Interacting within Virtual Worlds

(based on talks by Greg Welch and Mark Mine)

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)

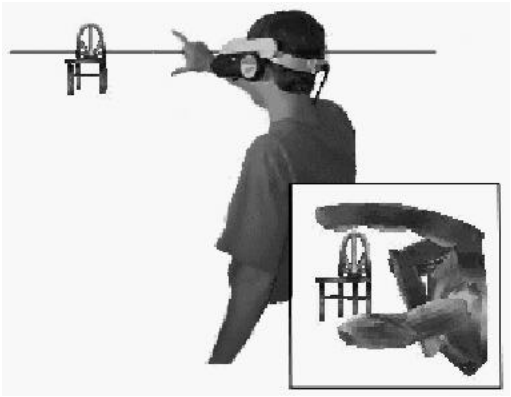
- **Head-pose interaction control**
- **Rapid orbital motion about a single object or groups of objects**
  - **—Object of interest remains in front of the user**
  - **—Head rotation causes the view to orbit about the object of interest**
  - **—No real-world analog yet highly effective**

Using Perspective

Image Plane Interaction (UVA, Brown, UNC)

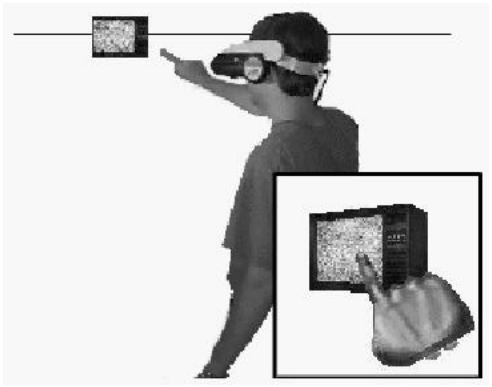
- **User interacts with 2D projections of 3D objects**
- **Multiple applications**
  - **—object selection and manipulation**
  - **—navigation/motion**

The “Head Crusher” Technique



Overview **Principles** **Examples**

The “Sticky Finger” Technique



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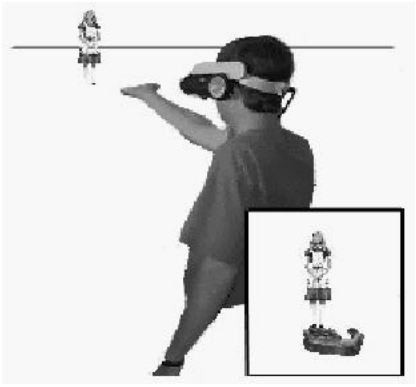
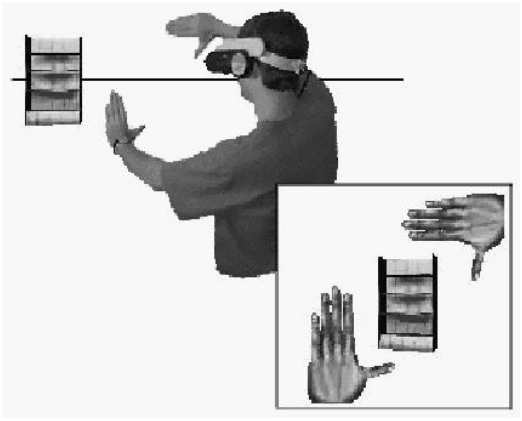
The “Lifting Palm” Technique



Overview **Principles** **Examples**

The “Framing Hands” Technique

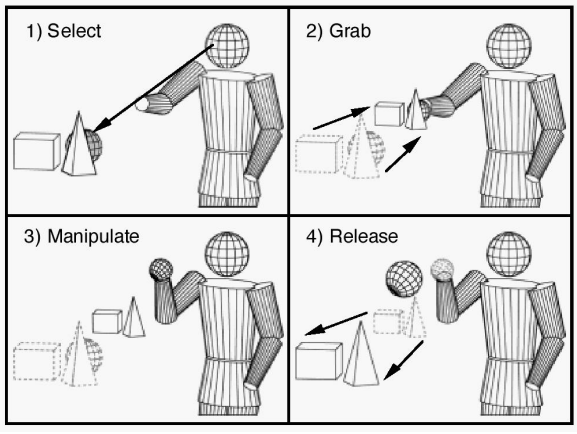


Overview **Principles** **Examples**

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)

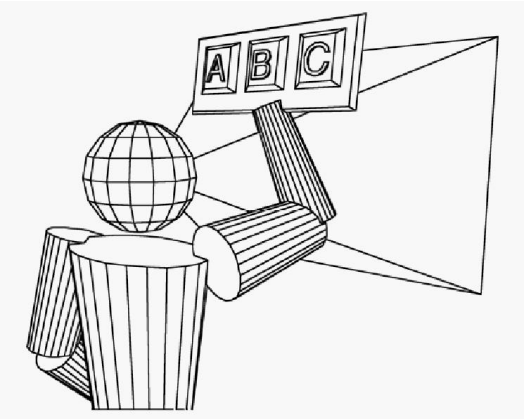


Interactive Numbers (Mine)

- **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)



Overview **Principles** **Examples**

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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Interactive Numbers (Mine)

