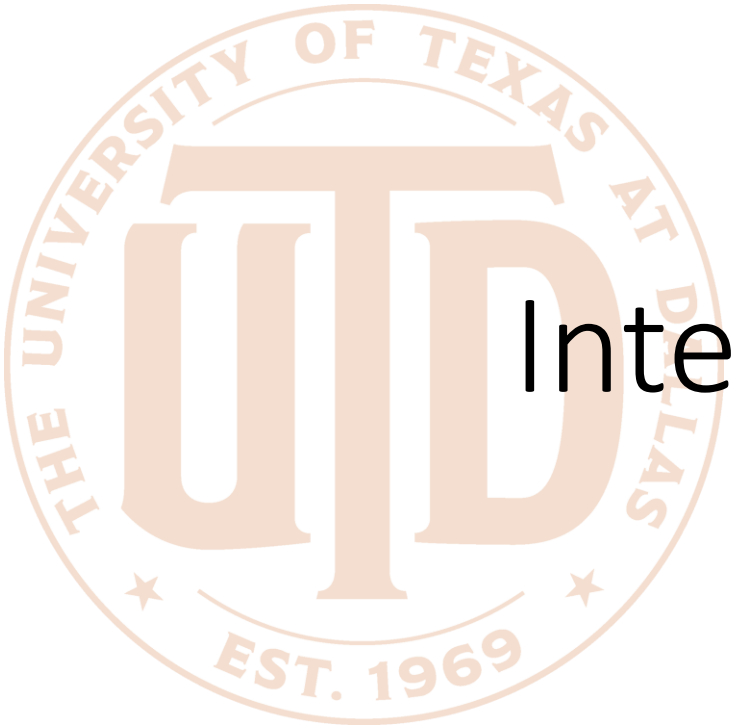


Interaction: Selection and Manipulation

CS 6334 Virtual Reality

Professor Yu Xiang

The University of Texas at Dallas

Some slides of this lecture are courtesy Jin Ryong Kim

Manipulation

- Complex sensorimotor relationships
- Evolution and experience
- Robot manipulation, a grand challenge
- We can make manipulation simple in VR
  - Remapping

Selection

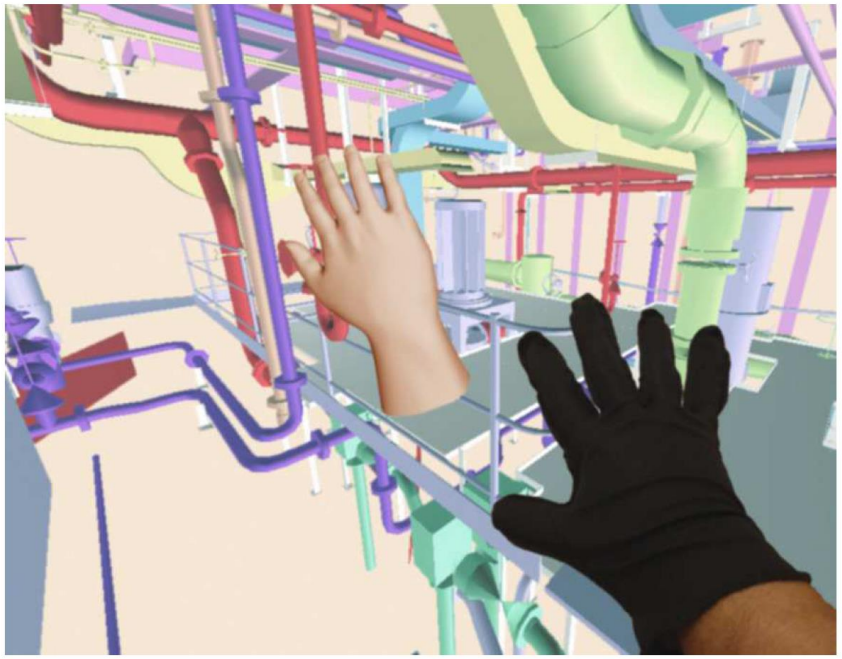
- The task of acquiring or identifying a particular object from the entire set of objects available

- In the real world
  - Picking up one object
  - Pointing to one object
  - Indicating one object by speech

Hand-based Grasping

- Track the position and orientation of the user's dominate hand

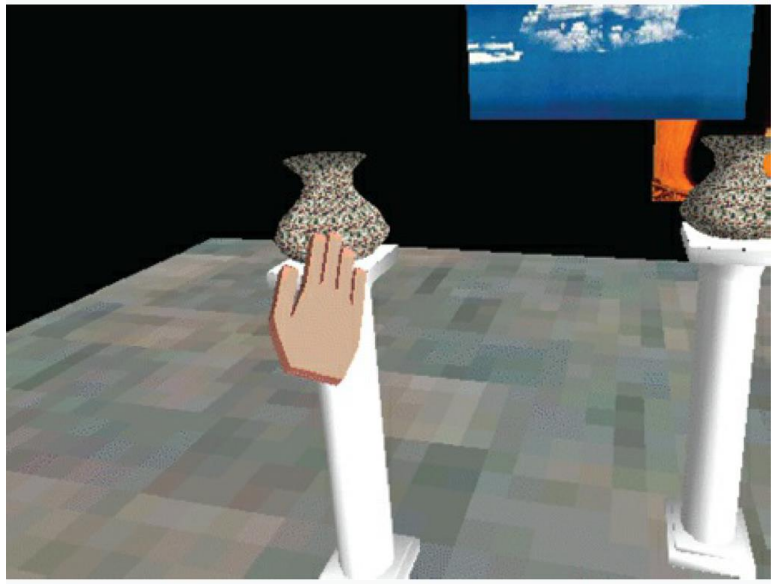
- Represent the user's virtual hand as a single-point effector



A Survey of 3D Object Selection Techniques for Virtual Environments. Computers and Graphics, Elsevier, 2013, 37 (3), pp.121-136.

