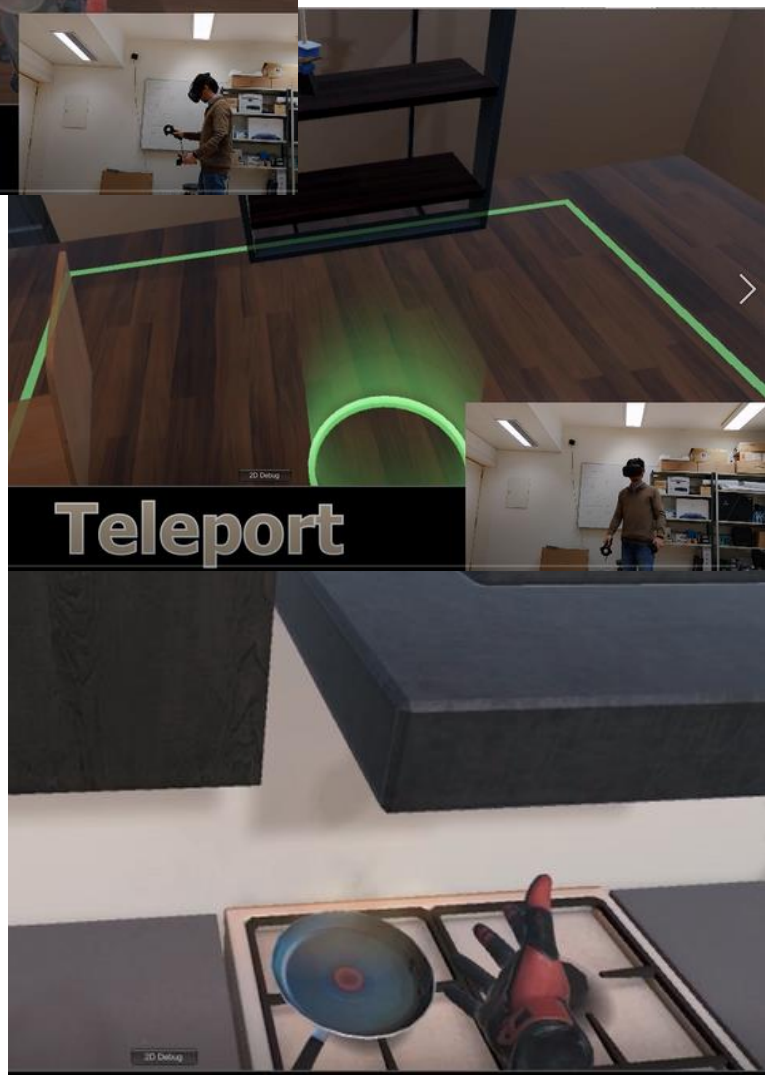


The user walks in a real room and navigates in the virtual room (similar to the real one)

