Interacting within Virtual Worlds

(based on talks by Greg Welch and Mark Mine)

Johns Hopkins Department of Computer Science
Course 600.460: Virtual Worlds, Spring 2000, Professor: Jonathan Cohen

Presentation Overview

- **Working in a virtual world**
- **Interaction principles**
- **Interaction examples**

Why VR in the First Place?

- Direct perception and *manipulation* of three-dimensional virtual-objects
- Intuitive view specification via head-tracking
  - —Decouples view-point specification
  - —Kinetic depth effect (Hans Wallach)
- Immersion within the virtual space

Immersive Virtual Environments

- Head-mounted display
- Tracking System
- Image Generator
- Additional sensory feedback
  - —Haptic displays
  - —2D or 3D localized sound

Technological challenges

- Display resolution/field-of-view
- Real-time tracking
- Real-time image generation
- Ergonomic Issues

Less Obvious Factors

- The precise manipulation of virtual objects is hard!
  - —Lack of haptic feedback
  - —Limited input information
  - —Limited precision
- IVEs lack a unifying framework for integration
  - —Not the real world
  - —Not for WIMPs
    - »(Window, Icons, Menus, Pointing devices)

What can you do?...

Pick the right application!

- **Best suited for visualization of, *and* interaction with:**
  - **Complex three-dimensional data**
  - **Models of what is, or could be**

Compensate for the Limitations

- A relatively new medium—treat it as such
- Take advantage of natural forms of interaction
- Explore the “supernatural”
- Minimize user energy
- Use what you have, e.g.,
  - —physcial objects
  - —your own body sense...

Proprioception & Body-Relative Interaction

- Take advantage of a person's body sense
  - —Physical real-world frame of reference
  - —More direct and precise sense of control
  - —"eyes off" interaction
- Three forms of body-relative interaction (Mine, 97)
  - —Direct manipulation
  - —Physical mnemonics
  - —Gestural actions

Principles

How do we interact with virtual environments?

- Basic forms of interaction with a virtual environment:
  - User movement
  - Object selection & manipulation
  - Menus/Widgets/Controls

What can we use to implement these forms of interaction?

- Direct user interaction
- Props and controls
  - —Physical
  - —Virtual

Direct User Interaction

Specify type of interaction and its parameters through:

- **Head/hand (feet...) pose (position and orientation)**
- **Relative position and orientations of head/hands**
- **Gestures**

Tradeoffs (Direct User Interaction)

- Most effective when the relationship between the action of the user and the result in the virtual environment is intuitive
- Accurate precise interaction limited by:
  - —Lack of haptic feedback
  - —Tracking noise, or geometric sensitivity
  - —Limited input device design

Props and Controls

- Physical
  - —General: buttons, dials, sliders, joysticks
  - —Specific: steering wheels, fire extinguisher
- Virtual
  - —Almost anything goes

Tradeoffs (Props and Controls)

- **Physical**
  - —**Haptic feedback, precise control**
  - —**Can get "lost", may not facilitate natural interaction, requires the real device**
- **Virtual**
  - —**Flexible, reconfigurable, can simulate anything**
  - —**Difficult to interact with w/o haptic feedback**

Movement: why is it difficult? What can we do about it?

- We usually don't move about freely in 3D
- Constrain motion as appropriate
  - —Translation only
  - —Sliding only
  - —Terrain following
  - —River metaphor

Typical Methods (Movement)

To move around we need to specify a direction and a speed. Straightforward methods include:

- **Walk in place or within a limited volume**
- **Use an appropriate, intuitive physical device**
  - **—Bike, treadmill, wheelchair, steering wheel and accelerator, etc.**
- **Joysticks or mice**

Flying

Most often used method of movement is flying. Direction can be indicated by:

- **Pointing**
- **Crosshairs**
- **Gaze-directed**
- **Two-handed (later)**

Speed Control

Speed can be:

- Constant or accelerating over time
  - —Proper rate of acceleration
  - —Cap on speed
- Related to head/hand/chest-to-hand distance
  - —Linear
  - —Zones: decelerate, constant, accelerate

Novel Methods of Movement

Innovative techniques that lack real world equivalents:

- **Scaled-world grab**
- **Orbital mode**
- **Worlds-in-Miniature (WIM)**
- **Dynamic scaling**

Object Selection

We want to be able to select a specific object or objects to interact with in a VE.

There are usually three stages to selection:

- User indicates which object is to be selected
- VE system indicates what object it thinks the user wants selected
- The user confirms the selection

Indicating Which Object

The most difficult part of selection is providing the means for easy and accurate indication of the desired object.

- **Voice commands or menus**
- **Grabbing locally or in a World-in-Miniature**
- **Action at a distance (AAAD)**
  - **—laser beam or spotlight**
  - **—occlusion selection**

Manipulating an Object

We want to be able to efficiently and intuitively manipulate objects in the VE. Among other things, we want to change an object's:

- **position**
- **orientation and center of rotation**
- **scale and center of scaling**

These are all often done with direct interaction.

Considerations (Manipulation)

Although it is intuitive, accurate, and efficient, direct manipulation of objects is still very difficult. Designers must consider:

- **Lack of haptic feedback**
- **Objects outside of reach or view**
- **Lack of precision (tracking data noise, whole hand input, etc.)**

Two-Handed Manipulation

VE systems often track and use only one hand, but we are finding that two can be useful.