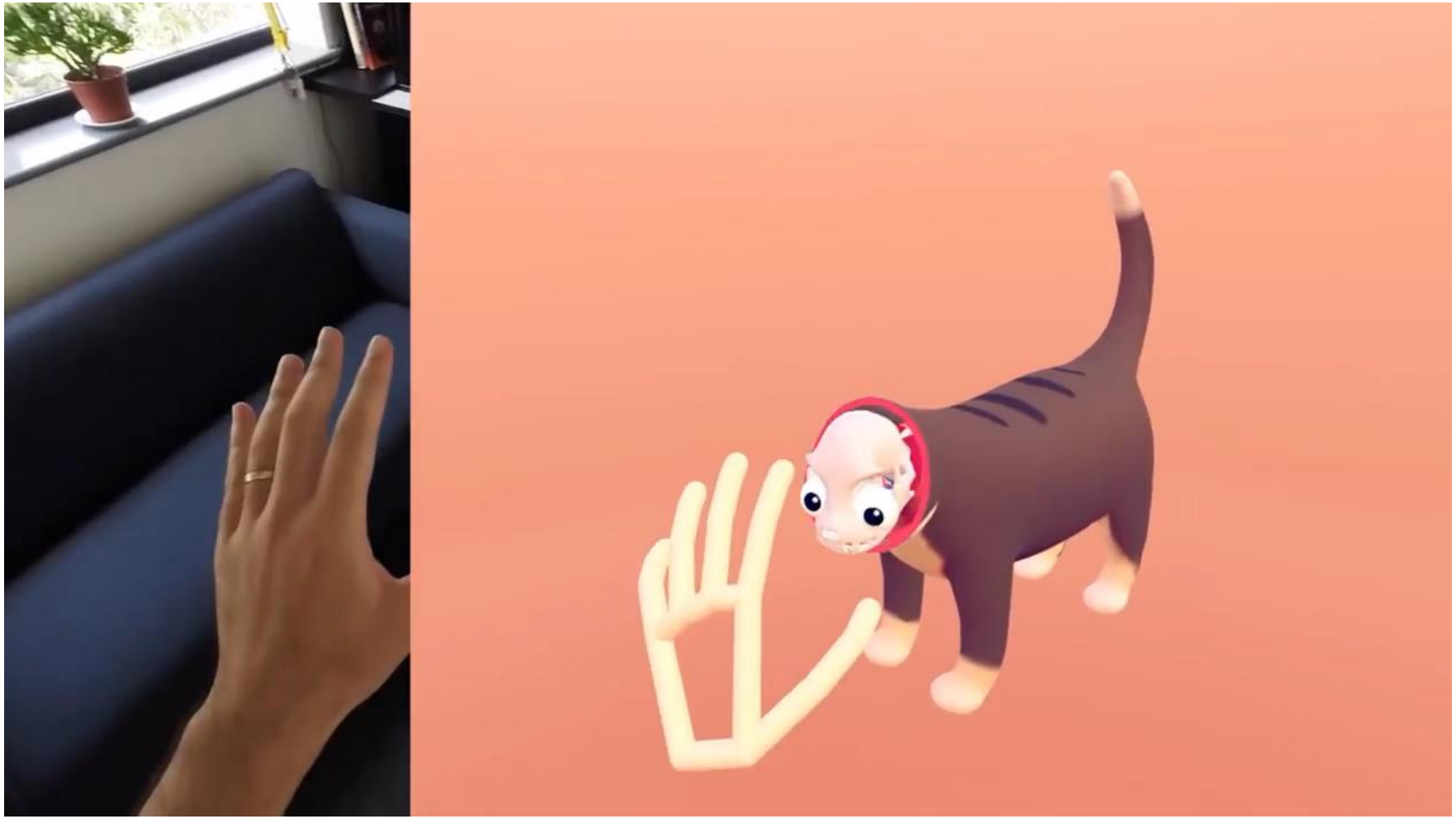
Simple Virtual Hand

- Uses a strict, one-to-one mapping of a 6-DOF hand tracker to a user's virtual hand
- Uses collisions to determine selection
- Most natural 3D manipulation technique
- Cannot select objects outside of the user's physical reach



https://s3dit.cs.uni-potsdam.de/detail/1

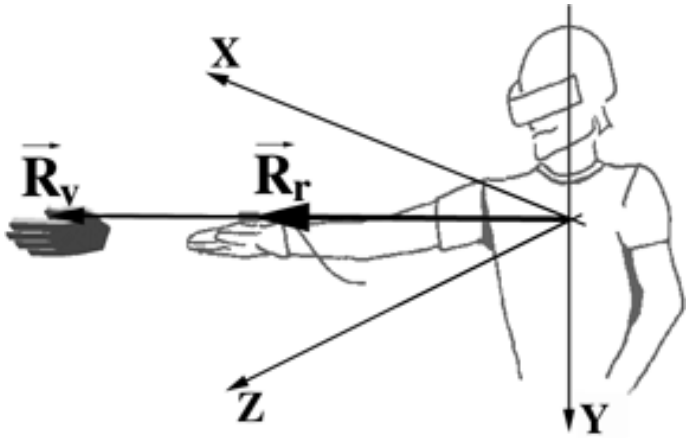
Simple Virtual Hand



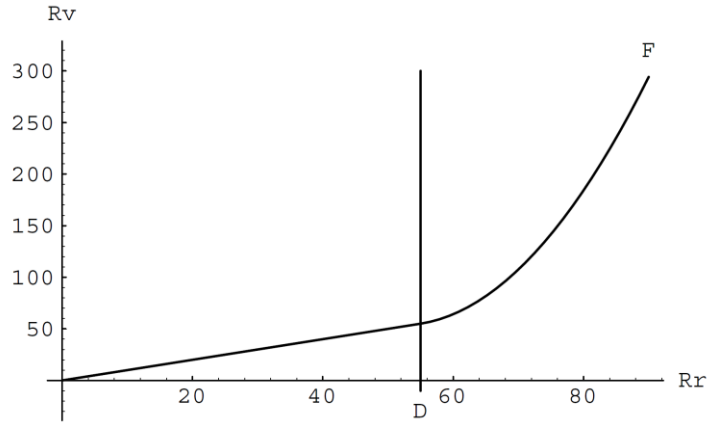
https://www.thisiscolossal.com/2018/06/virtual-reality-cat-explorer/

The Go-Go Interaction Technique

- Uses a threshold to separate near and remote interactions
- Within threshold, mapping is one to one
- Beyond threshold, a nonlinear mapping extends the virtual hand beyond the user's physical hand



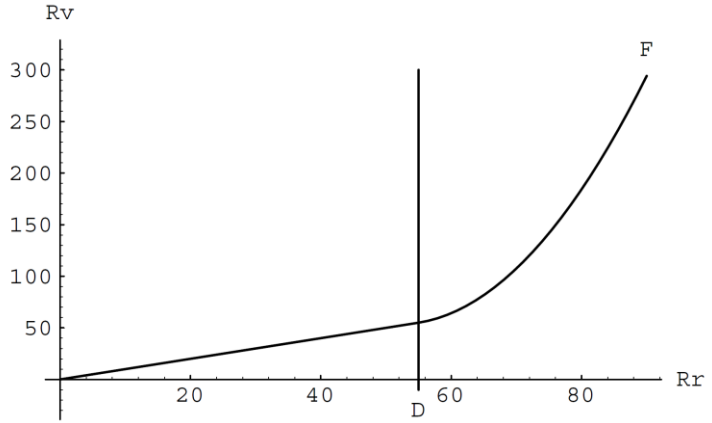
$$R_v = F(R_r) = \begin{cases} R_r & if\ R_r < D \\ R_r + k(R_r - D)^2 & otherwise \end{cases}$$



The Go-Go Interaction Technique

- Can select objects outside of the user's physical reach due to virtual hand extension

- Small objects are difficult to select beyond threshold due to nonlinear mapping



The Go-Go Interaction Technique: Non-linear Mapping for Direct Manipulation in VR.

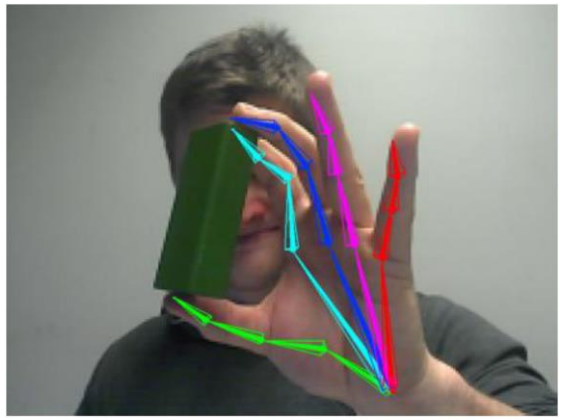
Poupyrev et al. ACM Symposium on User Interface Software and Technology (UIST) 1996.

