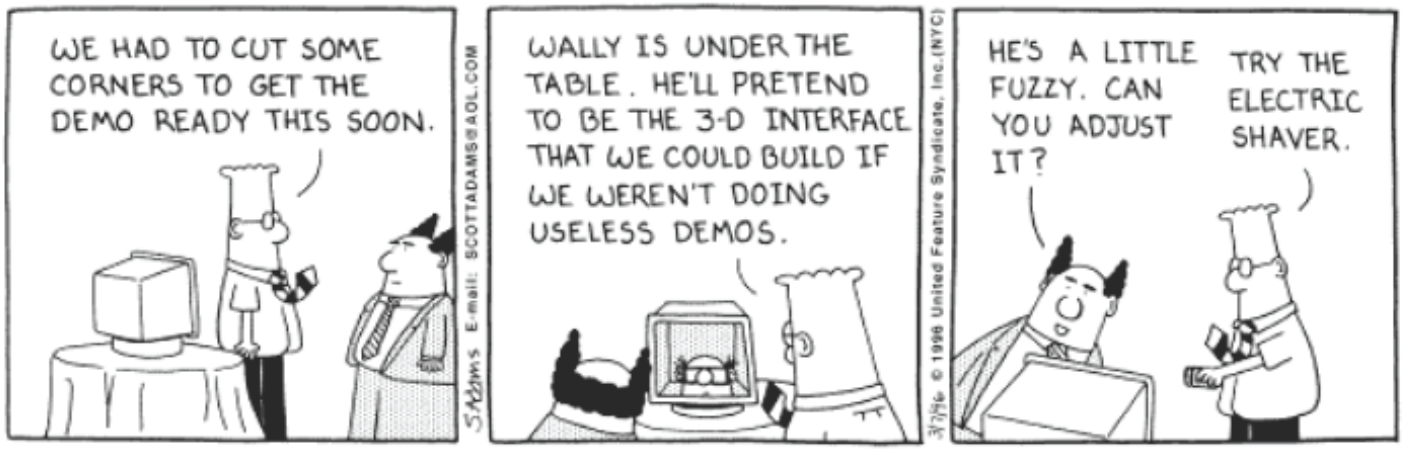
3D Interaction Techniques

Hannes Kaufmann

Interactive Media Systems Group (IMS)

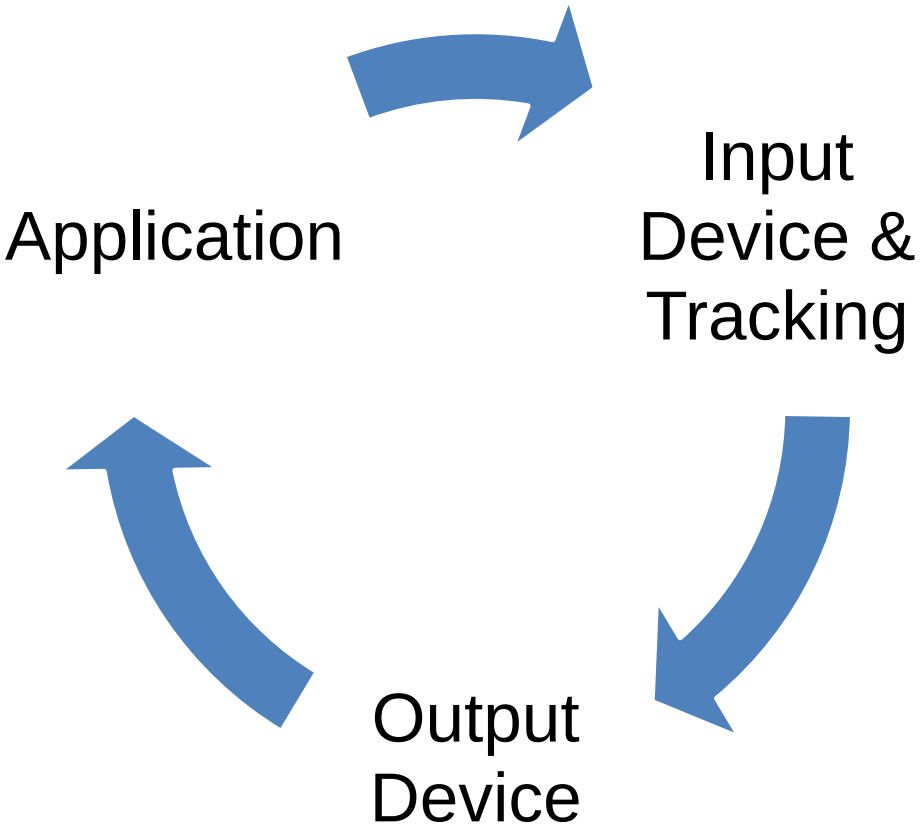
Institute of Software Technology and Interactive Systems

