XR Interaction

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What is Interaction?

- **Communication** between user and AR/VR application **mediated** through input and output devices

- Realism NOT necessarily (only) goal
  - Often preferable to make interaction better than reality

3D Interaction Difficult

- More degrees of freedom (than in 2D interaction)
- Physical world contains
  - More cues for understanding
  - Constraints and affordances for action
- Precision in interaction major issue
- Fatigue

Interaction Types

- Object Interaction
- Navigation
- Interaction for system control

Object Interaction

- Broadly TWO ways to interact with objects
  - Interaction for selection
  - Interaction for manipulation

Object Interaction (1st Type) - Selection

Selection - Goals

- There can be several reasons for interaction to select
  - Indicate action on object
  - Query object
  - Make object active
  - Travel to object location
  - Manipulation

Selection Parameters

- Variables that influence user performance while accomplishing selection
  - Distance and direction to the target
  - Target size
  - Density of objects around target
  - Number of targets to be selected
  - Target occlusion

Stages of Selection

- 3 stages
  - **Indication** of object - by touching, pointing etc
  - **Confirmation** of selection - by voice command, gesture, etc
  - **Feedback** - by Tactile, audio, graphical etc

Common Selection Techniques

- Selection with hand
- Pointing-based selection
- Image-plane selection
- Volume-based selection

Technique (1) - Selection with Hand

- User directly reaches out hand to *touch* some object and then *triggers* a *grab*

Hand Selection Techniques

- Virtual hand
  - Direct mapping of user's hand motion to a virtual hand's motion (1-1 mapping)
  - Realistic hand (hand tracking) or any input device can be used
  - Orientation of virtual hand directly mapped to orientation of input device/real hand
    - In some cases scaled rotation is used
  - Intuitive
  - Problem in selecting objects located further away
    - User must employ a travel technique to do that

Hand Selection Techniques

- Go-go technique
  - Allows user to interactively change length of virtual arm
  - One-to-one mapping like simple virtual hand when target is close to user
  - As distance increases, the technique maps small movements of user's hand to large movement of virtual hand
  - Low precision for distant small object selection

Hand Selection Techniques

- PRISM
  - Enhancement to virtual hand selection
  - Apply a scaled down motion to user's virtual hand, when user's hand is moving below a specified speed
    - May result in mismatch in real and virtual hand position
  - If velocity of user's hand slower than a specified minimum velocity, virtual hand remains still

Hand Selection Techniques

- Intent driven selection
  - Use posture of virtual fingers as indication of user's level of confidence in selecting an object
  - Employs *proximity spheres* to progressively refine selection objects

Technique (2) – Pointing-Based Selection

- Extends a *ray* into distance and first object intersected can then be selected via a user-controlled trigger

Ways of Pointing

- Hand pointing
  - Pointing using hand/handheld input devices
- Head pointing
  - Pointing using head movement
- Eye gaze pointing
  - Pointing with the eye gaze

Various Pointing Techniques

- **Ray casting -** user points at objects with a virtual ray (short line segment or infinite line)
    - Virtual ray can be attached directly to virtual hand
    - In case hand cannot be tracked, head position can be used
    - Some uses gaze pointing to estimate target and trigger selection with hand pointing
    - Selecting small objects located far away can be difficult

Various Pointing Techniques

- **Bendcast -** Bends the ray for pointing towards the object closest to the path
  - Closest object detected by calculating point-line distance from each selectable object
  - Once closest object determined, a circular arc can be used to provide visual feedback for bending
  - Works best when only a few objects are located near the pointing vector's path

Various Pointing Techniques

- **Depth ray -** used to disambiguate between objects user intends to select when pointing vector hits multiple targets
  - At selection time, object closest to *depth marker*, and intersected by pointing vector, is selected
  - User can control position of *depth marker* by moving hand forwards or backwards

Technique (3) – Image-Plane Selection

- Also known as **occlusion & framing**
- User holds one or two hands between the eye and the desired object
- Then provides a signal to select the object when the object lines up with the hand and eye

Other Image-Plane Selection Techniques

- Head crusher technique - user positions thumb and forefinger around desired object in the 2D image plane
- Sticky finger technique - object underneath user's finger is selected
- Lifting palm technique - user selects objects by flattening his outstretched hand and positions the palm so that it appears to lie below the desired object
- Framing hands technique - hands are positioned to form the two corners of a frame in the 2D image surrounding an object

Technique (4) – Volume-Plane Selection

- Enables selection of a 3D region in space (e.g. box, sphere, or cone)

Some Volume-plane Selection Techniques

- Cone-casting flashlight technique
  - Uses pointing, but instead of using a ray, a cone is used
  - Objects that fall within the cone can be selected
  - Becomes a problem when selection of small objects or tightly grouped objects is required