The Go-Go Interaction Technique

https://youtu.be/WhA8n4IXeoY

Finger-based Grasping

- Track fingers, i.e., hand pose, in the real world
- Allow users to manipulate objects with more precision
- Challenges
  - Haptic feedback
  - Mismatch in hand pose between the virtual world and the real world, e.g., fingers are not allowed to penetrate the virtual objects



GANerated Hands for Real-Time 3D Hand Tracking from Monocular RGB. Mueller et al.

Rigid-body Fingers

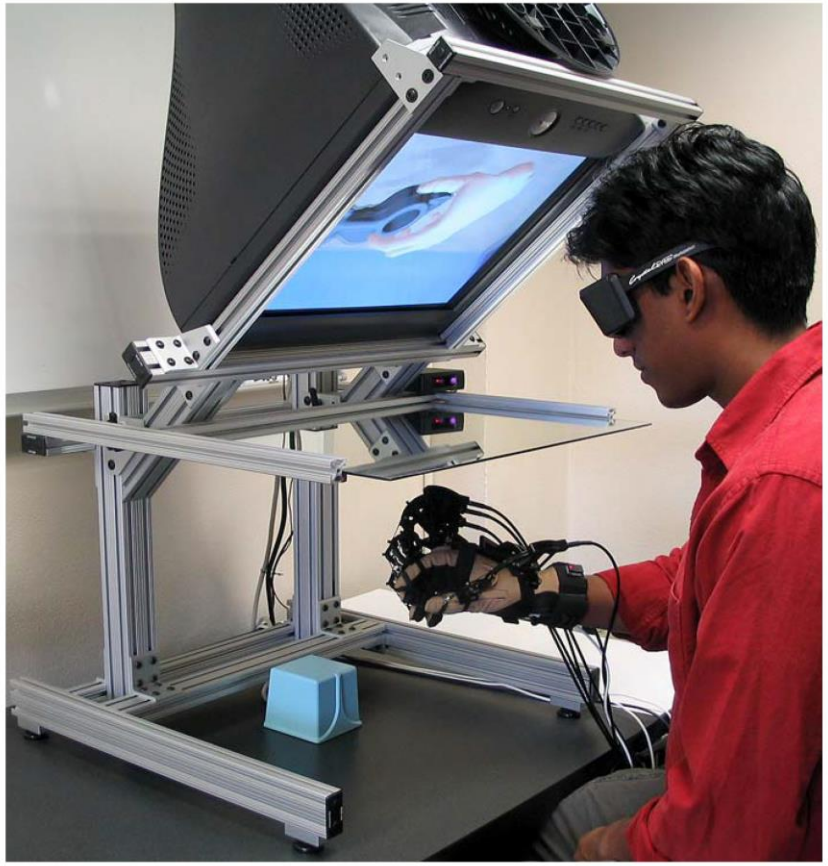


Figure 1: Desktop environment

22-sensor CyberGlove

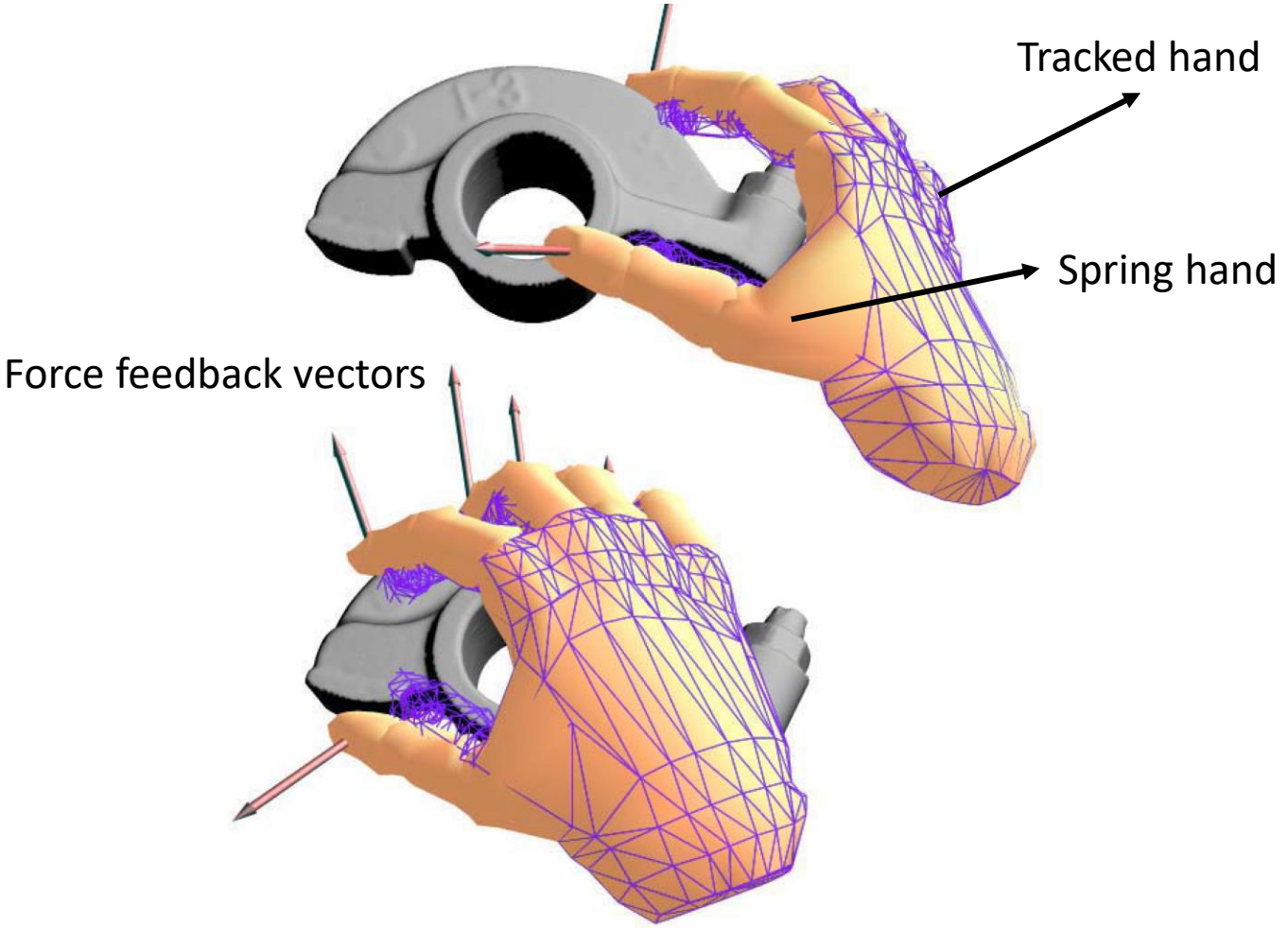
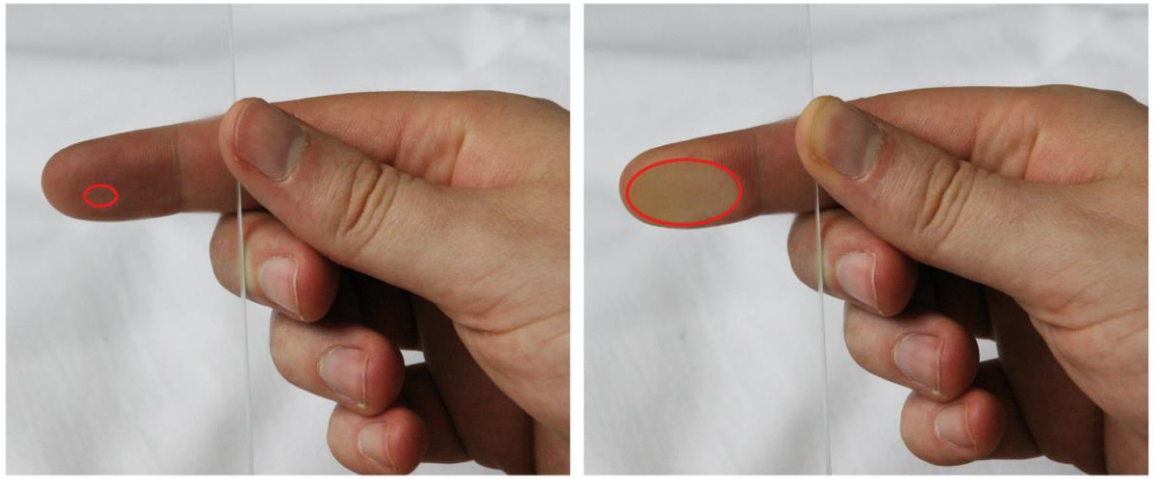


