Selection and Manipulation (Part 1)

Reading: Understanding Virtual Reality (2nd Edition), Ch. 7, pp. 538-574

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What makes 3D interaction difficult?

- Spatial input
- Lack of constraints
- Lack of standards
- Lack of tools
- Lack of precision
- Fatigue
- Layout complexity
- Perception in 3D
Example: Virtual-SAP

Video
Interface Concept: WorldBuilder

Video
WorldBuilder Today (Available on Steam)
Vision vs. Reality

There's still a lot of work to do...

Natural interface
Gesture and speech
Wide field-of-view
Full body input

Limited input
Wireless, limited range tracking
Reduced field-of-view
2D GUI in VR
Universal 3D Interaction Tasks in VR

Object Interaction
• Selection: picking objects 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
Goals of Selection

- Indicate action on an object
- Query an object
- Make an object active
- Travel to object location
- Set up manipulation
Manipulation involves physically handling objects with one or two hands.

More narrowly, in VR we are often concerned with spatial rigid object manipulation.
This means that the operation preserves the shape of objects.
Manipulation Tasks

Canonical tasks are the building blocks for more complex interaction scenarios.

Application-specific tasks are designed for a particular specialized purpose.
Canonicaal Tasks

Positioning
Changing object’s 3D location.

Rotation
Changing object’s 3D orientation.

Scaling
Uniformly changing the size of an object.
<table>
<thead>
<tr>
<th>Task</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection</td>
<td>Distance and direction to target, target size, density of objects around the target, number of targets to be selected, target occlusion</td>
</tr>
<tr>
<td>Positioning</td>
<td>Distance and direction to initial position, distance and direction to target position, translation distance, required precision of positioning</td>
</tr>
<tr>
<td>Rotation</td>
<td>Distance to target, initial orientation, final orientation, amount of rotation, required precision of rotation</td>
</tr>
<tr>
<td>Scaling</td>
<td>Distance to target, initial scale, final scale, amount of scale, required precision of scale</td>
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</table>
There is a close relationship between input devices and interaction techniques.

The number and integration of control dimensions will often determine which techniques can be used. Multiple integrated DOFs are typically best.
Device Shape

Generic

Application-Specific
Device Grip

Precision Grip

Power Grip
**Clutching** occurs when manipulation cannot be completed in a single motion.

For a mouse or touchpad, this means lifting the device or your finger off the surface and then restarting the motion from a different position.

For 3D manipulation, the virtual object must be released and regrasped.

This generally occurs less with precision grip compared to power grip.

You should generally try to design interaction techniques to avoid clutching as much as possible!
Isomorphic techniques have a realistic one-to-one correspondence between physical and virtual motions
e.g. reaching out to grab and release objects with your controller

Non-isomorphic techniques are also generally referred to as “magic” tools.
e.g., laser beams, rubber arms, etc.
Position vs. Force Control

Isomorphic position control is generally preferred for manipulation.

Non-isomorphic force control is suitable for controlling rates.
Classification by Task Decomposition

When designing 3D interactions, it is useful to **decompose tasks** into basic components.

New techniques can then be constructed by combining basic elements or “building blocks.”
Example Selection Decomposition

Selection

- Feedback
  - graphical
  - tactile
  - audio

- Object indication
  - object touching
  - pointing
  - indirect selection

- Indication to select
  - button
  - gesture
  - voice
Classification by Metaphor

Metaphors form the mental model of a technique.

Affordances communicate what actions are possible.

Constraints define what cannot be done.
Common Metaphors

- Grasping
- Pointing
- Surface
- Indirect
- Bimanual
- Hybrid
Common Metaphors

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Grasping
Simple Virtual Hand

This simple technique used a one-to-one mapping between physical and virtual hands. Object can be selected by “touching” with virtual hand.

Limitations
User’s reach
Fatigue
Grasping
Simple Virtual Hand

Video
Grasping
Go-Go Technique

Go-Go is an arm extension technique. Uses a non-linear mapping between physical and virtual hands.

Mapping changes between local and distant regions. (linear < D, non-linear > D)
Finger-Based Grasping

Figure 7.6 Rigid-body fingers use spring-dampers to map the user’s tracked physical fingers (green) to the user’s virtual fingers and to determine the applied forces for each rigid body (red arrows). (Image adapted from Borst and Indupula 2000)

Figure 7.7 The god-fingers technique simulates the contact between the user’s virtual finger pad and a virtual object. (a) The contact area is computed as if the finger’s surface were flat. (b) The contact area is fitted to the object’s geometry based on the god-object’s force direction. (c) An angular threshold between the god-object’s force direction and the normals of the involved faces is used to filter out odd deformations. (Image adapted from Talvas et al. 2013)
Grasping Enhancements