- **Scaling**
  - —**Intuitive and proprioceptive**
- **Rotation**
  - —**How we rotate large objects in the real world**
  - —**Constrained manipulation via widgets**

Menus and Widgets

Menus and widgets allow us to perform complex functions and select between alternatives.

In designing these tools we should consider:

- **Lessons from 2D menus**
- **Menu dimensionality vs. interaction task**
- **Menu and widget placement**
- **Technology limitations**

Direct Manipulation

Distance and Body-Relative

Action-at-a-Distance (Brown & others)

- **Purpose: Remotely manipulate objects using a "laser beam" for selection/interaction**
  - **Interaction without movement**
  - **Hand or object centered**
  - **Optimal for motions *perpendicular to beam***
    - **other requires grab/drop sequences**
  - **Inherent ambiguity in position specification**
  - **Amplifies tracking system noise**

Video

Bowman and Hodges, "An Evaluation of Techniques for Grabbing and Manipulating Remote Objects in Immersive Virtual Environments," ***Proceedings of 1997 Symposium on Interactive 3D Graphics.***

Working Within Arms Reach: Automatic Scaling

Use for object manipulation and navigation

- Takes advantage of proprioception
- More direct mapping between hand motion and object motion
- Stronger stereo & head-motion parallax cues
- Finer angular resolution

Worlds-in-Miniature (UVA)

- **Purpose: Move objects in immersive world by manipulating miniature representations**
  - **Brings virtual objects within reach**
  - **Gross motion of objects through virtual space**
  - **Multiple, simultaneous representations**
  - **Does not solve problem of precise positioning**
  - **Does not solve problems of visibility**
- **Combine with orbital mode for greater power**

Orbital Mode (Chung)

- Head-pose interaction control
- Rapid orbital motion about a single object or groups of objects
  - —Object of interest remains in front of the user
  - —Head rotation causes the view to orbit about the object of interest
  - —No real-world analog yet highly effective

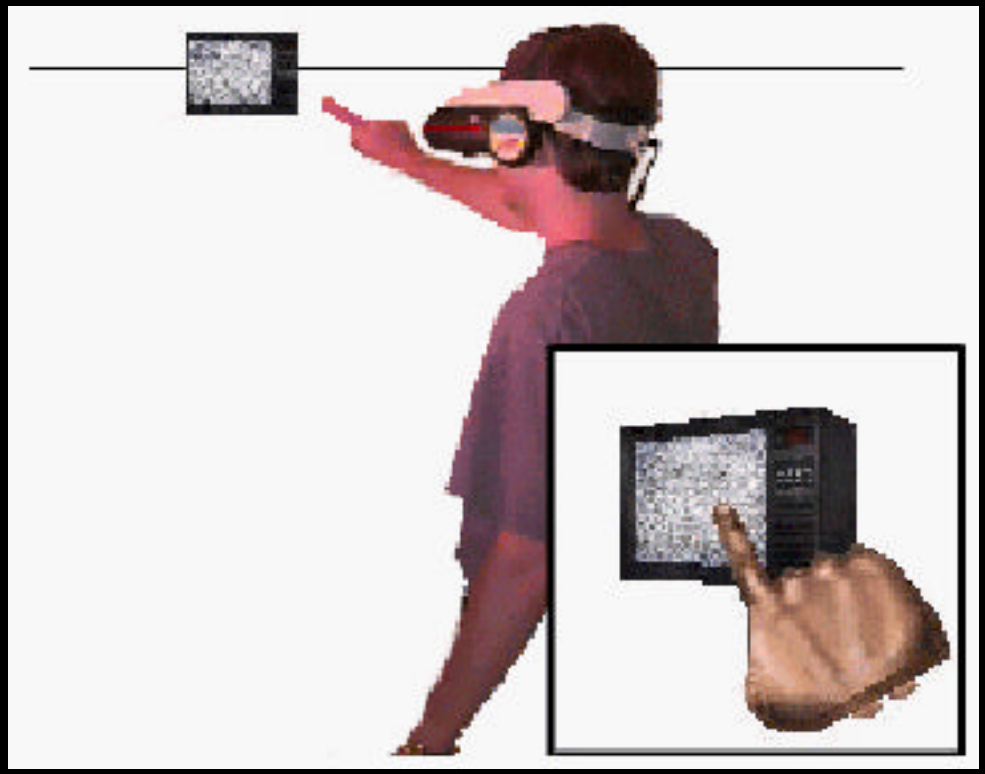
Using Perspective

Image Plane Interaction (UVA, Brown, UNC)