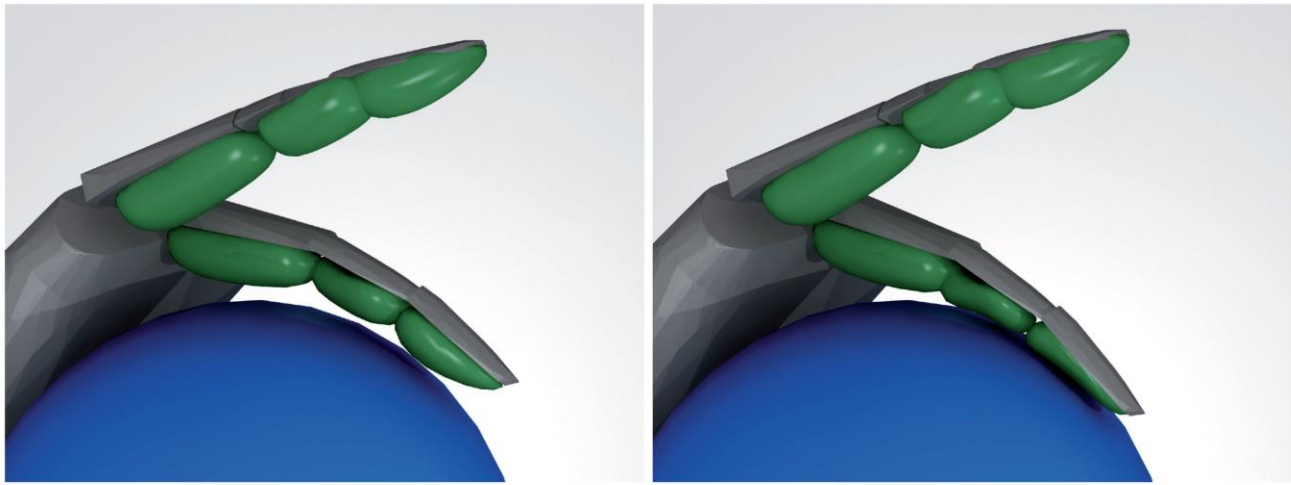
Figure 3: Grasps of a static rocker arm, showing tracked hand (mesh), spring hand (solid), and force feedback vectors

Realistic Virtual Grasping. Borst and Indugula. VR'05.

Soft-body Fingers



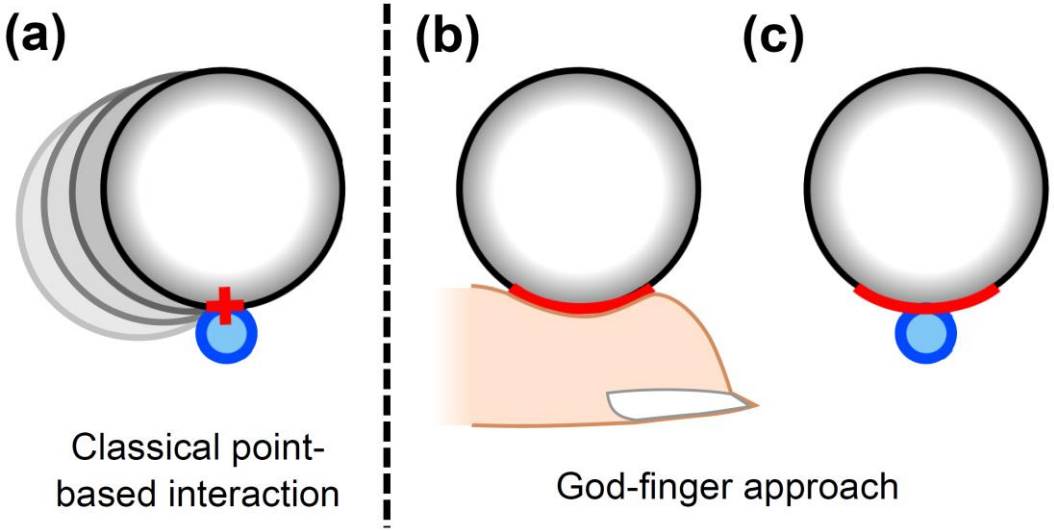
Increasing contact area with increasing contact force

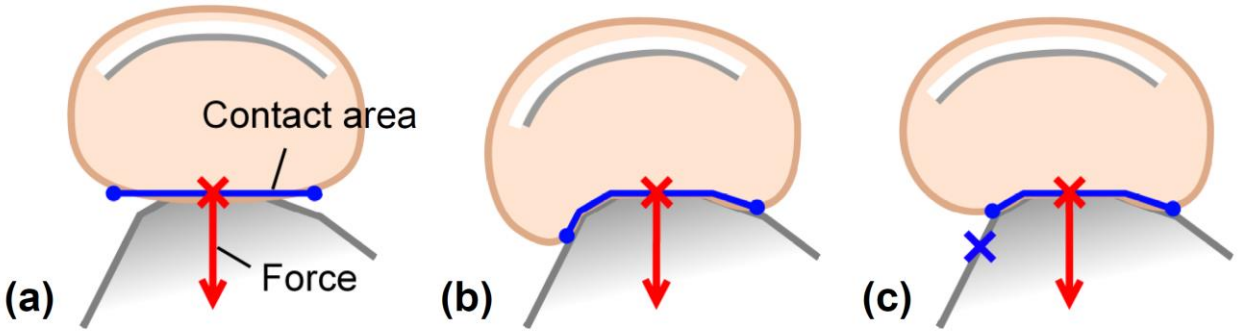


Developed hand model in lateral view while touching a virtual sphere. The deformation of finger-pads upon collision is clearly visible (right).