Based on material by Chris Shaw, derived from Doug Bowman's work



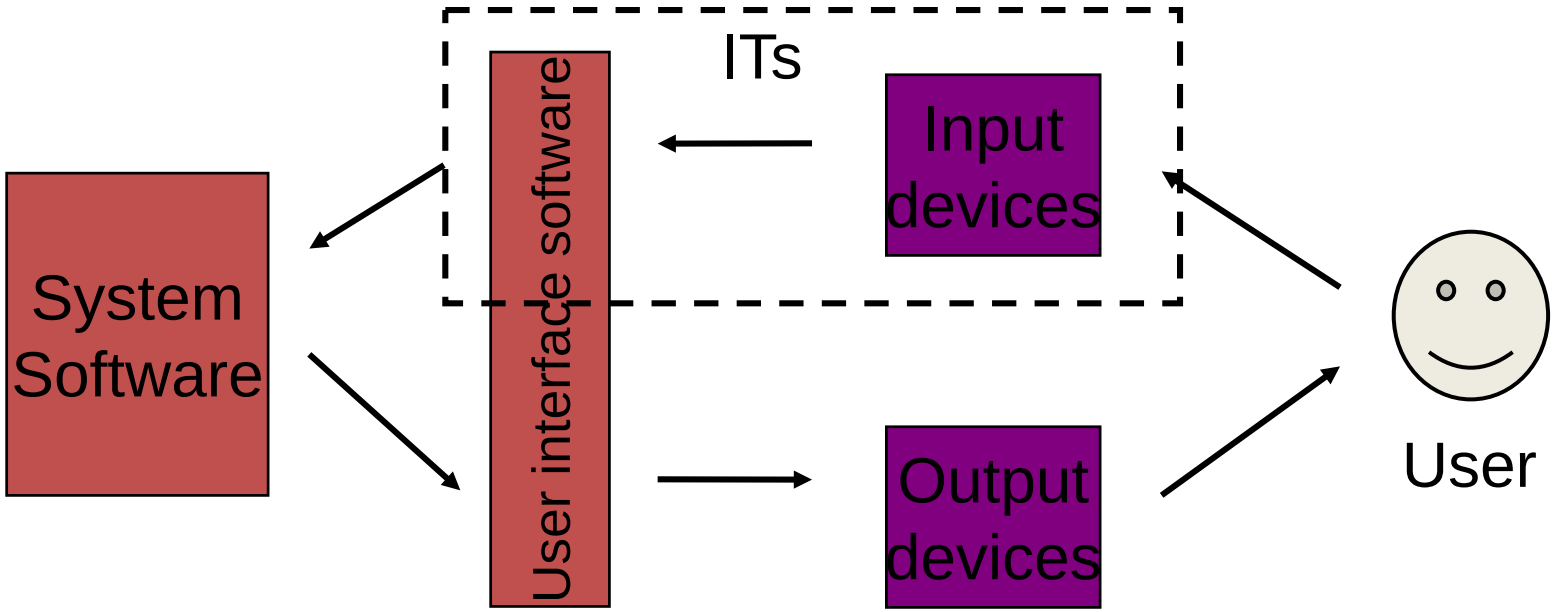
Hannes
Kaufmann

Why 3D Interaction?



3D Interaction Techniques

- Methods used to accomplish a given task via the interface
  - Hardware components: Input & Output devices
  - Software components = *control-display mappings*: translating information from input devices to system actions -> display to user

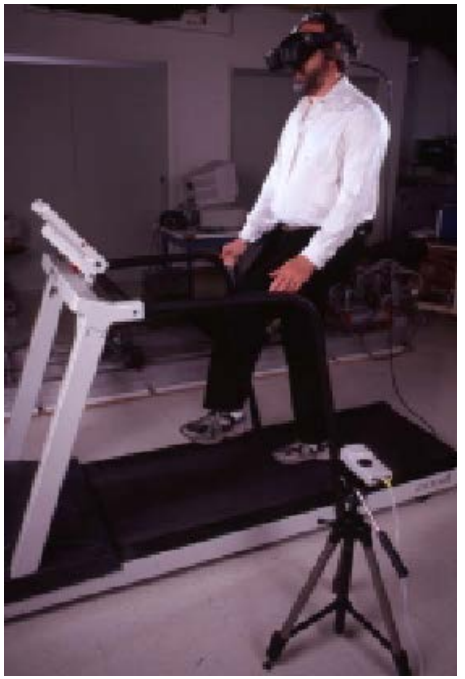


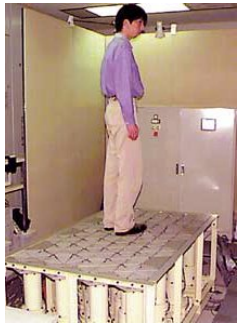
The Interface Challenge – The best of both Worlds

- Naturalism: make VE & interaction work exactly like real world.
- Magic: give user new abilities
  - Perceptual
  - Physical
  - Cognitive

The Interface Challenge

- Will the cognitive overhead required to use the interface distract users from the intended tasks and goals?





Goals of Interaction Design

- Performance
  - efficiency
  - accuracy
  - productivity
- Usability
  - ease of use
  - ease of learning
  - user comfort
- Usefulness
  - users focus on tasks
  - interaction helps users meet system goals

- But, most current VE apps either
  - are not complex interactively, or
  - have serious usability problems

What makes 3D Interaction difficult?

- Spatial input
- Lack of constraints
- Lack of standards
- Lack of tools
- Lack of precision
- Layout more complex
- Fatigue

Universal Interaction Tasks

- Selection: picking object(s) from a set
- Manipulation: modifying object properties (esp. position/orientation, shape, color,…)
- Navigation
  - Travel – motor component
  - Wayfinding – cognitive component; decision making
- System control: changing system state or mode
- Symbolic input (covered in Input Devices Part 1)
- [Modeling & Other tasks (create and modify 3d Obj.)]

Selection & Manipulation

Goals of Selection:

- Indicate action on object
- Make object active
- Travel to object location
- Set up manipulation

Isomorphic vs. Nonisomorphic

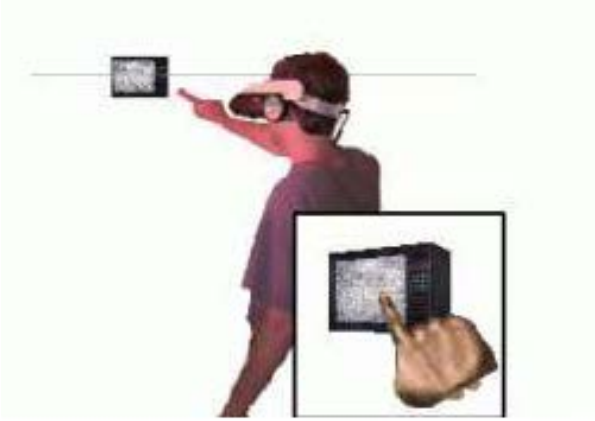
- Isomorphic:
  - strict, geometrical 1:1 correspondence between physical <-> virtual world
  - Most natural
  - Imitates physical reality and its limitations
- Nonisomorphic:
  - Magic virtual tools that extend working volume or arm length
  - Depends on application
  - Majority of manipulation techn. nonisomorphic

Selection performance

- Variables affecting user performance
  - Object distance from user
  - Object size
  - Density of objects in area

Common Selection Techniques

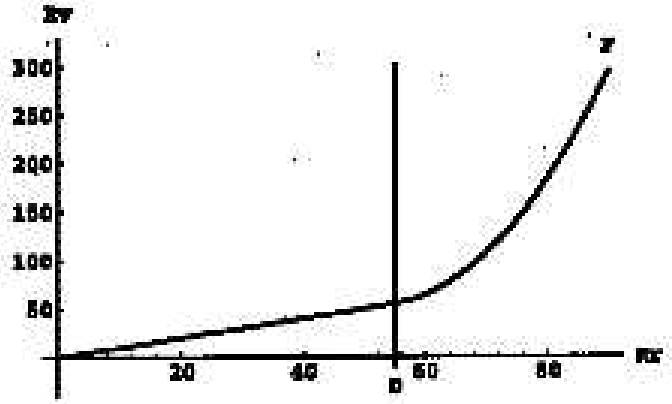
- Pointing
  - Touching with virtual hand/pointer
  - Ray casting
  - Cone casting (Flashlight)
  - Aperture
  - Two-handed pointing
  - Image plane
- Naming (speech rec.)