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

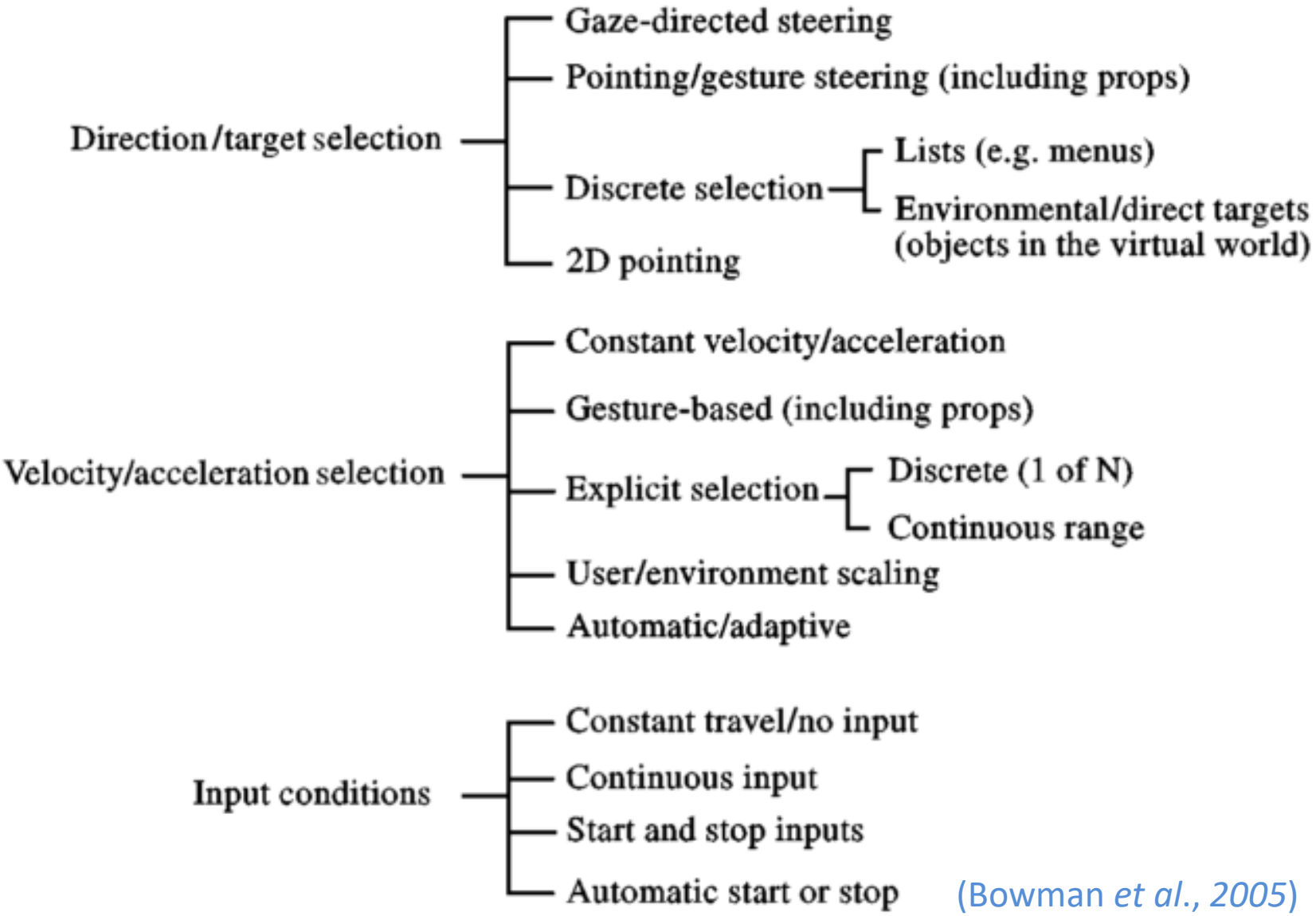
- 3D travel tasks according the user goal:
  - Exploration
  - Search
  - Maneuvering

- Other relevant characteristics:
  - distance to be traveled, curvature or turns, target visibility from the starting point

(Bowman et al., 2005)