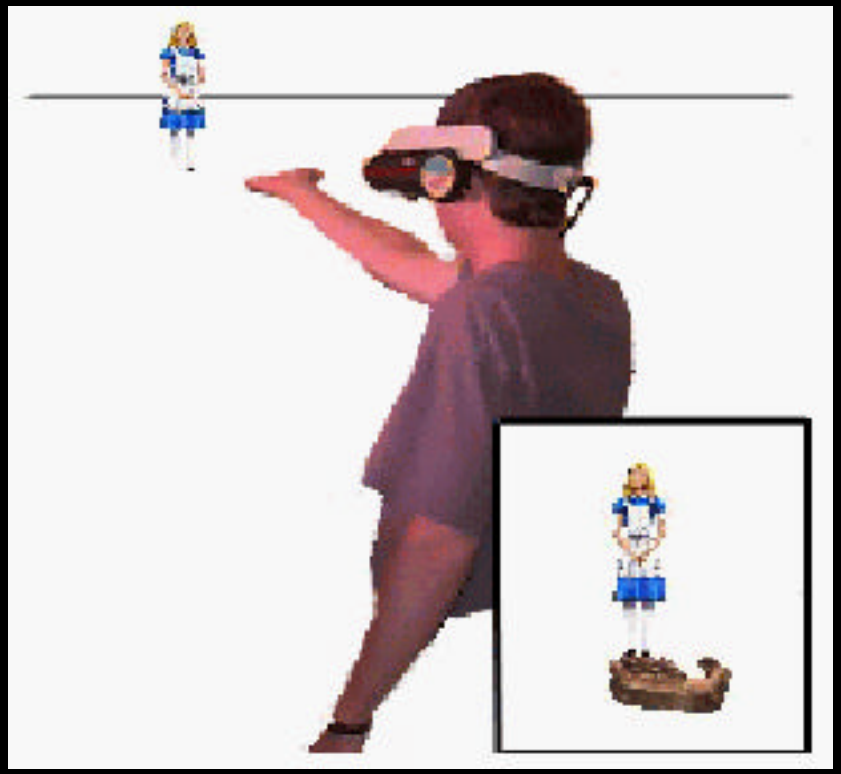
- User interacts with 2D projections of 3D objects
- Multiple applications
  - —object selection and manipulation
  - —navigation/motion