Hannes
Kaufmann

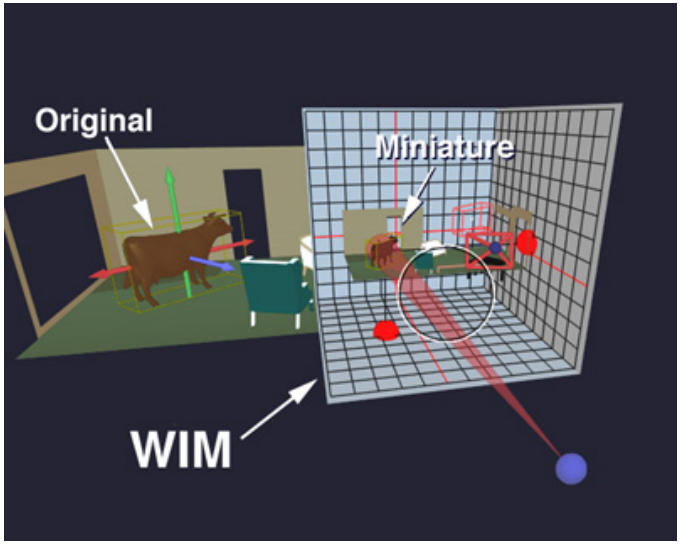
Enhancements to Basic Techniques

- Arm-extension
  - Go-Go Technique (mapping)

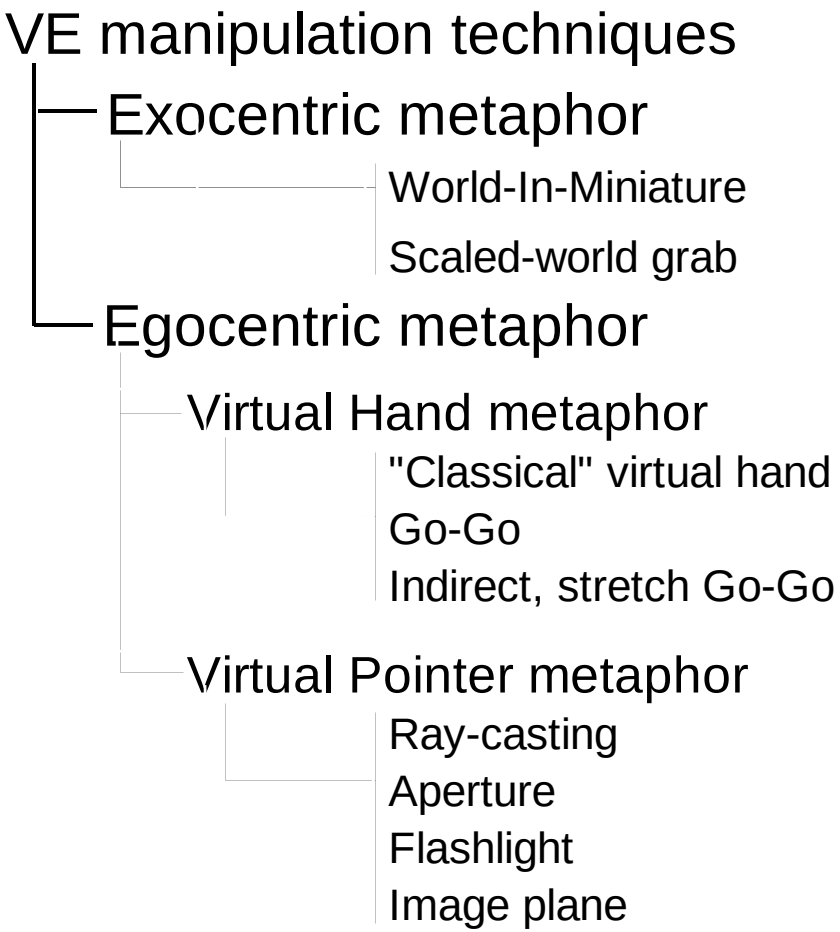


  - Fishing-Reel Technique (additional device: distance)

