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XR Interaction Interfaces

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Adapted from and with thanks to Mark Billinghurst
Typical Virtual Reality System

HMD → User Interface → Tracking → Input
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

3D physical input
3D virtual context

3D physical input
2D virtual context

2D physical input,
3D virtual context
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=FheQe8 rflWQ&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

Selection
  - indicate object
  - confirm select
  - feedback
    - object touching
      - pointing
      - indirect selection
    - button
    - gesture
      - voice
    - time
    - graphical
    - tactile
    - audio
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)

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

- World-in-miniature
  - Exocentric metaphors
  - Automatic scaling
    - Virtual hand metaphors
      - "Classical" virtual hand
      - Go-Go
      - Indirect Go-Go
    - Egocentric metaphors
      - Virtual pointer metaphors
        - Ray-casting
        - Aperture
        - Flashlight
        - Image plane

VE 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

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

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

Symmetric Bimanual Technique

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

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

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

Travel
- Start to Move
- Indicate Position
- Indicate Orientation
- Stop Moving

Specify Position
- discrete target specification (select object in environment, select from list, position 3D cursor, automatic selection, ...)
- one-time route specification (set series of markers, specify curvature and distance, ...)

Specify Velocity
- continuous specification (gaze-directed, pointing, physical steering props, virtual controls, 2D pointing, ...)

Specify Acceleration
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

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

Moving Your Own Body

- 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

Moving avatar in Map View

Moving avatar in WIM view
Redirected Walking

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

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

- Physical controllers
  - Buttons
  - Switches
- Graphical menus
  - Adapted 2D menus
  - 1 DOF menus
  - 3D widgets
- Voice commands
- Gestural commands
  - Mimic gestures
  - Symbolic gestures
  - Sweeping
  - Sign language
  - Speech connected hand gestures
  - Whole-body interaction
- Tools
  - Physical tools
  - Virtual tools
  - Tangibles
- Multimodal techniques
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