The “Head Crusher” Technique

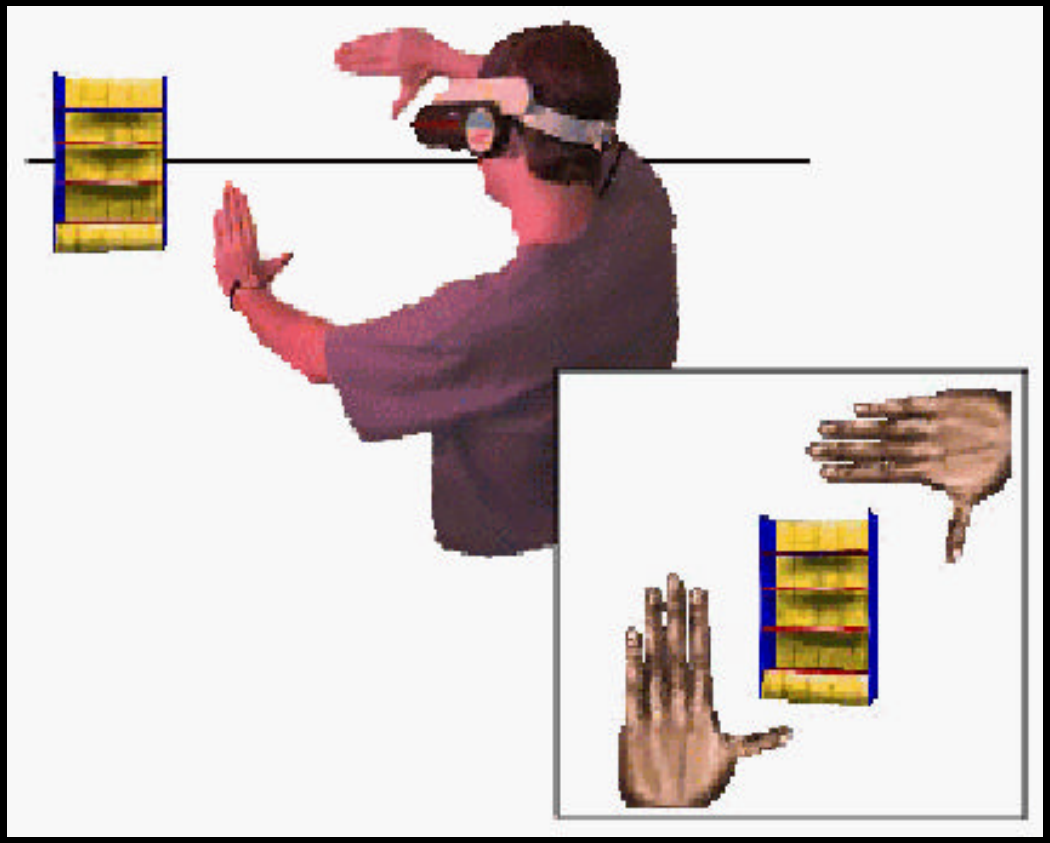
The “Sticky Finger” Technique



The “Lifting Palm” Technique



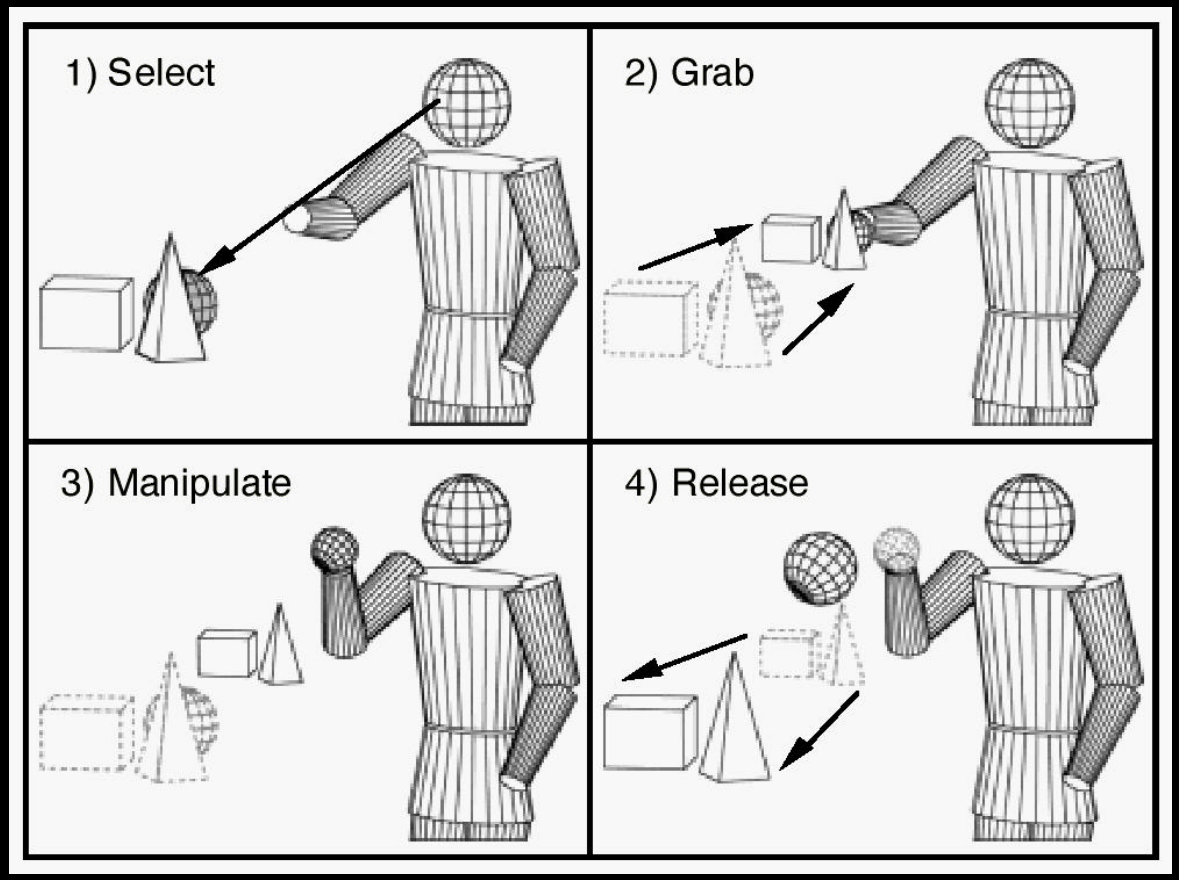
The “Framing Hands” Technique



Video

Pierce, Forsberg, et al., "Image Plane Interaction Techniques in 3D Immersive Environments," ***Proceedings of 1997 Symposium on Interactive 3D Graphics.***

Scaled World Grab (Mine)