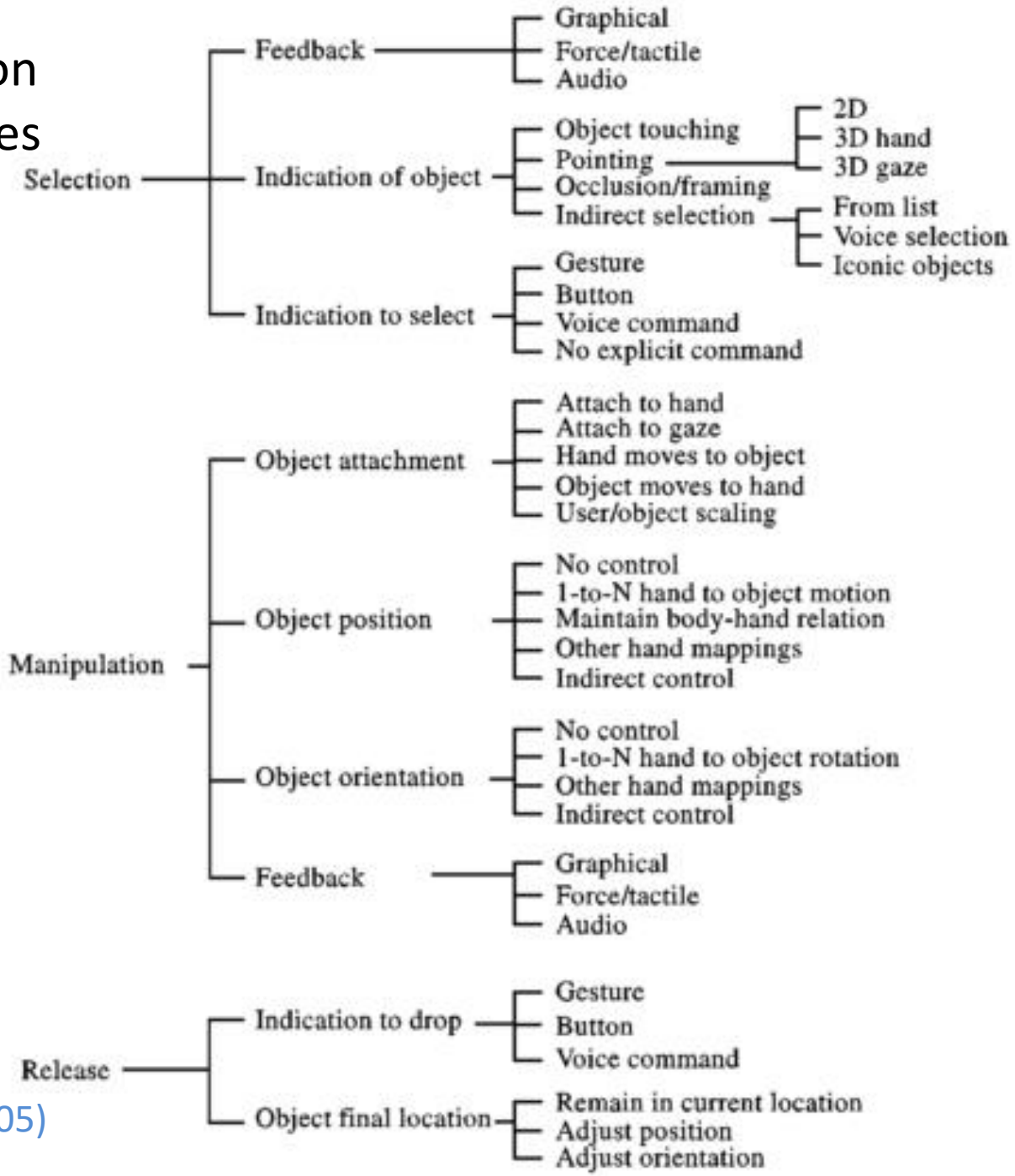
- Different taxonomies of travel techniques :
  - Active *vs* passive
  - Physical *vs* virtual
  - Metaphor
  - Subtasks