- Aperture selection technique
  - Modified cone selection technique that allows to control the spread of the selection volume

Some Volume-plane Selection Techniques

- Sphere-casting flashlight technique
  - Casts a sphere onto the nearest intersected surface
  - Objects found within the sphere are considered selectable

- Two-handed box selection technique
  - Uses both hands to position, orient, and shape a box via snapping and nudging
  - Both snap and nudge mechanisms have two stages of interaction—grab and reshape

Object Interaction (2nd Type) - Manipulation

Manipulation

- Modifying object properties
  - Position
  - Orientation
  - Scale
  - Shape
  - Color
  - Texture
  - Behavior
  - …

Goals of Manipulation

- Object Placement
  - Design
  - Layout
  - Grouping

Manipulation Parameters

- Distance and direction to initial/target position
  - Translation distance
  - Required precision of positioning
- Initial/final orientation
  - Amount of rotation
  - Required precision of rotation
- Initial/final scale
  - Amount of scale
  - Required precision of scale

Manipulation Stages

- FOUR stages
  - Object attachment
  - Object position
  - Object orientation
  - Feedback (result of operation)

Common Manipulation Techniques

- Hand manipulation
- Indirect manipulation
- Bimanual manipulation
- Integrated hybrid manipulation

Hand Manipulation

User directly reaches out the hand to manipulate the object

Various Hand Manipulation Techniques

- Virtual hand manipulation
  - Follows hand selection
  - Gloves/gesture/controller based interaction
  - Intuitive

- Go-go technique can be used to manipulate objects that are user's out of reach
  - Low precision while performing positioning tasks

Various Hand Manipulation Techniques

- Finger-based manipulation
  - Enables new interactions such as holding a virtual egg by its sides or twirling a virtual pencil between one's virtual finger
    - Offers more precision
    - Works better with haptic feedback
  - Cons - if virtual fingers not allowed to penetrate virtual objects, they may be in different positions than user's real fingers

Indirect Manipulation

- Allows user to manipulate virtual objects without directly interacting with them

Various Indirect Manipulation Techniques

- 3D Widgets - widgets and handles to put controls directly in the 3D scene with the objects
  - Each widget responsible for only a small set of manipulation DOF

Various Indirect Manipulation Techniques

- Indirect proxy technique - allows user to use a more natural grasping method to perform direct manipulations, by giving them local proxies

Various Indirect Manipulation Techniques

- World-in-Miniature (indirect proxy) - Provides user with a miniature handheld model of virtual environment
  - User can indirectly manipulate virtual objects by interacting with their representations in WIM
  - Allow manipulation both within and outside of area of user reach
- Manipulation in large VE difficult

Bimanual Manipulation

- Manipulating objects with both the hands
  - Can be synchronous or asynchronous

Bimanual Manipulation Technique - Spindle

- Symmetric synchronous bimanual technique
- Two 6-DOF handheld controllers used to define a virtual *spindle*
  - To move object, both hands moved in unison
  - Can also be used to simultaneously rotate (yaw and roll) object
- Requires training and practice to use efficiently

Bimanual Manipulation Technique – Spindle + Wheel

- Asymmetric synchronous
  - Extension of spindle technique

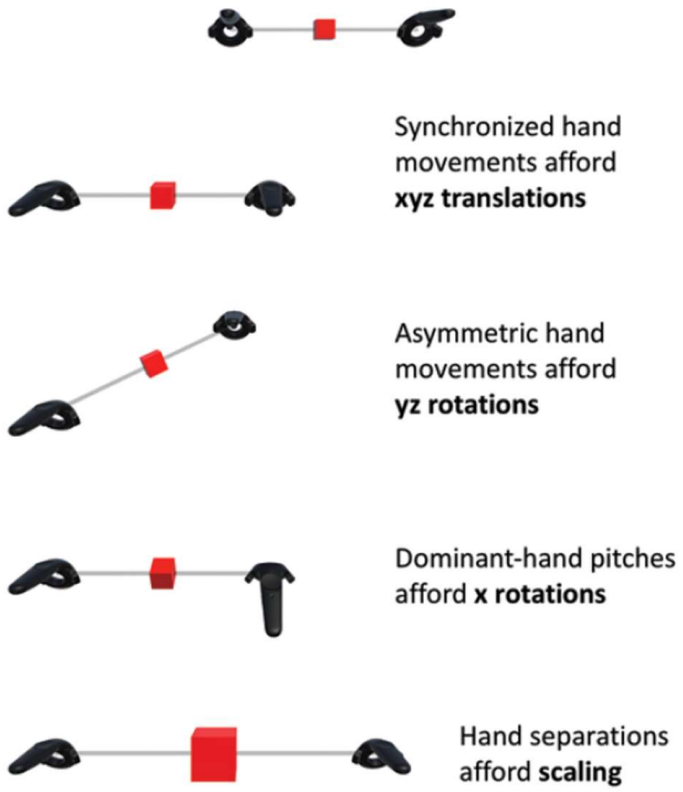


Image source: LaViola Jr, J.J., Kruijff, E., McMahan, R.P., Bowman, D. and Poupyrev, I.P., 2017. 3D user interfaces: theory and practice. Addison-Wesley Professional.