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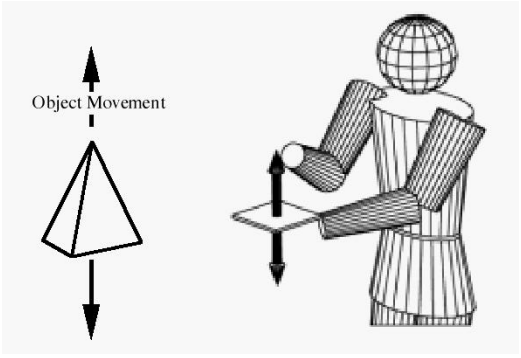
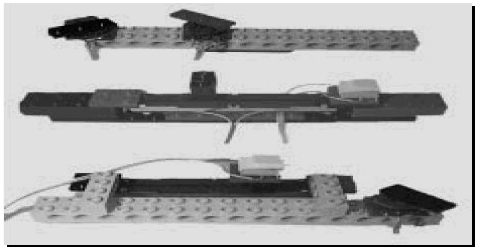
Hand-Held Widgets

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



The Lego™ Interface Toolkit (Brown)

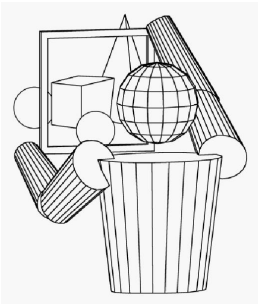


- **Inspired by UVA, ILM, and Henson Productions**
- **Rotational, linear, and push-button sensors**
- **Applied to air flow simulations for NASA's Space Shuttle**

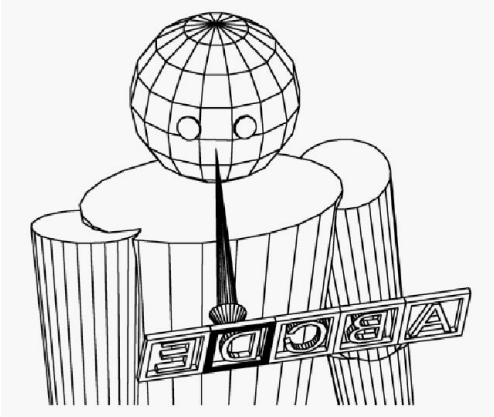
Gestural Actions

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)



Video

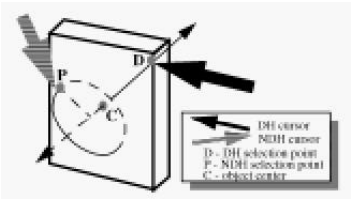
Mine, Brooks, and Sequin, "Moving Objects in Space: Exploiting Proprioception in Virtual Environment Interaction," *Proceedings of SIGGRAPH 97.*

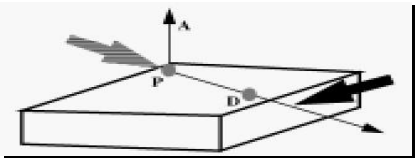
Two-Handed Interaction

- **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**





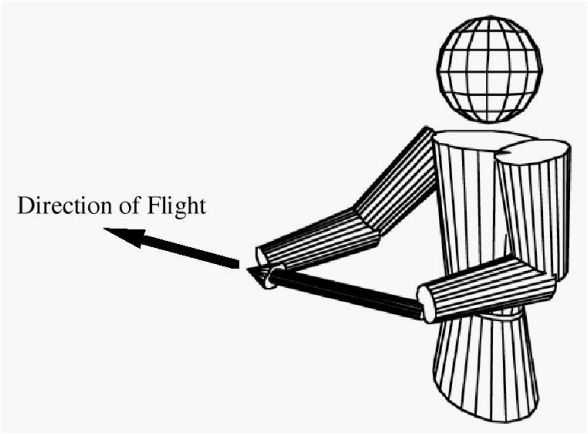
Other 2-Handed Techniques

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

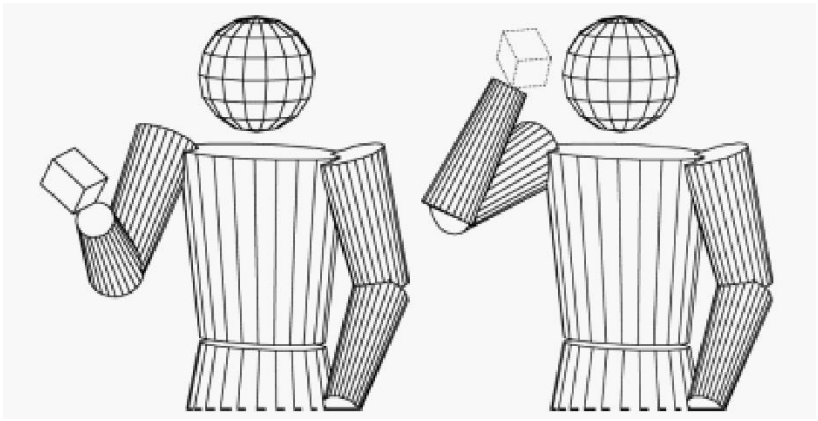
Video (if time permits)

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)



Overview **Principles** **Examples**

Constrained Object Manipulation (Mine)

Overview **Principles** **Examples**

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**