Travel – taxonomy of techniques concerning subtasks



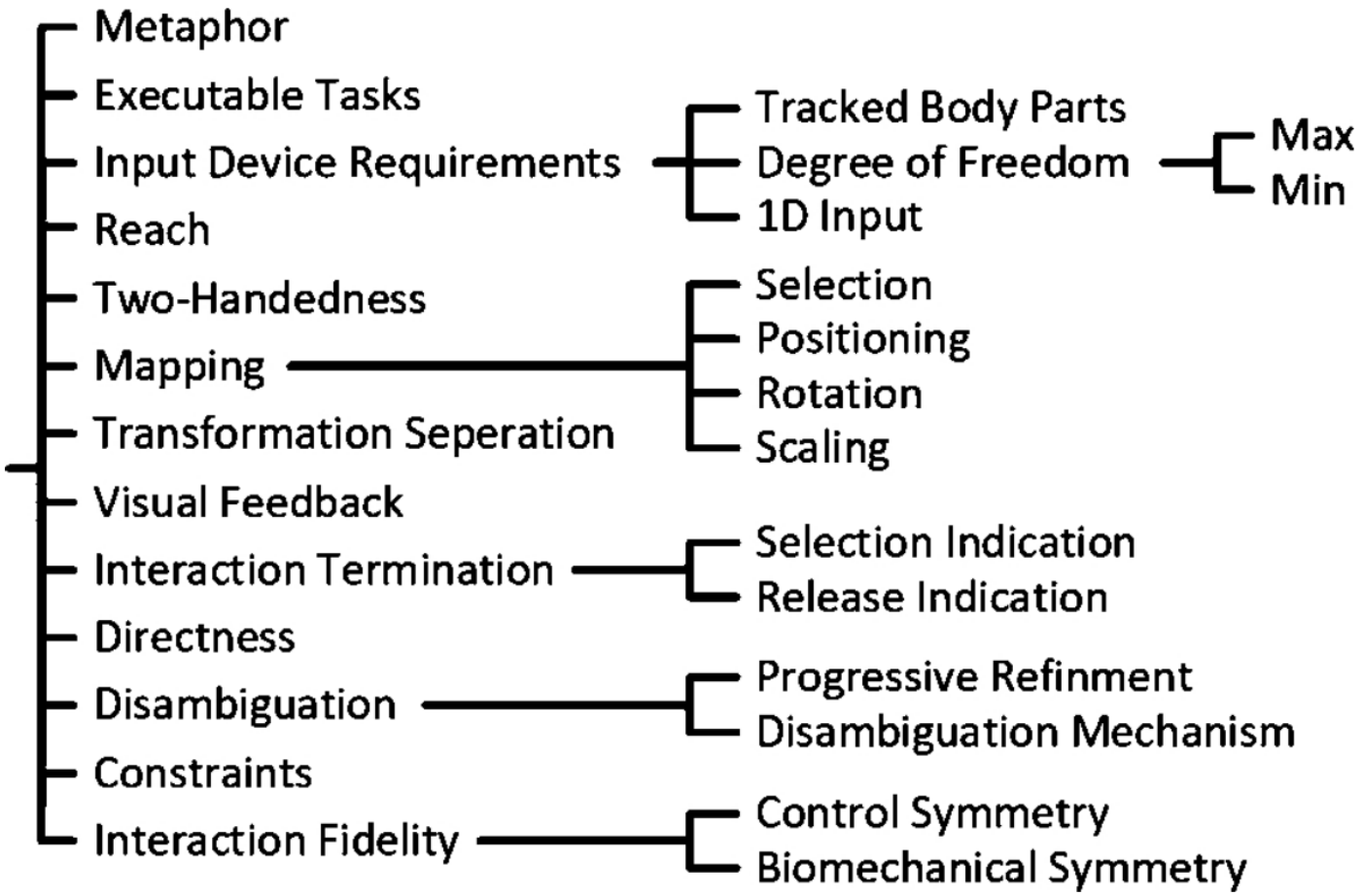
(Bowman *et al.*, *2005*)