- World in Miniature (WIM)
  - Select icon-like objects

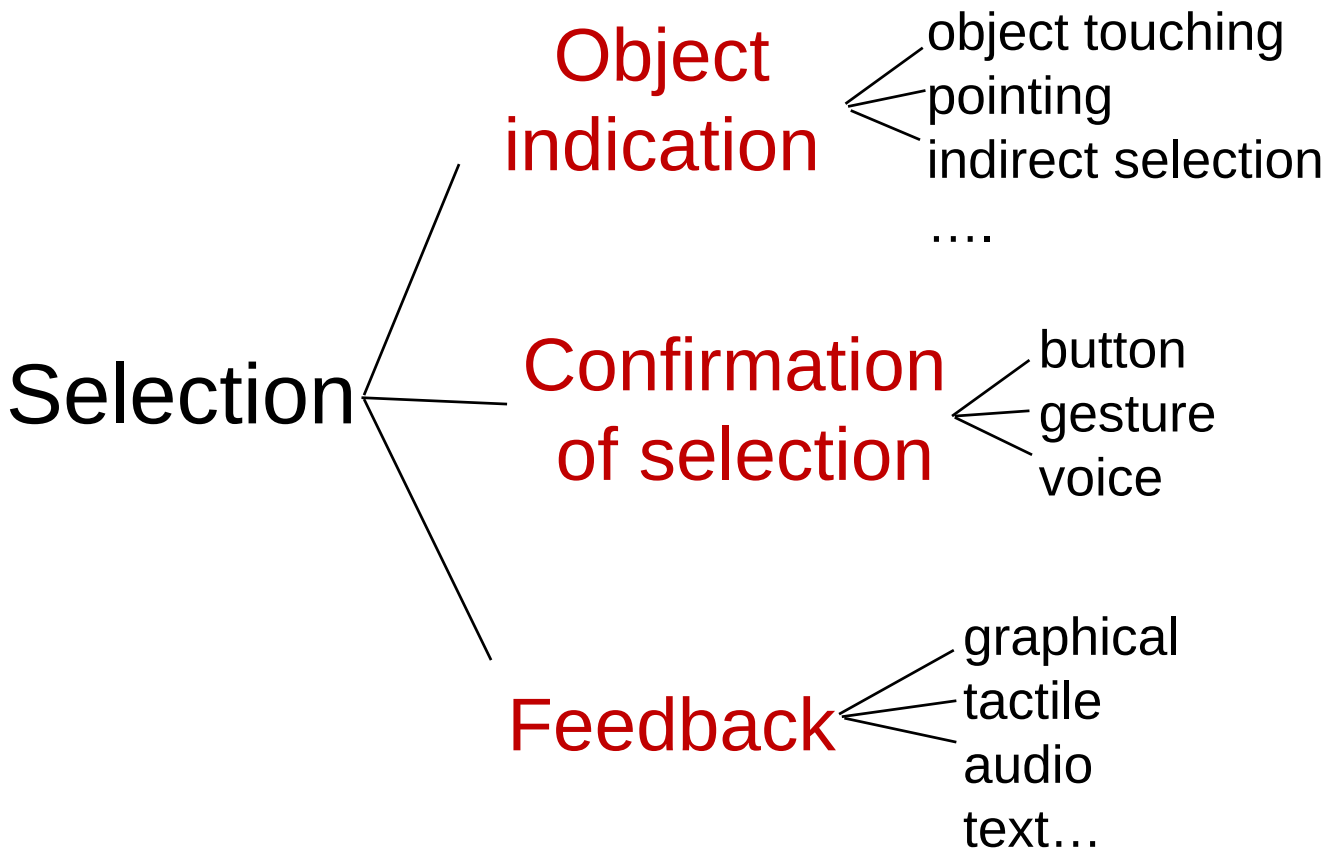


Technique Classification by Metaphor



Hannes
Kaufmann

Selection: Task Decomposition



Evaluation: Selection Task

- Ray-casting and image-plane generally more effective than Go-Go
  - Exception: selection of very small objects can be more difficult with pointing
- Ray-casting and image-plane techniques result in the same performance (2DOF)

Goals of Manipulation

- Object placement
  - Design
  - Layout
  - Grouping
- Tool usage
- Travel

Variables affecting user performance

- Required translation distance
- Amount of rotation (avoid clutching)
- Required precision of placement

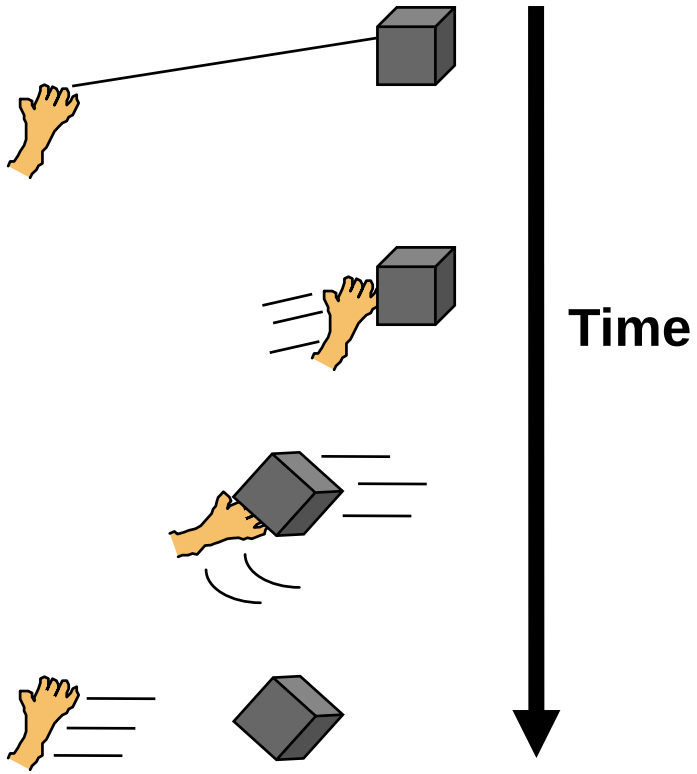
Manipulation Metaphors 1

- Simple virtual hand
  - Natural, easy placement
  - Limited reach, fatiguing, overshoot
  - 1:1 position mapping
- Ray casting
  - little effort required
  - Exact positioning and orienting very difficult (lever arm effect)
- Indirect depth control (e.g. mouse wheel)
  - Infinite reach, not tiring
  - Not natural, separates DOFs

HOMER technique

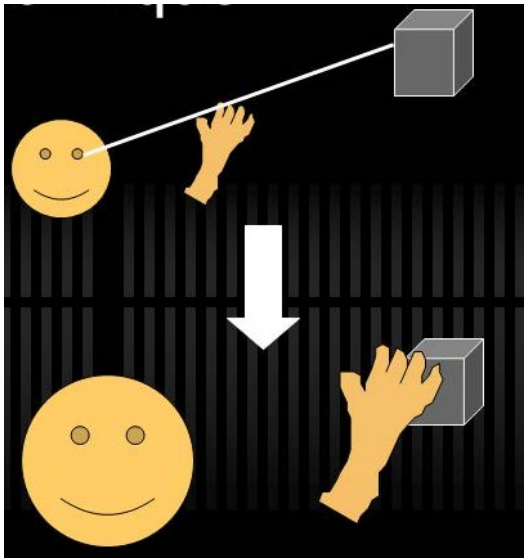
Hand-Centered **O**bject
Manipulation
Extending **R**ay-Casting