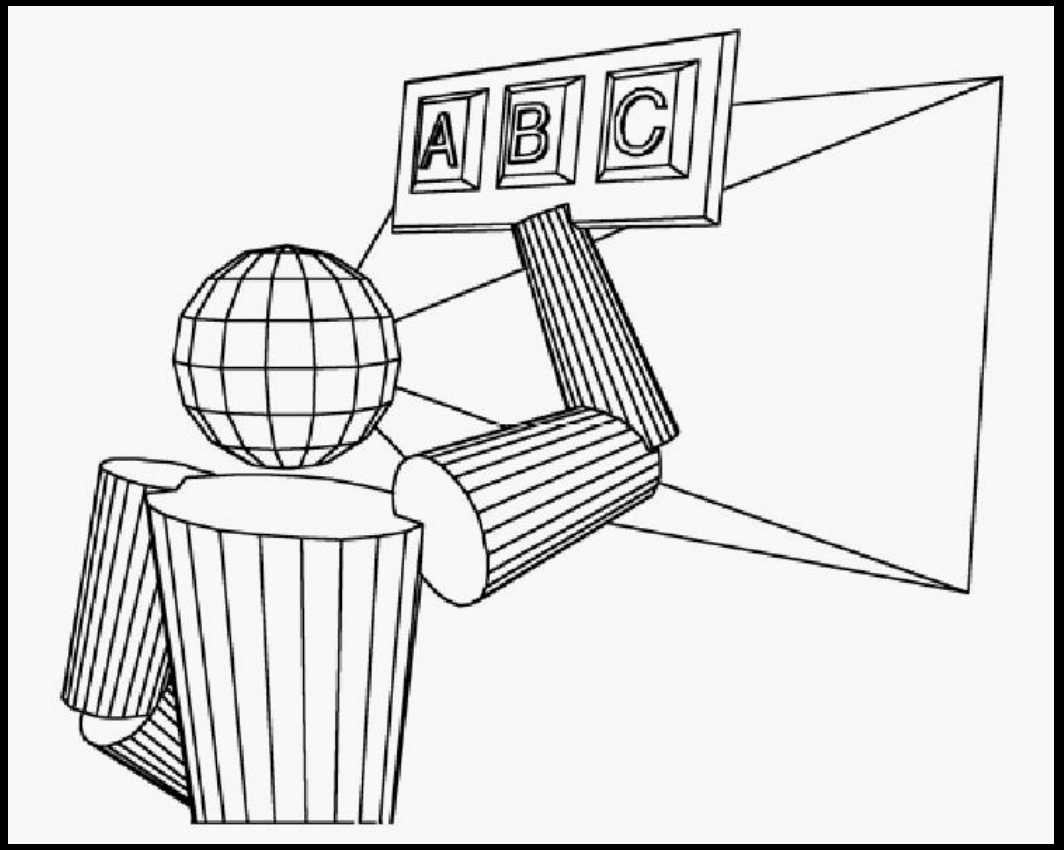


Interactive Numbers (Mine)

- Alphanumeric input difficult in VE
  - —Chord keyboards: hard to learn and retain
  - —Virtual keyboards: lack haptic feedback
  - —Speech recognition: almost works
- Technique for numeric input from within
- Doubles up on control-panel space usage
- Susceptible to tracking-system noise

Physical Mneumonics

Pull-Down Menus (Mine)



Pull-Down Menus (continued)

- No need for a dedicated menu button
- No ongoing scene occlusion
- Uses a common operation (grab) for activation
- Menus are easy to find/remember
- Experimental success with 3
  - —up left, center, and right

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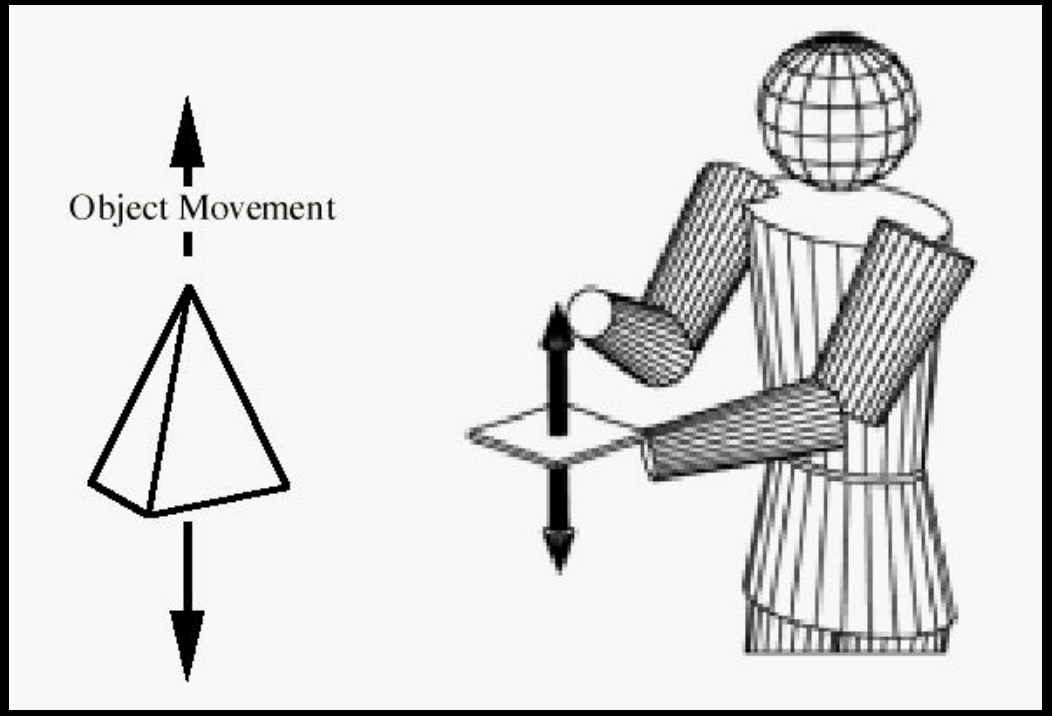
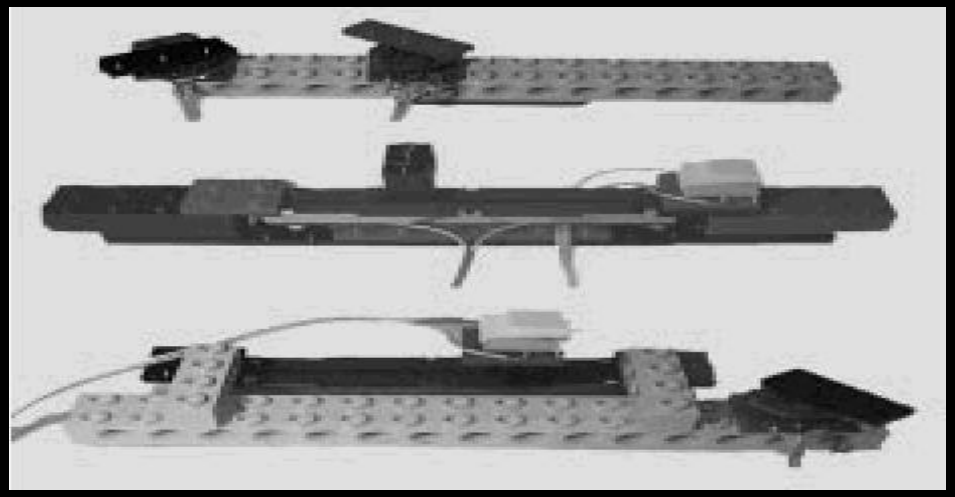
Hand-Held Widgets