A Soft Hand Model for Physically-based Manipulation of Virtual Objects. Jacob and Froehlich, VR'11.

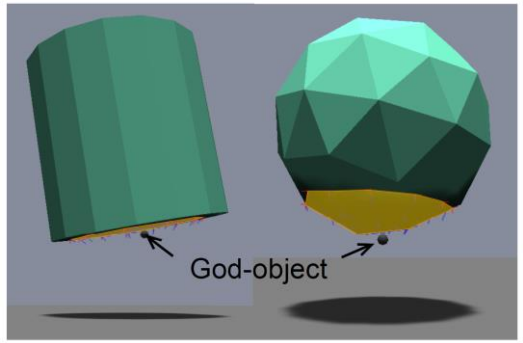
The God-Finger Method





(a) A contact area is generated as if the object was planar. **(b)** The contact area is then fit to the geometry of the object. **(c)** Odd deformations are prevented by adding an angular threshold between the contact normal and the face normals.

- Simulate a contact area from a single contact point determined by collision detection
- Usable in a rigid body physics engine



The god-finger method for improving 3D interaction with virtual objects through simulation of contact area. Talvas et al. 3DUI'13

Pointing

- Allow users to select and manipulate objects beyond their physical reach by pointing at the object

- Pro: Requires less physical hand movement from the user, better selection performance

- Con: expressive 6 DOF manipulation is impossible with pointing

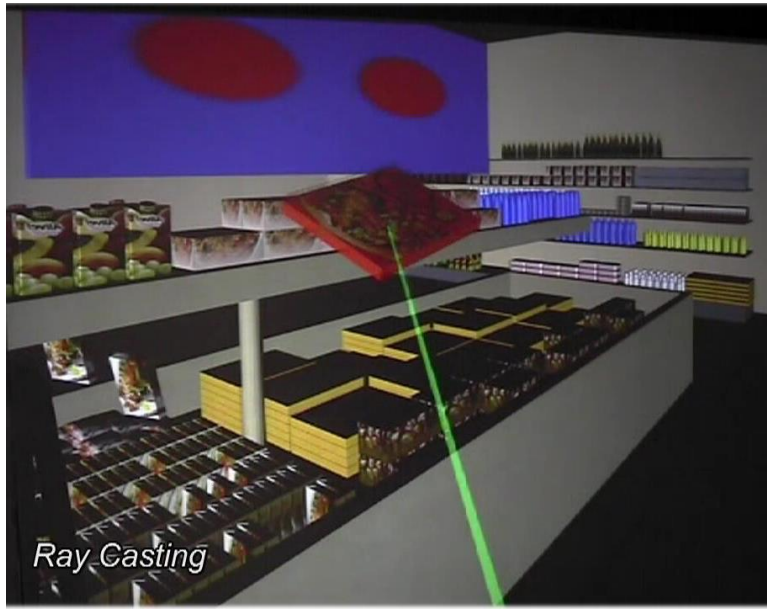
Pointing

- Vector-based Pointing
  - Uses a vector to determine what object is manipulated
  - Ray-casting
  - Fishing reel
  - Image-plane pointing

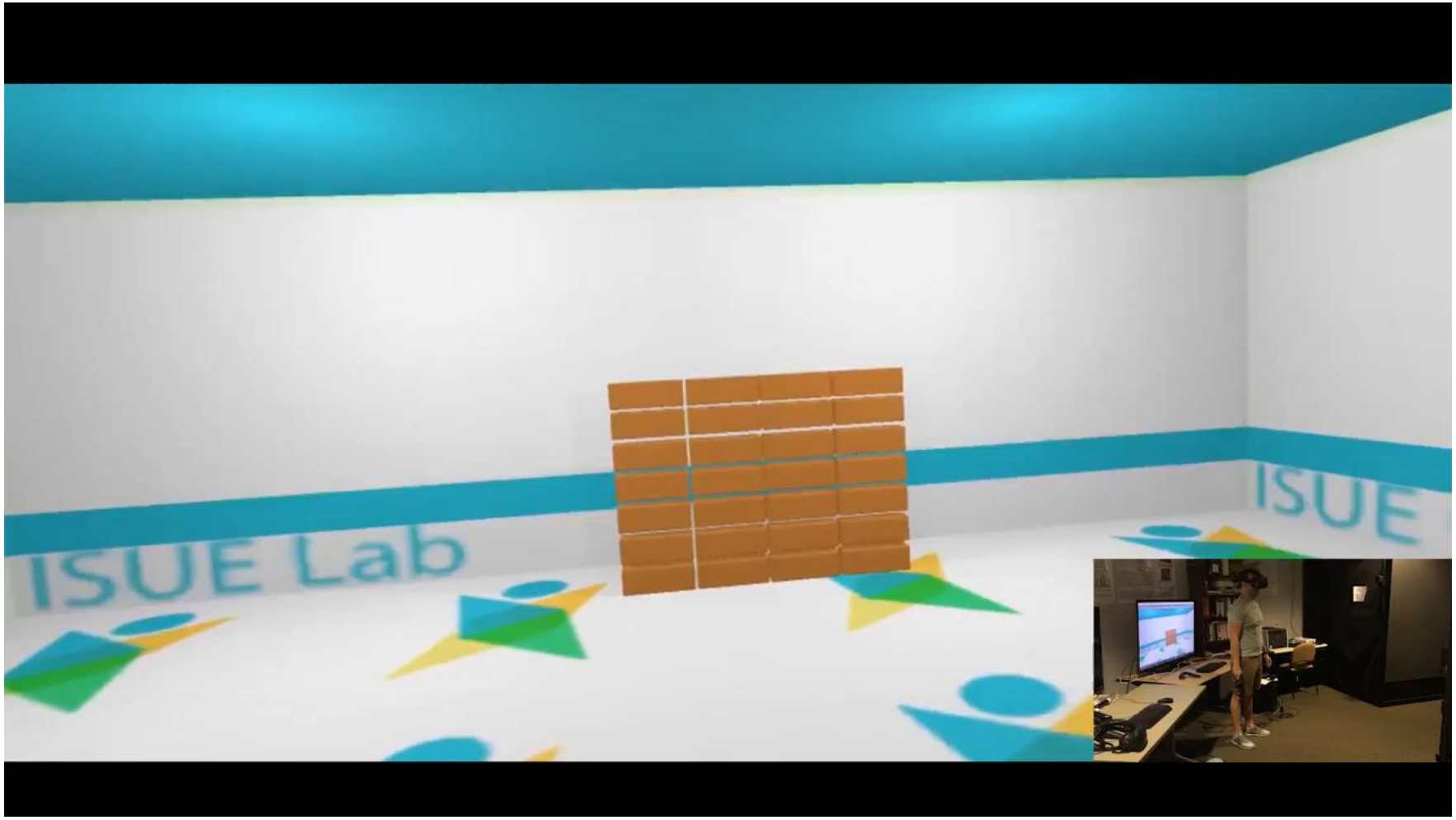
- Volume-based Pointing
  - Uses a volume to determine what is manipulated
  - Flashlight
  - Aperture selection
  - Sphere-casting