- Select: ray-casting
- Virtual hand moves to object
- Manipulate: hand



Manipulation Metaphors 2

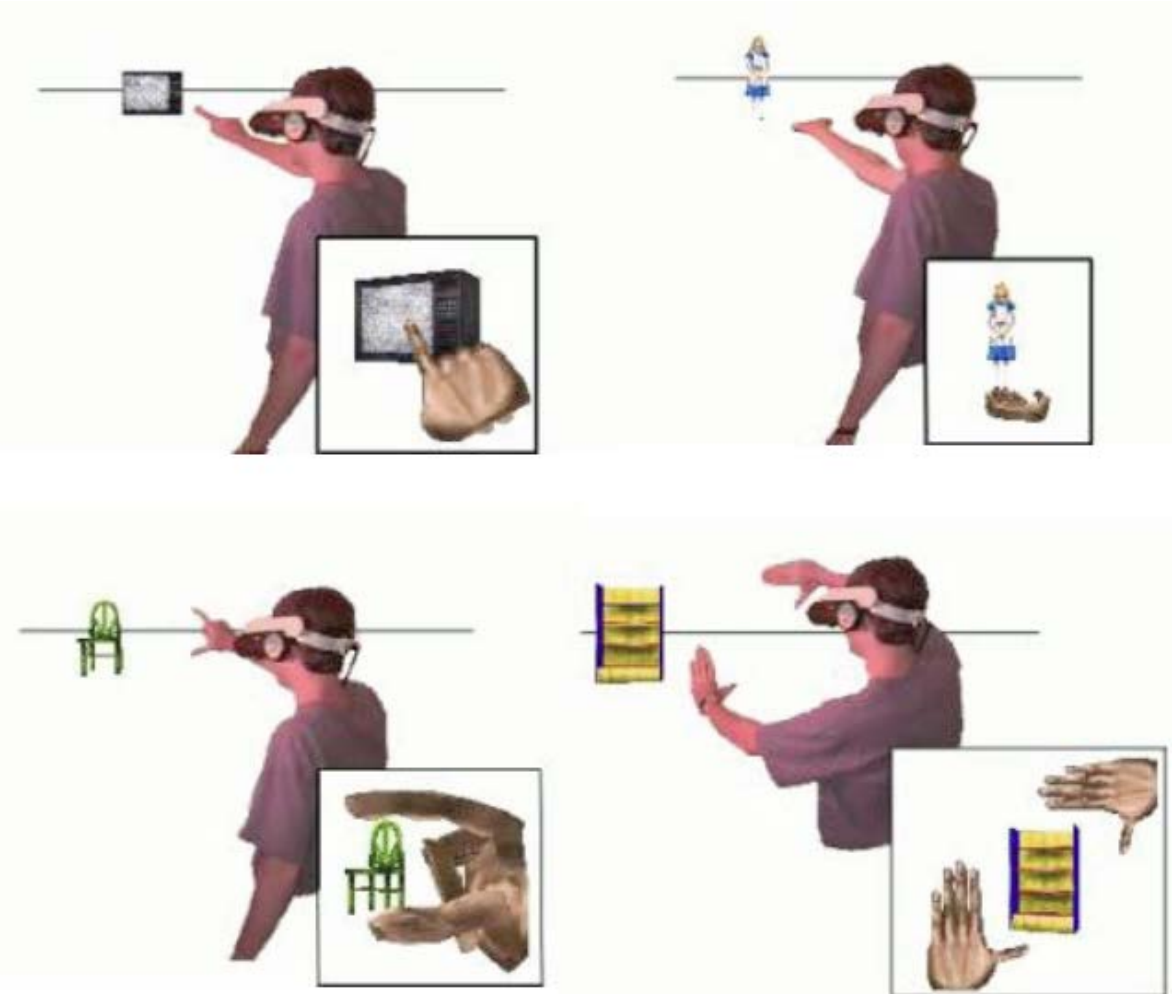
- HOMER (ray-casting + arm-extension)
  - Easy selection & manipulation
  - Expressive over range of distances
  - Hard to move objects away from you
- Scaled-world grab
  - Selection by image plane
  - World scaled down around virtual hand
  - Easy, natural manipulation
  - Hard to move objects away



