Selection and Manipulation (Part 2)

Reading: *Understanding Virtual Reality (2nd Edition)*, Ch. 7, pp. 575-600
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.”
Review: Metaphors

**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
**Grasping Enhancements**

**Bubble Cursor**

![Diagram](image)

**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 semi-transparent 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

PRISM

![Diagram of PRISM interaction modes]

**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 Periwicz and Iles 2015)
Grasping Enhancements

Intent Driven Selection

Video
Common Metaphors

- Grasping
- Pointing
- Surface
- Indirect
- Bimanual
- Hybrid
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
Ray Casting

Video
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
“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. McMahan)
**Pointing Enhancements**

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.
Common Metaphors

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Surface Metaphors
Surface-Based 2D Interaction Techniques

Position Dragging
Two Finger Rotation
Pinch-to-Zoom (Scale)
Virtual objects project shadows up onto a stereoscopic touch surface. Computed using invisible shadow plane above the surface. Multiple stacked objects cast nested shadows. Manipulation is limited to 2DOF horizontal plane.

Figure 7.18 The concept of void shadows: (a) the shadow of each object cast upon the surface is calculated based on an unseen shadow plane located above the touch surface; (b) stacked objects of the same size cast nested shadows of various sizes. (Image adapted from Giesler et al. 2014)
Surface Metaphors

Void Shadows

(a) Puzzle Task (VOID)
(b) Table Task (HAND)

Figure 4. In the puzzle task, participants had to assemble 8 boxes into a puzzle around a stationary reference puzzle piece. The illustration (a) shows the VOID technique in action during this task. In the table task (b), illustrated with the HAND technique, participants had to drop four objects on the table (a monoscopic projection was used while these images were captured).

Image Credit: Giesler et al. 2014
Surface Metaphors

Ballon Selection

Figure 4: Frames from a Balloon Selection interaction sequence (captured through a video-mixed display). (a) Placing two fingers (the anchor and the stretching finger) adjacent to each other on the tabletop instantiates the 3D cursor (balloon). (b) Moving the stretching finger away from the anchor stretches the virtual string between the two fingers. (c) Moving the fingers closer together raises the balloon from the surface. (d–e) Moving the thumb on the anchor’s hand towards or away from the anchor scales the balloon up (for easier) or down (for more precise) selection. (f) Moving the anchor on the surface translates the balloon parallel to the plane of the table, while varying the distance between the anchor and the stretching finger determines the balloon’s height. Placing the thumb of the stretching finger’s hand adjacent to the stretching finger triggers the selection of the target cube.

Image Credit: Benko and Feiner 2007
Surface Metaphors

Corkscrew Widget

**Figure 7.20** The corkscrew widget: (a) dragging the widget changes the horizontal position of the selection point; (b) rotating the widget changes the vertical position of the selection point. (Image courtesy of Ryan P. McMahan)
Surface Metaphors

Corkscrew Widget

Figure 2: Balloon/Fishnet Selection: a) The basic tool selection menu. b) The fishnet tool allows the balloon selection for objects with positive parallax.

Figure 3: Corkscrew Selection: a) Dragging the circle widget allows x-, y-translation. b) A circular movement performs the z-translation.

Image Credit: Daiber et al. 2012
Surface Metaphors

Triangle Cursor

Figure 7.21 The triangle cursor uses the midpoint between two contact points to define the horizontal position of the cursor, the distance between the contact points to determine the vertical position of the cursor, and the angle of the points about their midpoint to change the yaw of selected objects. (Image courtesy of Ryan P. McMahan)
Surface Metaphors

Triangle Cursor

Video
Common Metaphors

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**Indirect Metaphors**

**Control-space** techniques allow the user to interact in a physical space distinct from the display.

**Proxy** techniques have the user directly interact with representative copies of the object.

**Widget** techniques place GUI elements in the environment that the user can directly manipulate.
Indirect Control-Space Techniques

Indirect Touch

Figure 7.22 An example of an indirect control-space technique. (Image courtesy of Ryan P. McMahan)
Indirect Control-Space Techniques

Virtual Interaction Surface

Figure 7.23  A virtual interaction surface turns the complex 3D task of translating and rotating a box along the surface of a cylinder into a simple 2D action. (Ohnishi et al. 2012, © 2012 IEEE; reprinted by permission)
Indirect Control-Space Techniques

Levels-of-Precision Cursor

Figure 7.24 The LOP cursor: (a) the user can freely point the smartphone at the display to change the mapping of the smaller indirect surface to the display surface; (b) the user can precisely change the position of the cursor by dragging a thumb on the smartphone screen. (Image adapted from Debarba et al. 2012)
Indirect Control-Space Techniques

Levels-of-Precision Cursor

Video
Indirect Control-Space Techniques

Virtual Pad

Figure 7.25 Instead of using ray-casting to directly interact with remote objects, the virtual pad technique allows the user to use virtual hand with a local control space to control remote selections. (Image adapted from Andujar and Argelaguet 2007)
Indirect Proxy Techniques

World-in-Miniature

Scale entire world down and bring within user’s reach with a miniature handheld model.
Manipulation object in the WIM is mapped to the object in the VE.
Indirect Proxy Techniques

World-in-Miniature

Video
Indirect Proxy Techniques

World-in-Miniature
Indirect Proxy Techniques

Voodoo Dolls

Manipulate objects indirectly using temporary handheld copies of objects.
User can create a “doll” by using image plane selection.
Indirect Proxy Techniques

Voodoo Dolls

Video
Indirect Widget Techniques
Common Metaphors

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Bimanual Metaphors

Bimanual metaphors use two hands in cooperation. But remember, most users have a dominant and non-dominant hand!