- Simplifies interaction
- Remote control
- Visual clutter
- Obscuration
- Greater cognitive distance



The Lego™ Interface Toolkit (Brown)

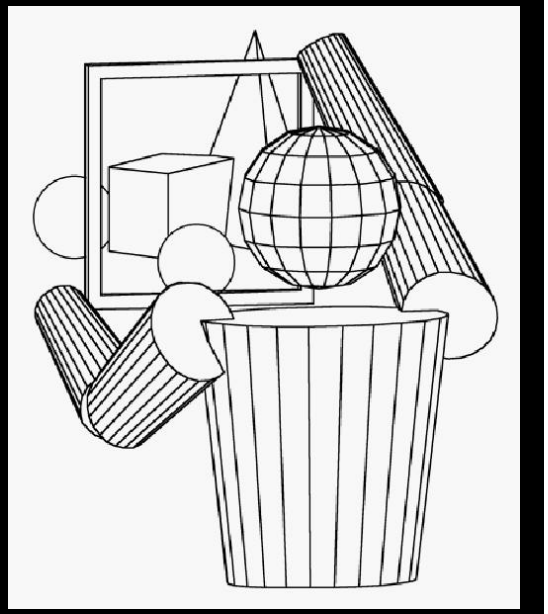


- **Inspired by UVA, ILM, and Henson Productions**
- **Rotational, linear, and push-button sensors**
- **Applied to air flow simulations for NASA's Space Shuttle**

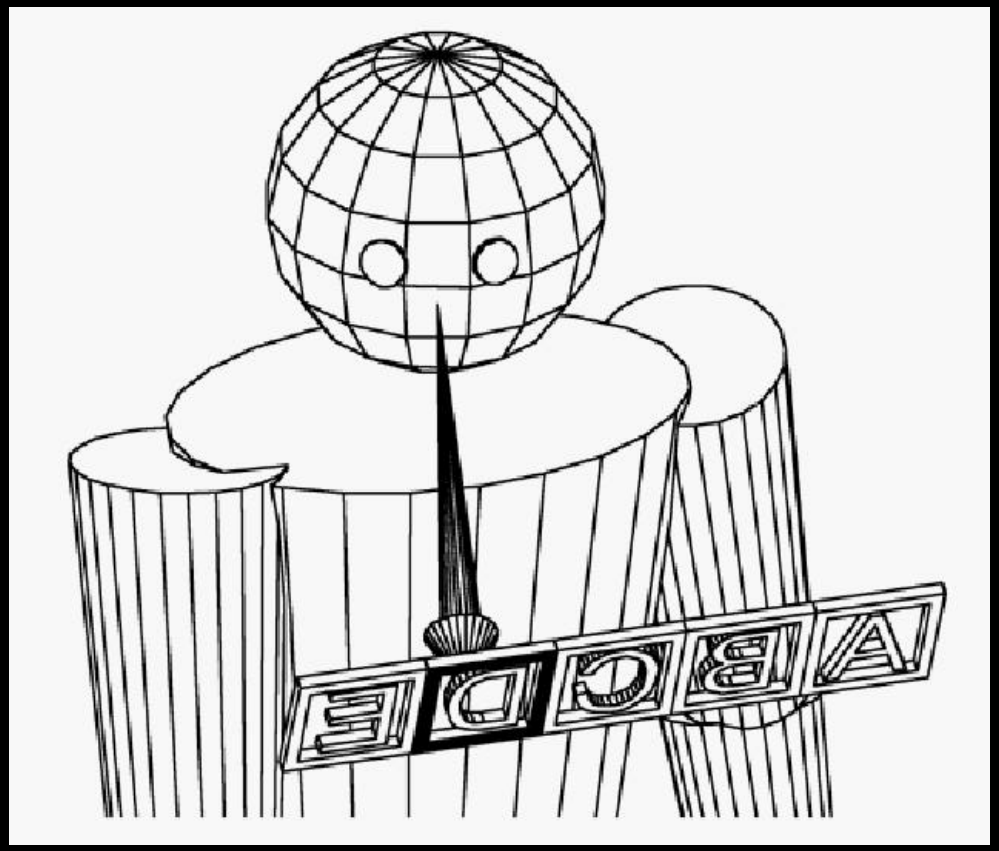
Gestural Actions

Head-Butt Zoom (Mine)

- Head-pose interaction control
- Users frequently switched between close-up detailed views and pulled-back global views.
- Augment intuitive gesture of leaning forward for a closer view.
- Hands free interaction.