Hannes
Kaufmann

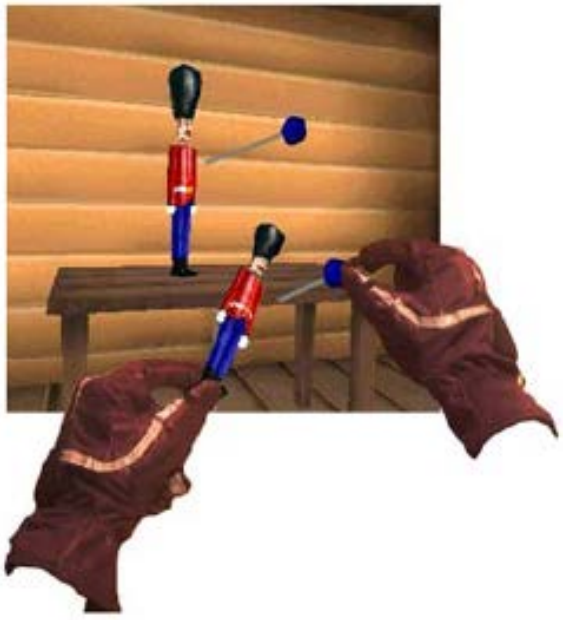
Image plane interaction

- Selection and manipulation
- Different gestures

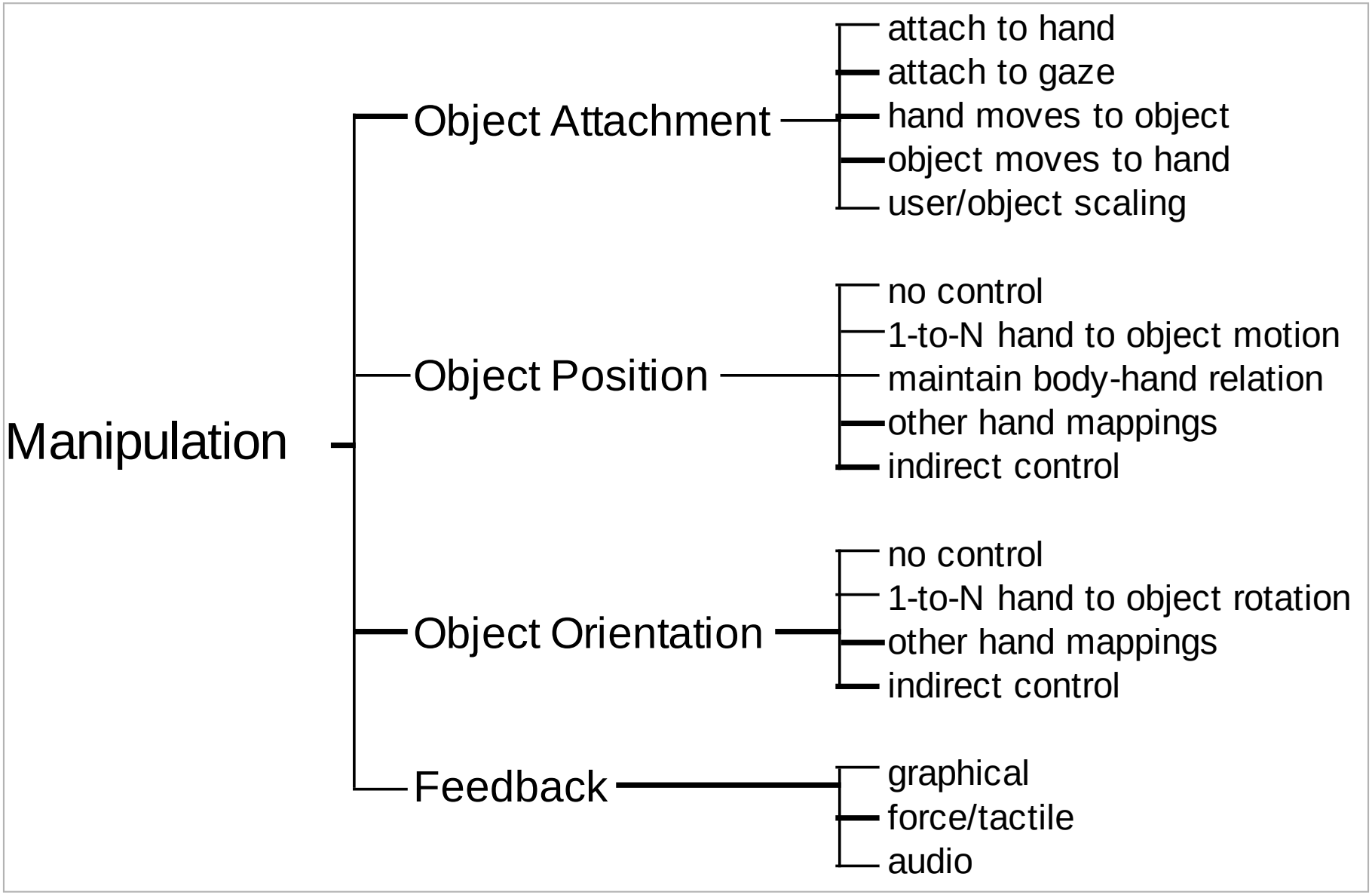


Manipulation Metaphors 3

- World-in-miniature
  - All manipulation in reach
  - Doesn't scale well for large environments
  - Indirect
- Voodoo Dolls
  - Two-handed (2 pinch gloves)
  - Create "dolls" by image-plane technique
  - Indirect manipulation



Classification by Components



Evaluation: Positioning Task

- Ray casting effective if the object is repositioned at constant distance
- Scaling techniques (HOMER, scaled world grab) difficult in outward positioning of objects: e.g. pick an object located within reach and move it far away
- If outward positioning is not needed then scaling techniques might be effective

Evaluation: Orientation Task

- Setting precise orientation can be very difficult
- Shape of objects is important
- Orienting at-a-distance harder than positioning at-a-distance
- Techniques should be hand-centered

Manipulation notes

- No universally best technique
- Constraints and reduced DOFs
- Naturalism not always desirable
- If VE is not based in the real, design your environment for optimal manipulation

Navigation

- Travel: motor component
- Wayfinding: cognitive component

Travel

- Motor component of navigation
- Movement between 2 locations
- Setting the position (and orientation) of the user's viewpoint
- Most basic and common VE interaction technique
  - used in almost any large-scale VE
- Travel often directly controlled in AR !
  - Viewpoint controlled by user

Travel Tasks

- Exploration
  - travel which has no specific target
  - build knowledge of environment
- Search
  - naive: travel to find a target whose position is not known
  - primed: travel to a target whose position is known
  - build layout knowledge
  - move to task location
- Maneuvering
  - travel to position the viewpoint for a task
  - short, precise movements

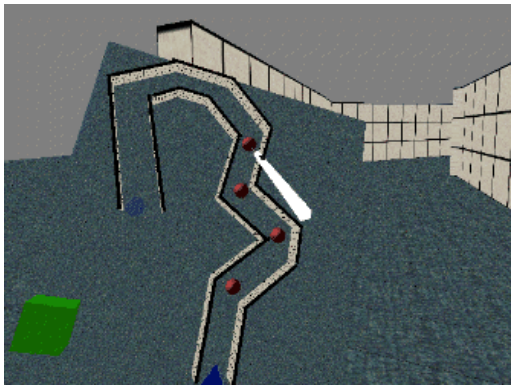
Traveling metaphors 1/2

- Steering metaphor: continuous specification of direction of motion
  - gaze-directed
  - Pointing (the “fly” gesture)
  - physical device (steering wheel, joystick)
  - Examples: Beckhaus – chair (video)

- Target-based metaphor: discrete specification of the goal location
  - point at object
  - choose from list
  - enter coordinates
  - Example: Reitmayr - Outdoor

Hannes
Kaufmann

Traveling metaphors 1/2



- Route-planning metaphor: one-time specification of path
  - place markers in world
  - move icon on map
- Manipulation metaphor: manual manipulation of viewpoint
  - “camera in hand”
  - fixed object manip.
    - Example: film camera movement
  - Grabbing in the air technique (2 gloves)

Evaluation results (by Bowman)

- “Teleportation” can lead to significant disorientation
- Environment complexity affects information gathering
- Travel IT and user’s strategies affect spatial orientation

Hannes
Kaufmann

Evaluation results

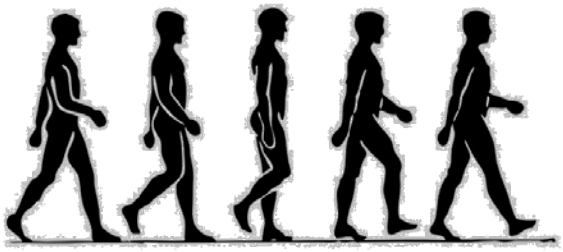
- Steering techniques best for naive and primed search
- Map-based techniques not effective in unfamiliar environments, or if any precision is required

“Natural” travel metaphors

- Walking techniques
- Treadmills
- Bicycles
- Other physical motion
  - VMC / Magic carpet
  - Disney’s river raft ride
  - Simulation of flying

Hannes
Kaufmann

Real Walking



- **Real Walking** in virtual worlds
  - Enhances sense of presence
  - Enhances perception of size and distance
  - Focuses attention
  - Improves task performance