Can be symmetric or asymmetric. Are different tasks assigned to each hand?

Can be synchronous or asynchronous. Do both hands operate at the same time?
Symmetric Bimanual Techniques

Spindle

Two 6DOF controllers are used to define a virtual spindle between the hands. The center of spindle represents primary point of interaction.

Interaction Methods
Translation: move both hands in unison
Rotation: yaw and roll by rotating hands
Scale: lengthen or shorten distance of hands
Symmetric Bimanual Techniques

Spindle

Video
Symmetric Bimanual Techniques
Intersection-based Spatial Interaction for Two Hands (iSith)

Two 6DOF controllers define separate rays
Shortest line between two rays is found by crossing two vectors to find vector perpendicular to both.
The projected intersection point is the center of interaction.

Figure 7.32 With the bimanual iSith technique, (a) the point of interaction can be quickly translated by (b) rotating the two handheld controllers (image adapted from Wyss et al, 2006)
Symmetric Bimanual Techniques

Intersection-based Spatial Interaction for Two Hands (iSith)

Video
Asymmetric Bimanual Techniques

How should we assign tasks between the two hands?
The non-dominant hand should control the reference frame.
The dominant hand should perform manipulations that require fine control.

⚠️ I will expect you to apply these principles when integrating bimanual interaction in your project!
Asymmetric Bimanual Techniques
Spindle + Wheel

Extended Spindle to include pitch rotation
Uses virtual wheel collocated with dominant hand cursor.
The dominant hand is twisted for rotation.
Asymmetric Bimanual Techniques

Spindle + Wheel
Asymmetric Bimanual Techniques

Flexible Pointer

Figure 7.34 A flexible pointer can be used to point at partially obscured objects. (Olwal and Feiner 2003; reprinted by permission of the authors)

Two-handed pointing for partially obscured objects
The nearest hand, the farthest hand, and a control point map to the position, length, and curvature of a Bezier spline.
Asymmetric Bimanual Techniques

Flexible Pointer

Video
Bimanual Volumetric Selection

Defining custom selection boxes
Hand-on-Corner (asymmetric asynchronous)
Hand-in-Middle (asymmetric asynchronous)
Two Corners (symmetric synchronous)

Figure 1: Performing a selection.

Figure 5: Positioning, orienting, and scaling box in HOC.

Figure 6: Positioning, orienting, and scaling box in HIM.

Figure 7: Positioning, orienting, and scaling box in TC.

Image Credit: Ulinski et al. 2007
Common Metaphors

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Hybrid Metaphors
Hand-Centered Object Manipulation Extended Ray-Casting (HOMER)

Hybrid grasping / pointing technique
An object is first selected using ray casting.
Hand then attaches to the object for manipulation.
Hybrid Metaphors
Hand-Centered Object Manipulation Extended Ray-Casting (HOMER)
Hybrid Metaphors
Scaled World Grab

Hybrid grasping / pointing technique
An object is first selected using ray casting.
Entire VE is scaled down until object is within reach.

Image Credit: Mine et al. 1997
General Considerations for 3D Manipulation

Nonisomorphic Rotation
Amplification can increase range and decrease clutching.
Slowing down can increase precision.

Multiple Object Selection
Options include serial selection, volume-based selection techniques, and defining custom selection volumes.

Progressive Refinement
For dense environments, reduce set of objects until only one remains.
Consider multiple fast selections with low precision requirements.
Design Guidelines

- There is no single best manipulation technique.
- Don't just choose the default techniques in your engine!
- Use task decomposition when choosing techniques.
- Match the interaction technique to the device.
- Select techniques that can help to reduce clutching.
Design Guidelines

- Non-isomorphic (“magic”) techniques are useful.
- Pointing is appropriate for distant object selection.
- Grasping is appropriate for precise manipulation.
- Reduce degrees of freedom when possible.
- Consider trade-off between interaction technique complexity and virtual environment design.
Participation Exercise

For today's participation exercise, you will need to register your final project team on Canvas.

If you would like to work alone or would like me to assign you a partner now, please indicate this.

Project proposals will be due on Thursday, November 4.

Project fast forward presentations will be on Tuesday, November 11.
Image Credits

- 3D User Interfaces: Theory and Practice (2nd Edition)
- Understanding Virtual Reality: Interface, Application, and Design (2nd Edition)