Ray-Casting

- Uses the forward vector of a 6-DOF input device
- Uses an infinite ray to visually represent vector
- Uses a button to select first intersected object
- Can select objects outside of the user's physical reach due to the infinite vector
- Small or faraway objects are difficult to select
- Cannot select occluded objects



Ray-Casting



Fishing Reel

- Extends the basic concept of ray-casting
- Uses one button to push a selected object away
- Uses another button to bring a selected object closer

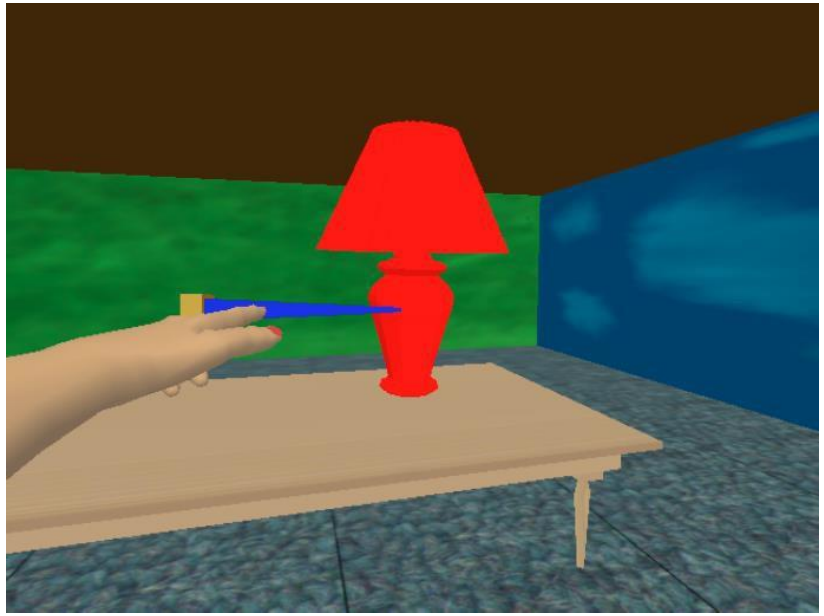
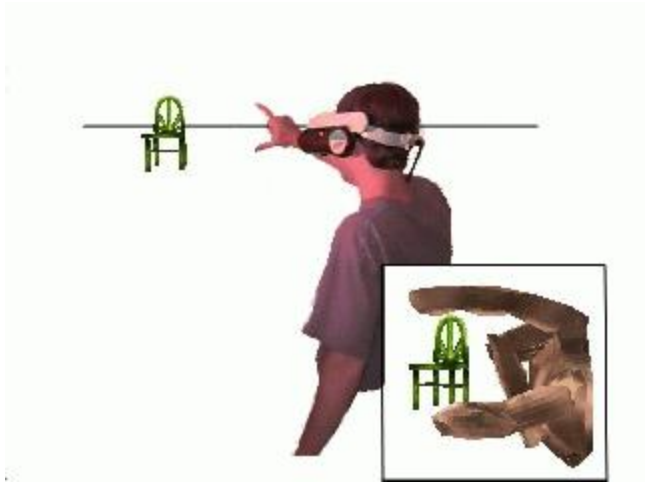
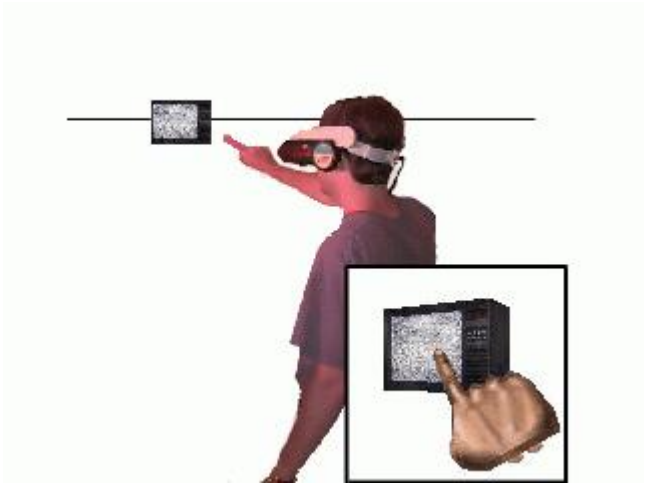


Image-Plane Pointing

- Projects the 3D scene on a virtual image plane located in front of the user
- The user selects and manipulates 3D objects by touching and manipulating their 2D projections