Look-At Menus (Mine)



Overview **Principles** **Examples**

Video

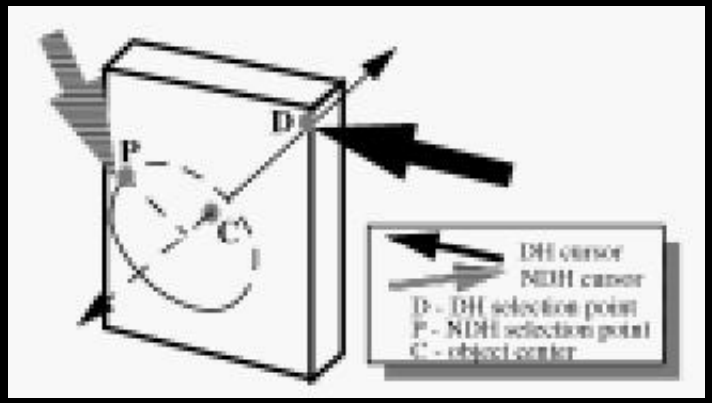
Mine, Brooks, and Sequin, "Moving Objects in Space: Exploiting Proprioception in Virtual Environment Interaction," *Proceedings of SIGGRAPH 97.*

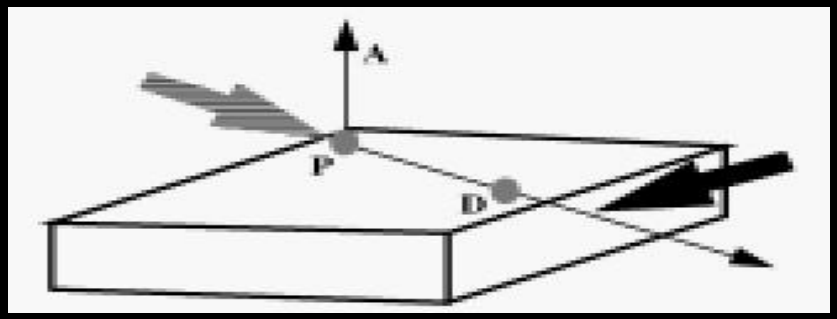
Two-Handed Interaction

- Intuitive form of interaction
  - —Dominant hand (DH) & non-DH (NDH)
- Proprioceptive feedback!
  - —Hand orientation
  - —Hand separation
  - —Relative hand position
- “1/2 the steps” of one-handed interaction

2-Handed Object Transformations (Brown & SGI)

- Translate & rotate
- Scaling
- Vertex, Face, Edge editing and manipulation





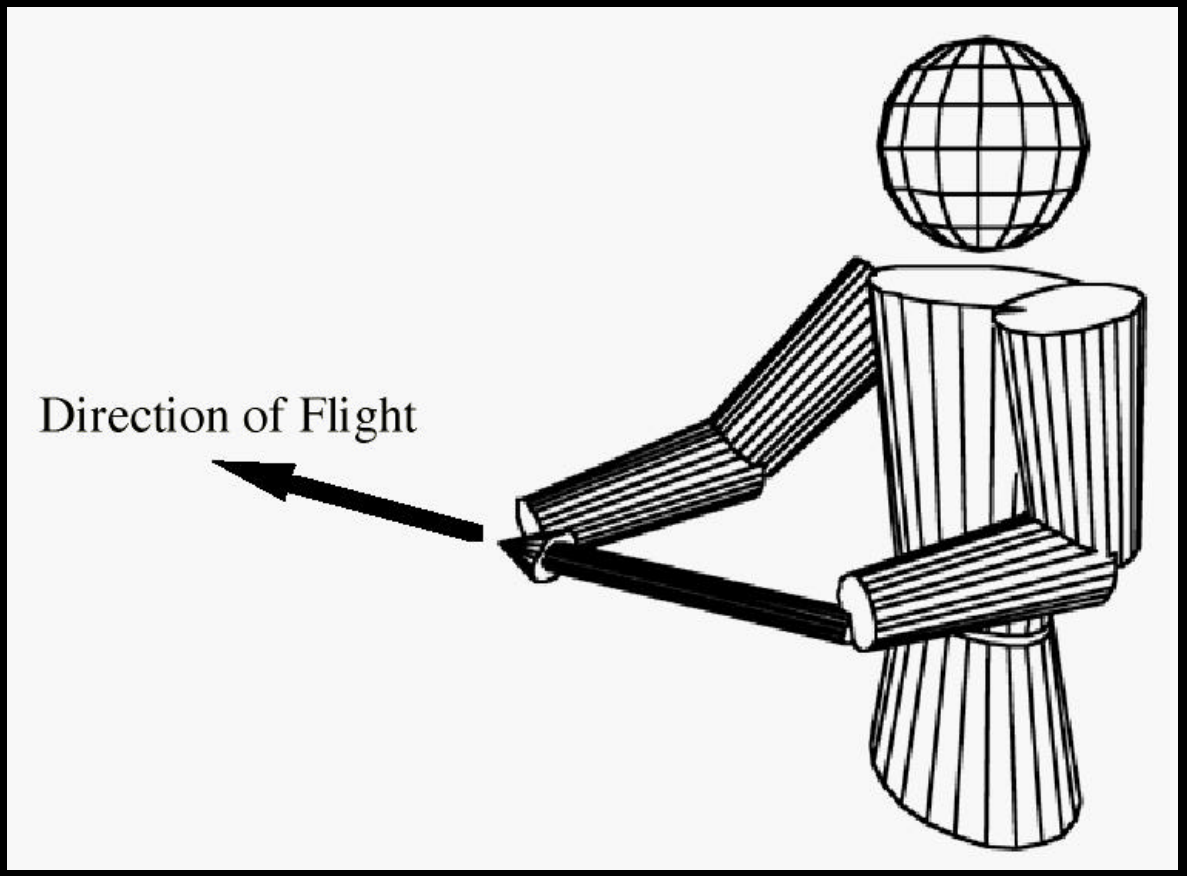
Other 2-Handed Techniques

- Camera Controls
  - —Camera and object manipulation
  - —Position, orientation, zoom
- Editing Operations
  - —Line segments, polylines
  - —Interactive shadows
  - —Grouping, ungrouping, duplication