Integrated Hybrid Manipulation

Interface can switch from selection to manipulation technique after selection, and switches back to selection mode after manipulation

IHM Technique - HOMER

- Stands for Hand-centered Object Manipulation Extending Ray-casting

- User selects object using a ray-casting technique
- Instead of object being attached to the ray, user's virtual hand instantly *moves* and *attaches* to it
- Technique switches to manipulation mode, allowing user to position and rotate object

IHM Technique – Scaled-World Grab

- Entire VE scaled down around user's virtual viewpoint
- Scaling coefficient calculated to bring object within user's reach and manipulated using virtual hand technique
- May not be effective when user wants to pick up an object located within arm's reach and move it farther away

Interaction for Navigation

Goal

- Move user in the virtual world
  - Combination of **travel** and **wayfinding**

Travel

- M**otor component** of navigation
  - Movement between two locations

Types of Travel

- Exploration
  - No explicit goal for the movement
- Search
  - Moving to specific target location
- Maneuvering
  - Short, precise movements changing viewpoint

Locomotion Techniques

- FOUR types of virtual locomotion techniques
  - Walking based
  - Steering based
  - Selection based
  - Manipulation based

Walking-Based Locomotion

- Can be further divided into
  - Full Gait Techniques
  - Partial Gait Techniques
  - Gait Negation Techniques

Full Gait Techniques

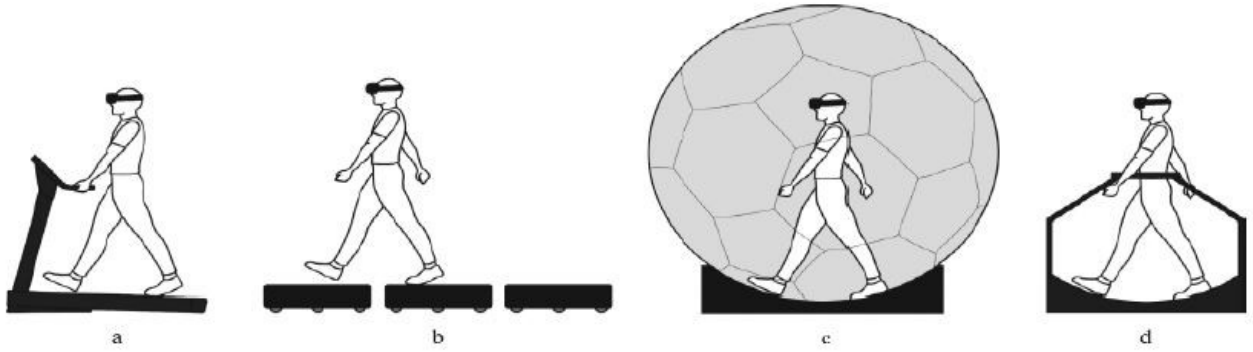
- Real Walking
  - Most Natural way to travel

Partial Gait Techniques

- Walk In Place
- Active Walking Interface

Gait Negation Techniques

- Cancels user's lateral movement keeping his physical position fixed
- Specialized set up needed



(a) a traditional linear treadmill, (b) motorized floor tiles, (c) a human-sized hamster ball, and (d) a friction-free platform.

Image Source: Nilsson, N.C., Serafin, S., Steinicke, F. and Nordahl, R., 2018. Natural walking in virtual reality: A review. *Computers in Entertainment (CIE)*, *16*(2), pp.1-22.

Steering-Based Locomotion

- Continuous control of direction and speed
- TWO types
  - Spatial steering - controlled using users' body parts
  - Physical Steering - controlled using vehicular props

Spatial Steering

- Gaze directed - travel follows where the user is looking

- Hand directed - hand direction determines direction of travel
- Body-leaning directed
- Torso directed

Physical Steering

- Bike locomotion platforms
- VR simulators for aircrafts, merchant ships, cars, boats and spaceships

Selection-Based Locomotion

- Allow users to focus on where to go (rather than how to)
- Can be divided into
  - Target selection
  - Route planning

Target selection

- User selects target destination and virtual viewpoint moved to target
- Teleportation, Map dragging, Step WIM, Jumper in CAVE

Route Planning

- More granular control over travel
  - User selects the route to navigate from source to destination

Manipulation-Based Locomotion

- Work by manipulating user's position, orientation, or scale
  - Using gestures that control either virtual viewpoint or virtual world

Manipulation-Based Locomotion

- GoGo manipulation
- HOMER manipulation
- World-In-Miniature (WIM) metaphor
- ….