Selection/ Manipulation Taxonomy of techniques



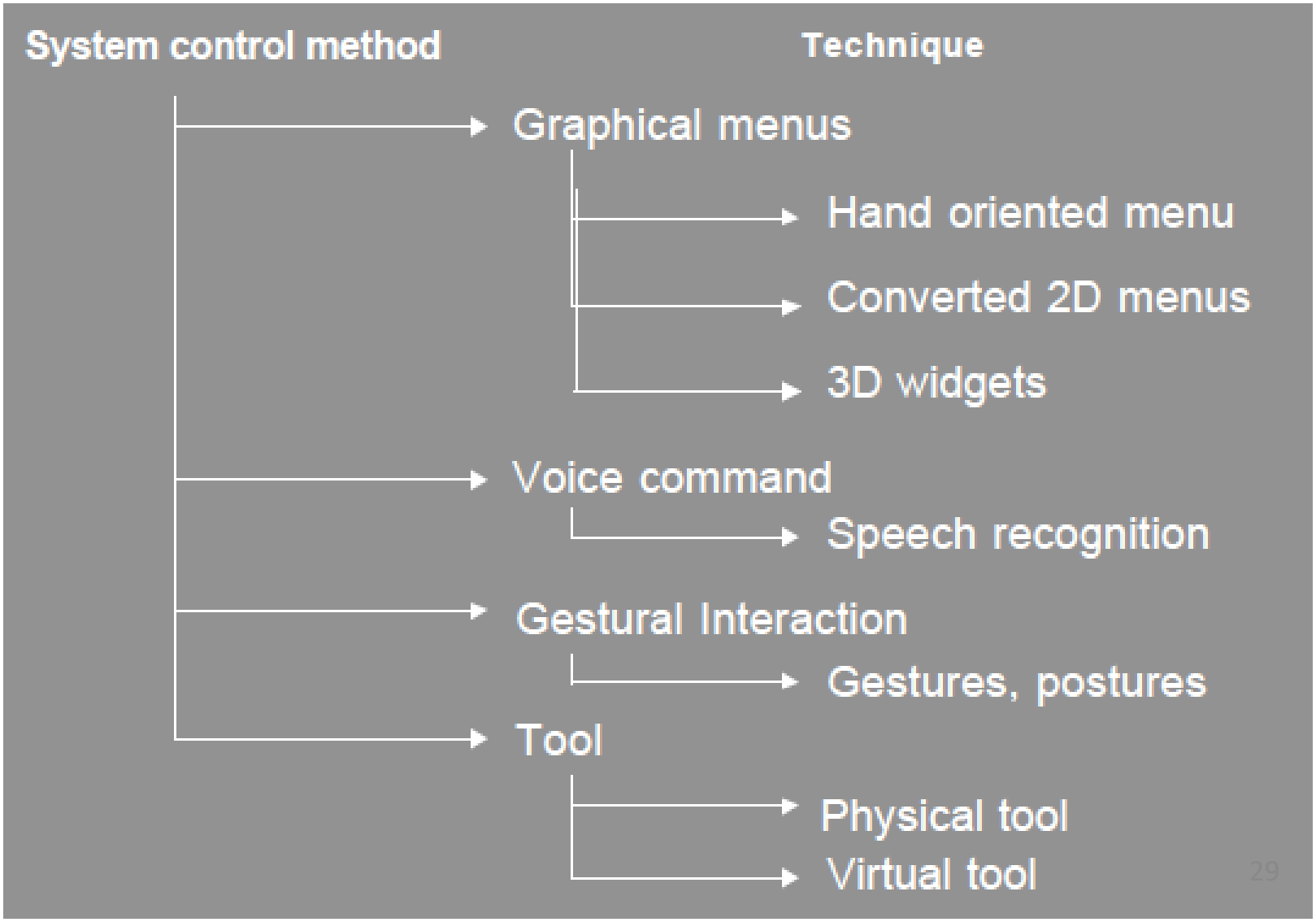
(Bowman et al. , 2005)

Solving Issues of Interaction in VR by Choosing Suitable Selection and Manipulation Techniques



W. Matthias et al., "How Can I Grab That?: Solving Issues of Interaction in VR by Choosing Suitable Selection and Manipulation Techniques" *i-com*, vol. 19, no. 2, 2020, pp. 67-85 https://doi.org/10.1515/icom-2020-0011