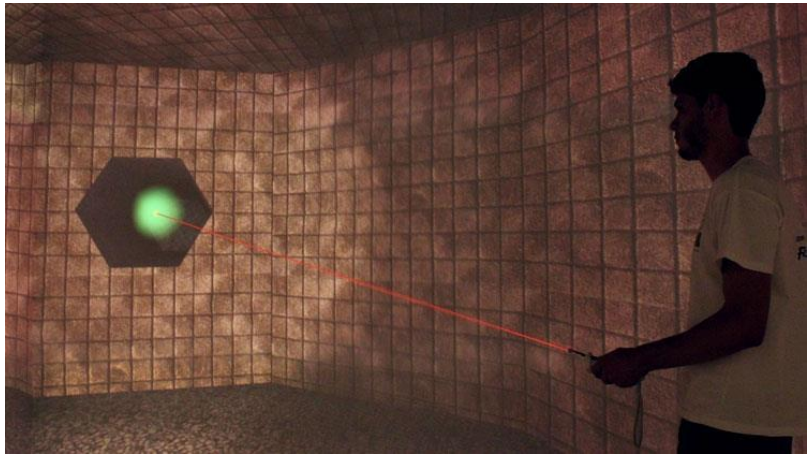




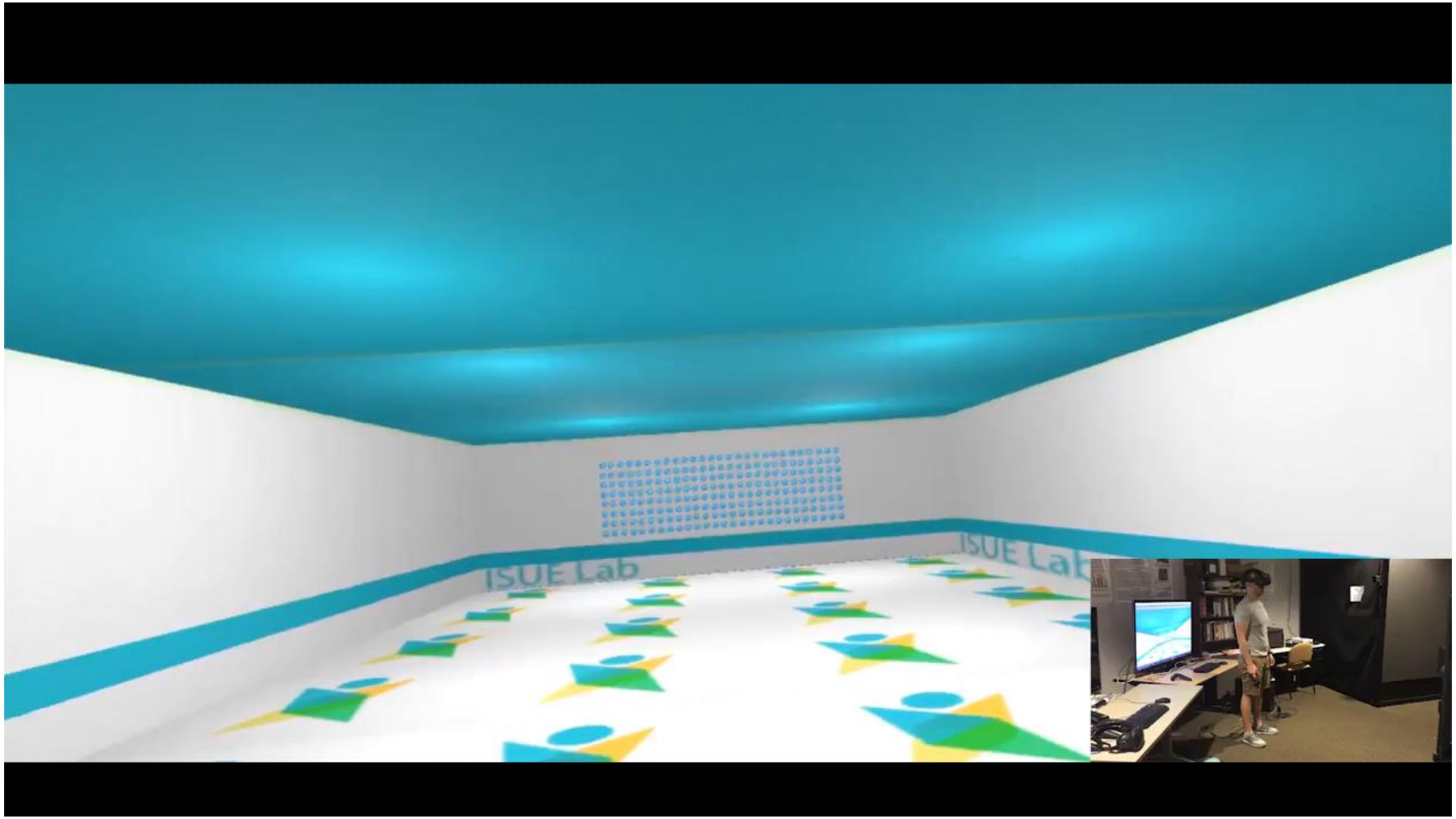
http://www.cs.cmu.edu/~stage3/publications/97/conferences/3DSymposium/HeadCrusher/

Flashlight

- Uses a cone to select objects within the volume
- Selects the object closest to the centerline
- If there's a tie, it selects the object closest to the cone's origin (i.e., the device)
- Requires less precision than ray-casting
- Can be difficult to use when multiple objects are present