- Already discussed theses ideas before

Wayfinding

- Refers to
  - Determining awareness or where one is located
  - And ascertaining a path through the environment to the desired destination
  - Transferring spatial knowledge to the real world

- **Goal - to build mental model (cognitive map)**
- 6DOF makes wayfinding hard
  - Extra freedom can disorient people easily

Knowledge

- Spatial knowledge in a mental model
  - Landmark knowledge
  - Procedural knowledge (sequence of actions to follow a path)
  - Map-like (topological) knowledge

How to Create Mental Model?

- Systematic study of map
- Exploration of real space
- Exploration of a copy of the real space

Wayfinding Support in VE

- Landmarks
  - Any obvious, distinct, non-mobile object
  - Good landmark can be seen from several locations

Wayfinding Support in VE

- Maps
  - Copy of real world maps
  - WIM

Wayfinding Aids

- Path following
  - Easy method of wayfinding
  - Multiple paths through a single space may be denoted by colors

Wayfinding Aids

- Bread crumbs(leaving a trail)
  - Leaving a trail of markers
  - Allows users to know when they have been somewhere before
  - Having too many markers can make the space cluttered

Wayfinding Aids

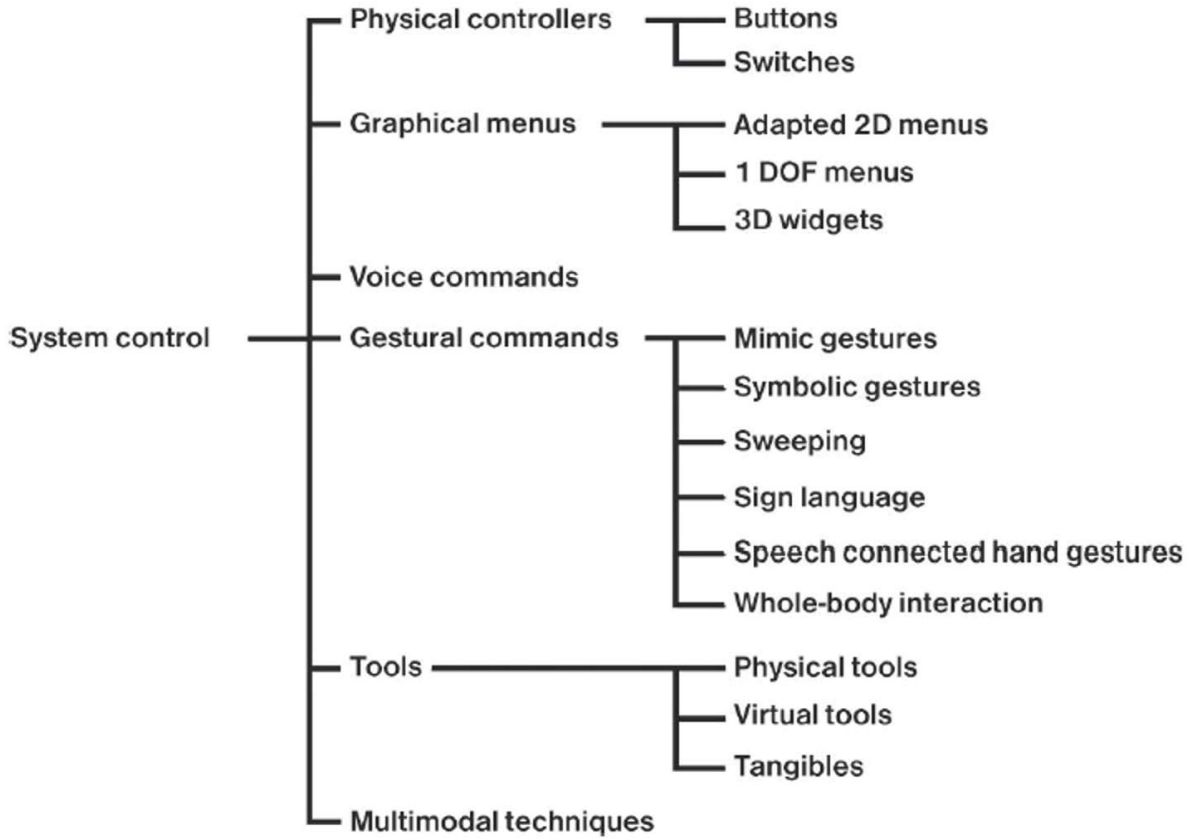
- Compass
  - Other form of direction indicator
  - Can specify directions in both 2D or 3D space

Interaction for System Control

Goal

- Issuing command to change system state or mode
  - Examples
    - Launching application
    - Changing system settings
    - Opening a file
- Make commands visible to the user
- Support easy selection

How it is Done?



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