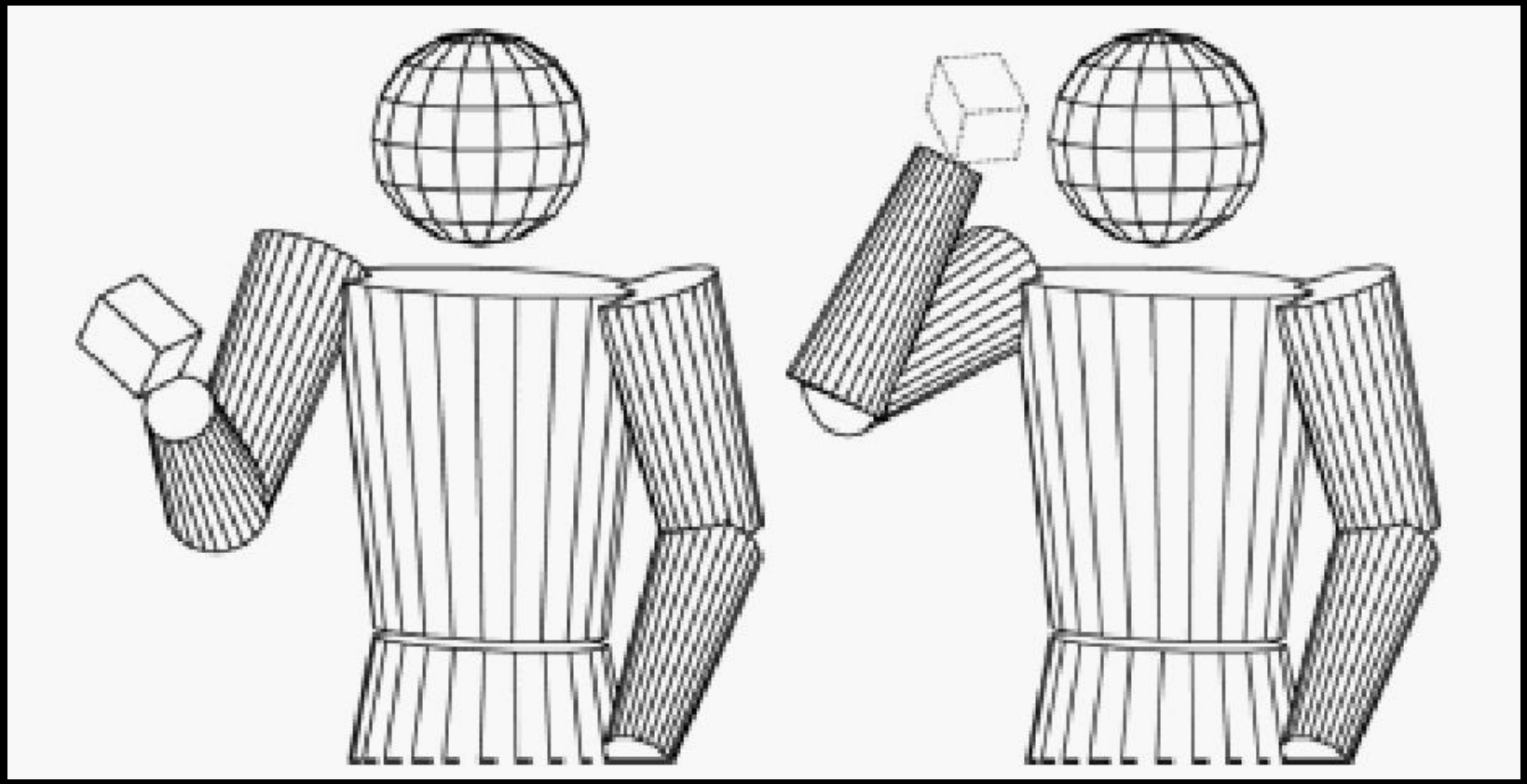
Video (if time permits)

Zeleznik, Forsbert, and Strauss, "Two Pointer Input for 3D Interaction," ***Proceedings of 1997 Symposium on Interactive 3D Graphics.***

Two-Handed Flying



Over-the-Shoulder Deletion (Mine)



Constrained Object Manipulation (Mine)

Constrained Object Manipulation

- Similar spirit as 2D draw constraints
- Purpose: Controlled object manipulation
  - —Allows for greater control of object manipulation
  - —Requires constrained motion modes or free motion plus object snap functions
- Object's degrees-of-freedom reduced via:
  - —Menu selectable interaction modes
  - —Widgets

Tradeoffs

- Widget design complicated by:
  - Affordances, cues, feedback, etc.
  - Visibility and reachability big problems
  - Visual clutter
- Constraints must be overridable with reset

Early Versions

- Based on early widget work at Brown University
  - —Widgets co-located with objects
- VR Version
  - —Difficult to select
  - —Difficult interaction
  - —Non-intuitive affordances