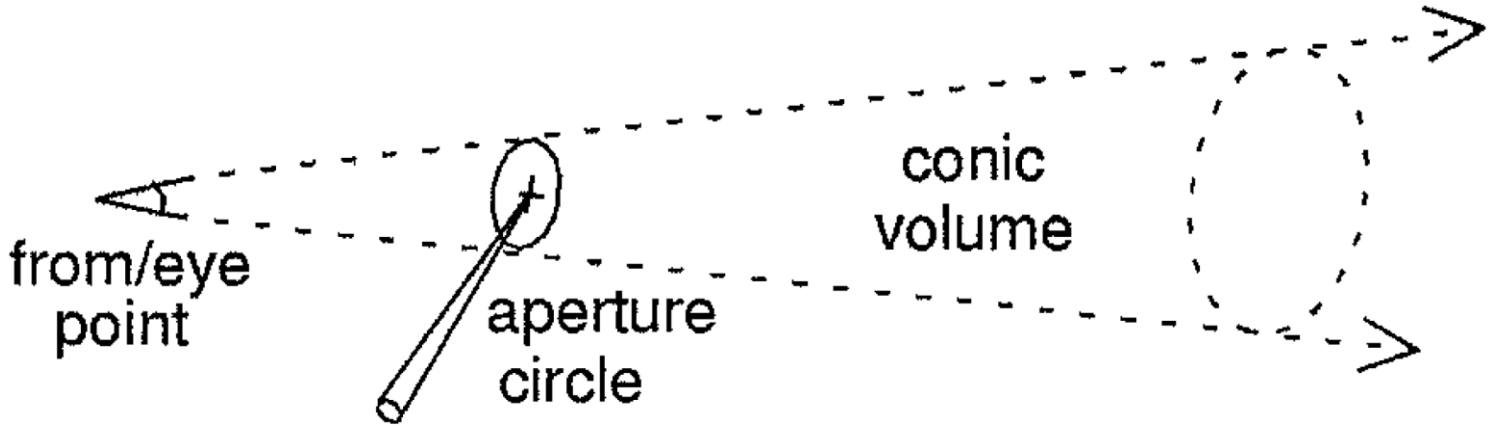


Flashlight



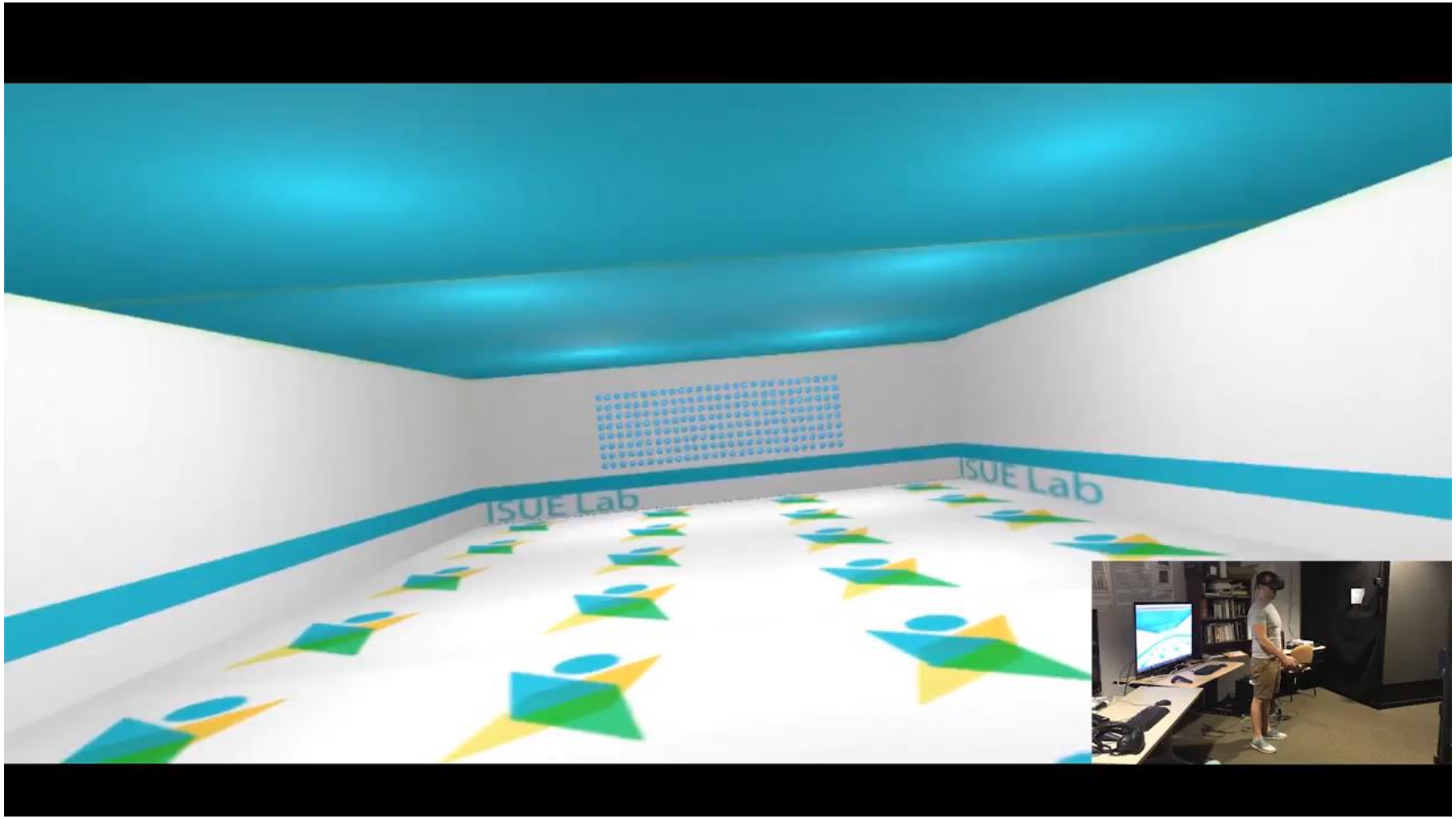
Aperture Selection

- Extends the basic concept of flashlight
- Allows the user to control the spread of the cone selection volume
- Allows the user to disambiguate among multiple objects by twisting the selection volume



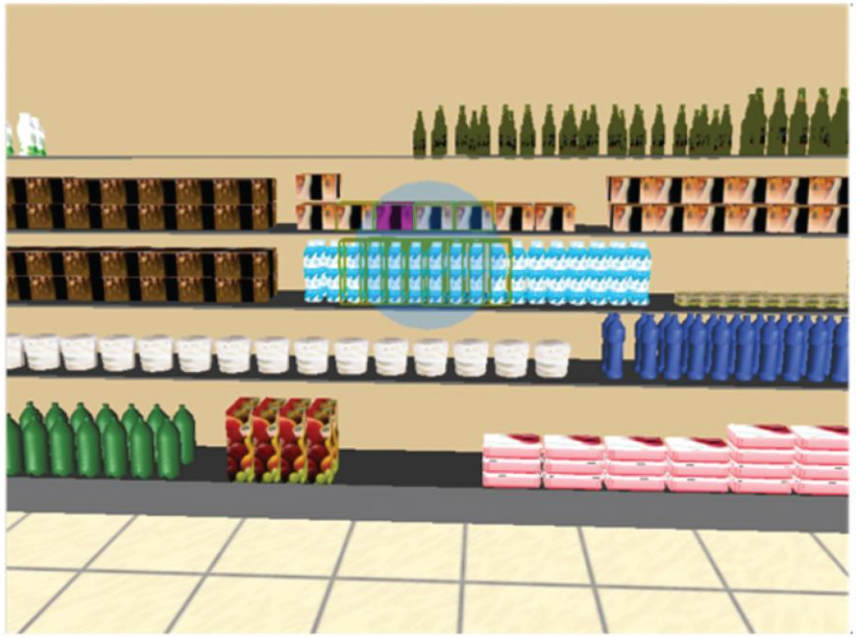
Aperture Based Selection for Immersive Virtual Environments. Forsberg et al. UIST'96

Aperture Selection



Sphere-Casting

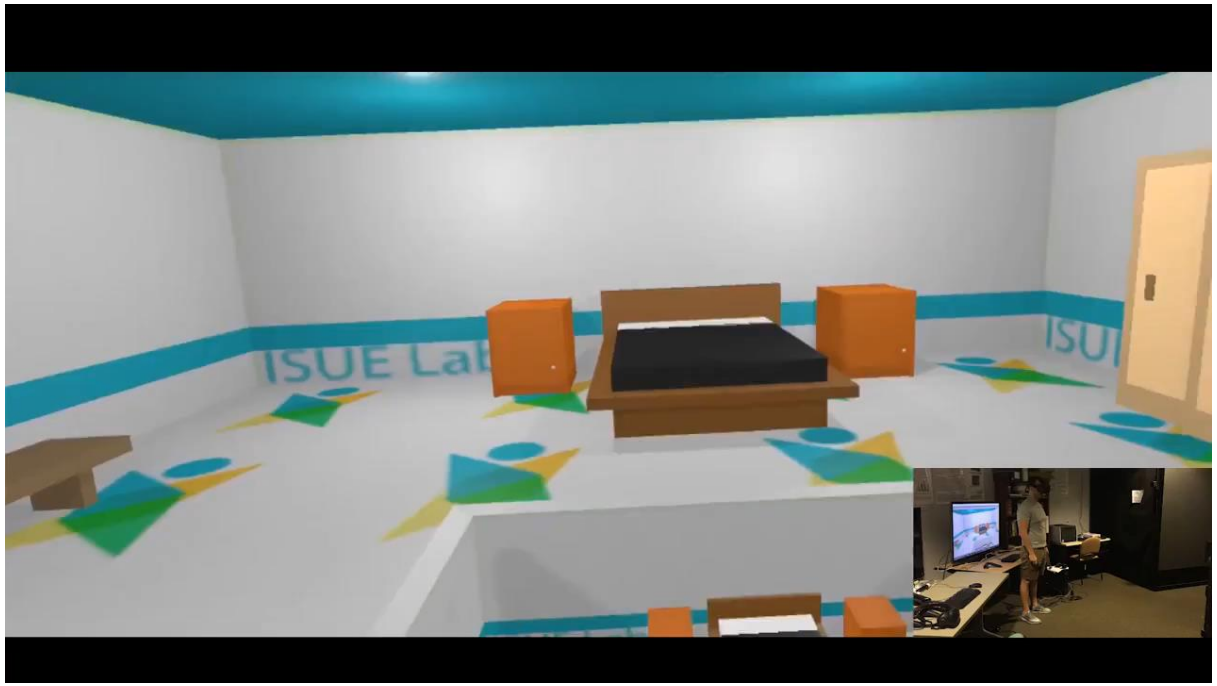
- A modified version of ray-casting
- Casts a sphere onto the nearest intersected surface



Rapid and accurate 3D selection by progressive refinement. Kopper et al. 3DUI'11.

Indirect Approaches

- Allow users to manipulate virtual objects without directly interacting with them
- Example, world in miniature



Bimanual Approaches

- Allow users to manipulate objects using both hands

Hybrid Approaches

- Combine multiple techniques to provide interactions
- Hand-centered Object Manipulation Extending Ray-casting (HOMER)
  - Uses ray-casting for selection
  - Uses Go-Go-like virtual hand for manipulation

Summary

- Grasping metaphors
- Pointing metaphors
- Indirect metaphors
- Bimanual metaphors
- Hybrid metaphors

Further Reading

- Section 10.3, Virtual Reality, Steven LaValle

- Chapter 7, 3D User Interfaces: Theory and Practice, LaViola et al.