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

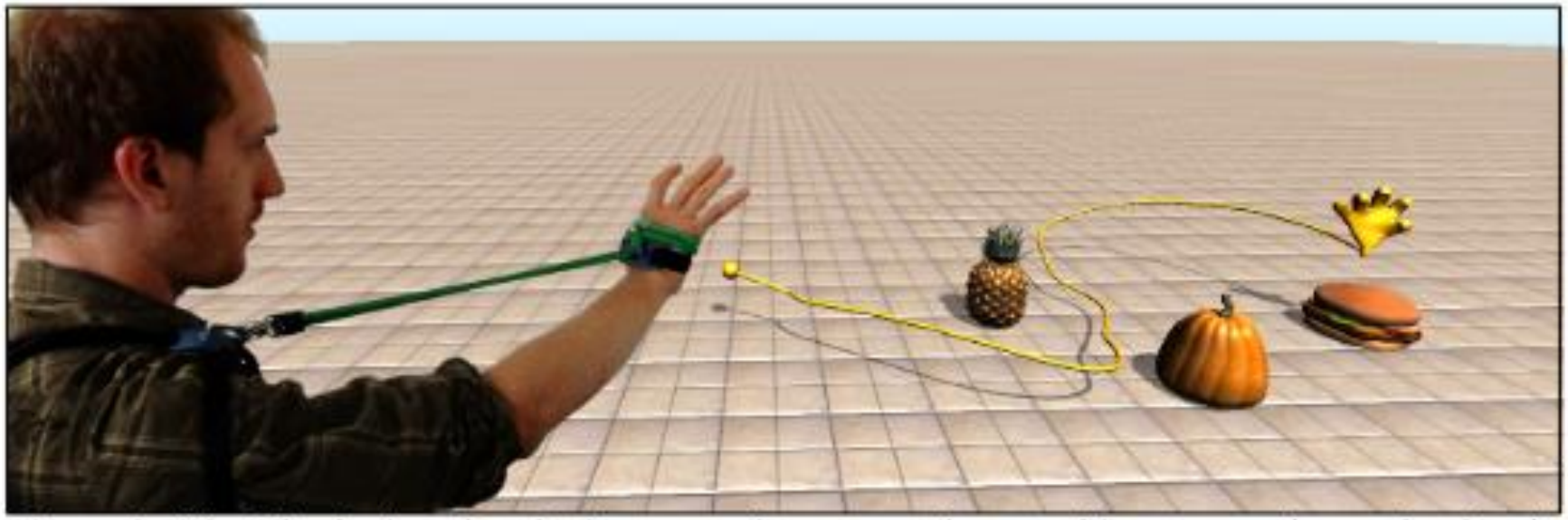


Figure 1. The Elastic-Arm is a body-mounted armature that provides egocentric passive haptic

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

Passive *vs* active haptic feedback in a medical simulator

Virtual Reality (VR) simulators are playing increasingly prominent role in orthopaedic training and education

Controlled experiment (38 participants) to **compare face validity** between two high fidelity VR simulators employing **passive and active haptic feedback**

There was no difference in face-validity

K. Vaghela et al., “Active vs passive haptic feedback technology in virtual reality arthroscopy simulation: Which is most realistic?” *Journal of Clinical Orthopaedics and Trauma*, vol 16, pp. 249-256, 2021
https://doi.org/10.1016/j.jcot.2021.02.014

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)

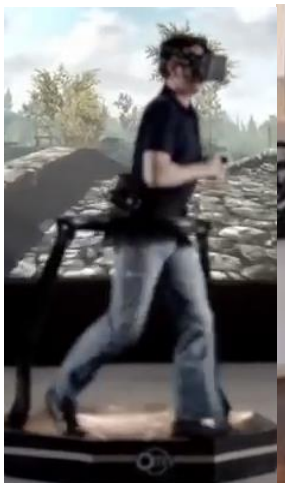
- Common approaches to general problems:
  - described from the user's point of view,
  - ≈ implementation independent

- **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

Main bibliography

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