Bubble Cursor

Figure 7.8 The 3D bubble cursor allows efficient selection of the nearest virtual object. (a) The radius of the cursor automatically enlarges to encapsulate the nearest virtual object. (b) To avoid intersecting other nearby objects when enlarging the radius, a second semitransparent sphere is used to encapsulate the nearest virtual object. (Image adapted from Vanacken et al. 2007)

**Bubble Cursor** uses a semi-transparent sphere that dynamically resizes to encapsulate the nearest virtual object.

When sphere is too large and begins to intersect a nearby object, a second semi-transparent sphere is created to encapsulate that object.
Grasping Enhancements

Bubble Cursor

Video
Grasping Enhancements

**Figure 7.9** PRISM employs four interaction modes to afford precise interactions for grasping metaphors. (Image adapted from Frees and Kessler 2005)

**Precise and Rapid Interaction through Scaled Manipulation**

Apply scaled down motion to user’s virtual hand when the physical hand is moving below a specified speed.

Use offset recovery mechanism when moving above a specified maximum speed to allow virtual hand to “catch up.”
Intent Driven Selection used the posture of virtual fingers as confidence level. Proximity sphere is positioned within grasp of the virtual hand. Anything within the sphere is selectable. As hand closes, additional proximity spheres are made to specify a smaller subset of selectable objects until one target is selected.

Figure 7.10 Intent-driven selection employs proximity spheres to progressively refine the selection of objects. (Image adapted from Pervezov and Iles 2015)
Grasping Enhancements
Intent Driven Selection

Video
Common Metaphors

- Grasping
- Pointing
- Surface
- Indirect
- Bimanual
- Hybrid
Pointing

Pointing is a powerful tool for selection.
Allows selection of distant objects.
Fewer DOFs to control compared to grasping.
Less hand movement is required.

Pointing is poor for positioning.
Three dimensions, but only two DOFs.
Less hand movement results in lower precision.
“Laser pointer” attached to virtual hand.
First object intersected by ray may be selected.
User only needs to control 2 DOFs.

“Fishing Reel” variant adds additional DOF.
Use an additional input mechanism (e.g., thumbstick) to reel the
object back and forth along the ray.
Pointing

Image Plane Pointing

**Image plane** techniques select and manipulate objects with their 2D projections. Essentially performs a ray-cast from the user's head and intersecting the point of contact.

Examples include Head Crusher, Lifting Palms, Sticky Finger, and Framing.
Pointing

Image Plane Pointing

Video
Pointing
Flashlight

“Cone casting” does not require as much precision for distant objects.
Uses a conic selection volume with the apex at the input device.

Must deal with object disambiguation.
Select the object closest to the centerline.
Pointing
Aperture Selection

Aperture selection is a modification of the flashlight technique.
User can interactively control the spread of selection volume.

Pointing direction defined by 3D positions of user’s head and hand.
Moving the hand closer or farther away changes aperture.

Figure 7.13 Aperture selection technique. (Forsberg et al. 1996, © 1996 ACM; reprinted by permission)
Figure 7.14 Aperture technique: (a) an example of use; (b) selection sensitivity based on grasp orientation. (Reprinted by permission of Brown University)
Pointing
Sphere-Casting (SQUAD)

Two phase technique involves sphere casting followed by quad menu selection.
For dense objects, this requires multiple low precision selections.

Limitations
Quad menu phase is done outside spatial context
Target needs to be unique or selectable among identical ones.
Pointing
Sphere-Casting (SQUAD)
**Bendcast** is the pointing version of the 3D bubble cursor.

Bends the pointing vector toward object closet to the vector’s path.

Render a circular arc to provide visualization for the user.
Pointing Enhancements

Depth Ray

Used to disambiguate which object the user intends to select when pointing vector intersects multiple targets.

Uses depth marker along the ray length.
Object closest to the marker is selected.
User can control marker by moving hand backwards or forwards.

Figure 7.15: The depth ray enhancement uses a depth marker to determine which object to select when multiple objects are intersected by the pointing vector: (a) the depth ray selected the intersected object closest to the depth marker; (b) the depth marker can be repositioned by moving the hand forwards or backwards. (Image courtesy of Ryan P. McMahon)
Pointing Enhancements
Absolute and Relative Mapping

**Absolute and Relative Mapping** provides manual control of gain ratio between virtual and physical motions. This lets users increase the effective angular width of targets.

Useful in dense environments, but can give the user impression of a slow motion pointer.
Image Credits

- 3D User Interfaces: Theory and Practice (2nd Edition)
- Understanding Virtual Reality: Interface, Application, and Design (2nd Edition)
- Mark Billinghurst and Bruce Thomas, COMP 4010 Lecture on 3D User Interfaces for VR
  https://www.slideshare.net/marknb00/lecture-5-3d-user-interfaces-for-virtual-reality