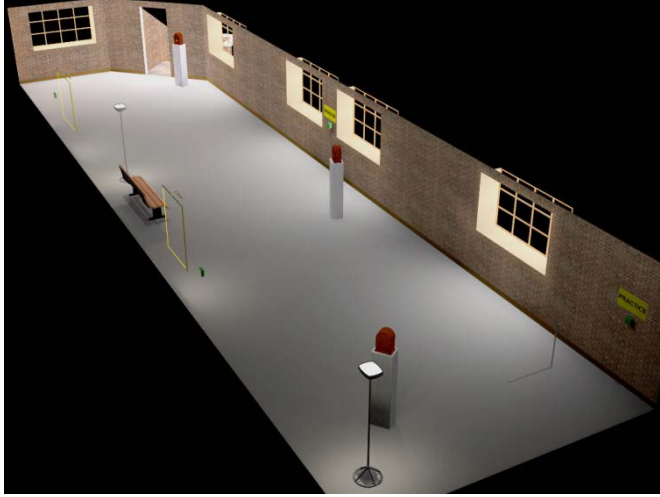
  But:
  - Limits size of virtual environment to size of tracking space

ImmersiveDeck

→ Have to make the user believe to walk in a much larger space

Hannes
Kaufmann

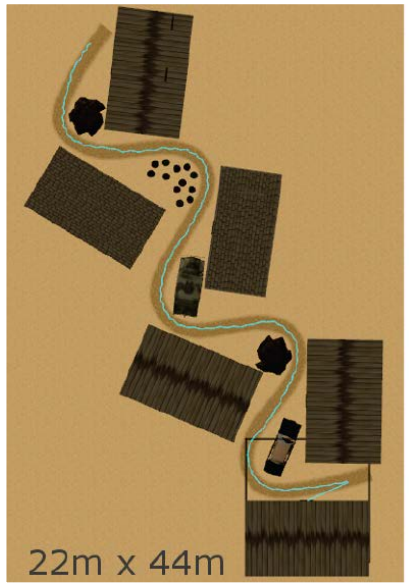
Redirected Walking

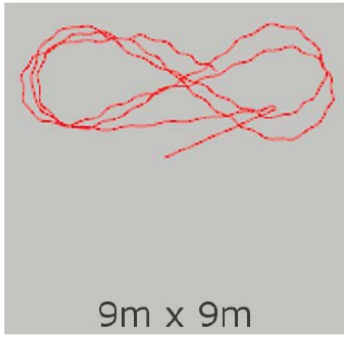


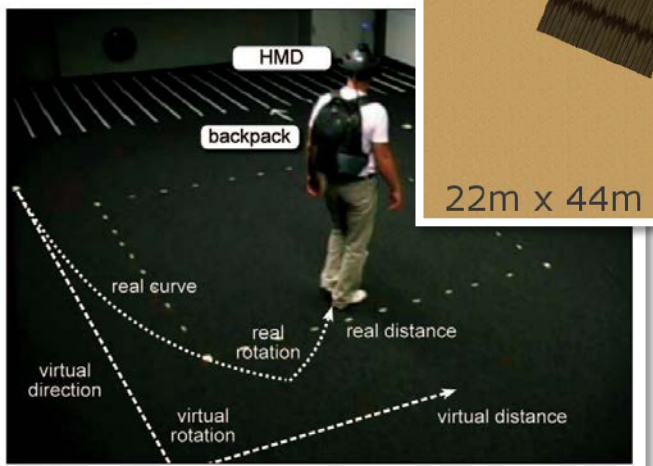
- Same benefits as real walking
- Extends the possible size of the VE

Different methods:

- Way points
- Distractions
- Gains:
  - Translation
  - Rotation
  - Curvature



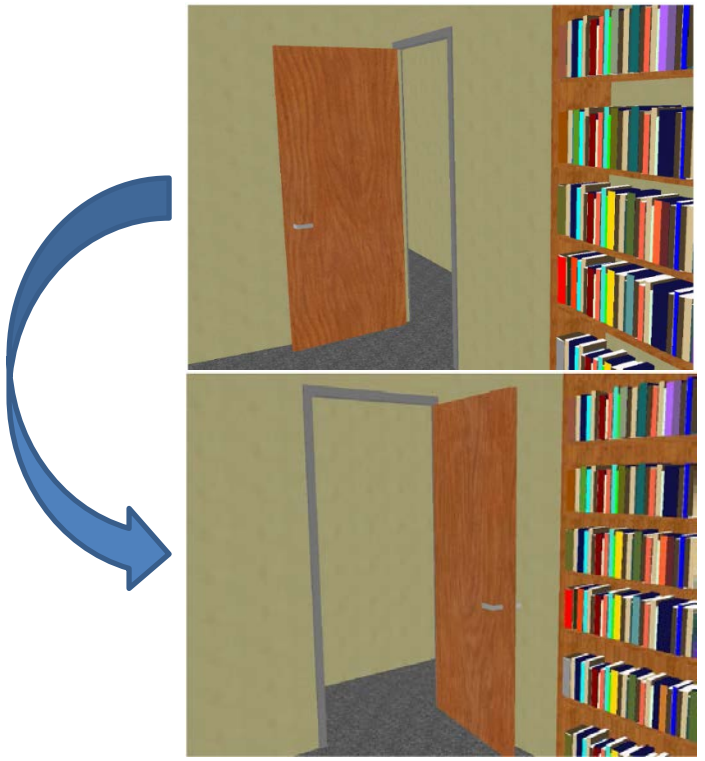




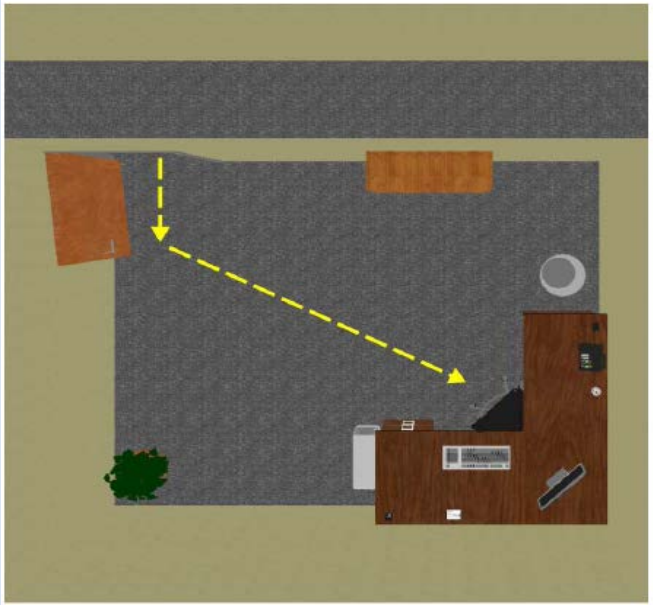
Hannes
Kaufmann

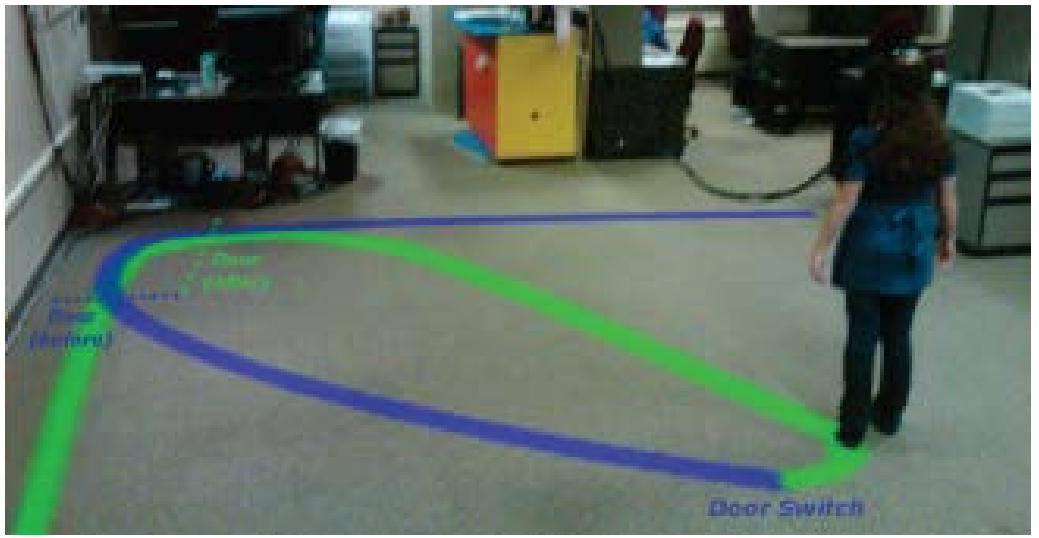
Change Blindness

- Changes are applied while the user is distracted



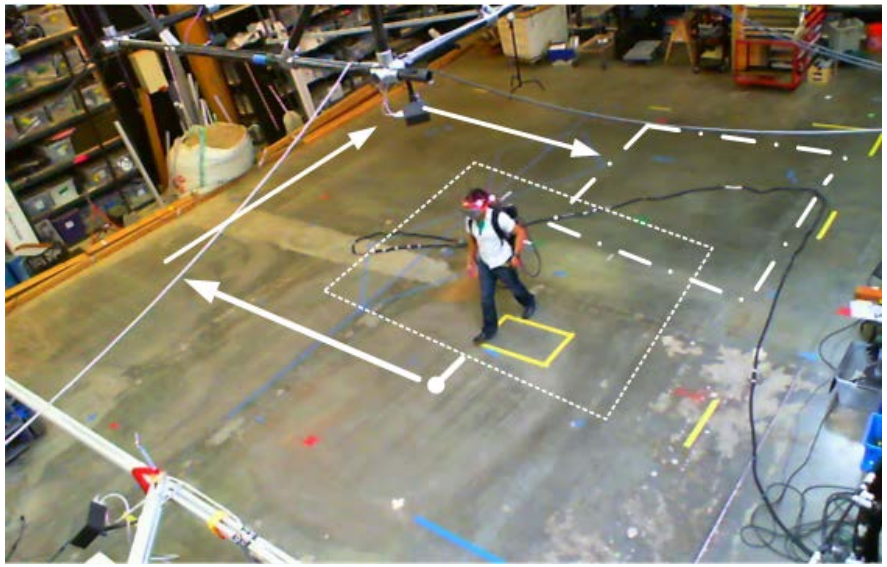
- Cyclic paths possible





Our approach:

Flexible Spaces



- Real world rules do **not** apply
- Real walking
- Natural constraints
- Focus on virtual content
- Bigger distance between the rooms – more overlap
- Procedural layout generation

Navigation: **Myths**

- *There is one optimal travel technique for VEs.*
- *A "natural" technique will always be better than another technique.*
- *Desktop 3D, workbench, and CAVE applications should use the same travel ITs as HMD-based VEs.*

WRONG !

Navigation: Design Guidelines

- Make simple travel tasks simple (target-based techniques for motion to an object, steering techniques for search).
- Provide multiple travel techniques to support different travel tasks in the same application.
- Use transitional motions (not teleportation!) if overall environment context is important.

System control

- Catch-all for other types of VE interaction
  - Issuing command
  - Changing mode
  - Choosing tool
- Often composed of other tasks

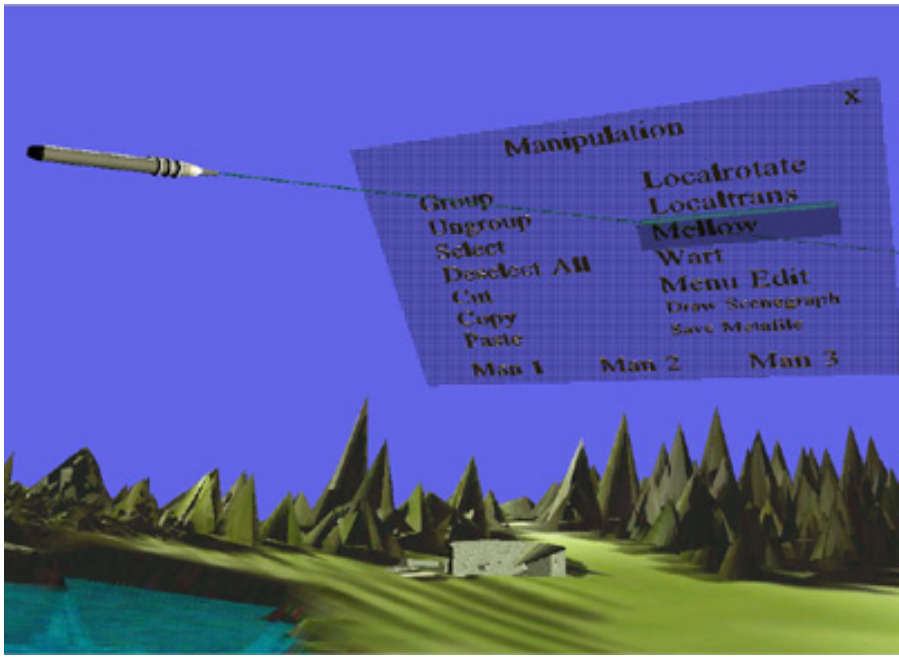
Common types of system control techniques

- Menu systems
- Voice commands
- Gestures/postures
- Implicit control (e.g. pick up new tool to switch modes)

Hannes
Kaufmann

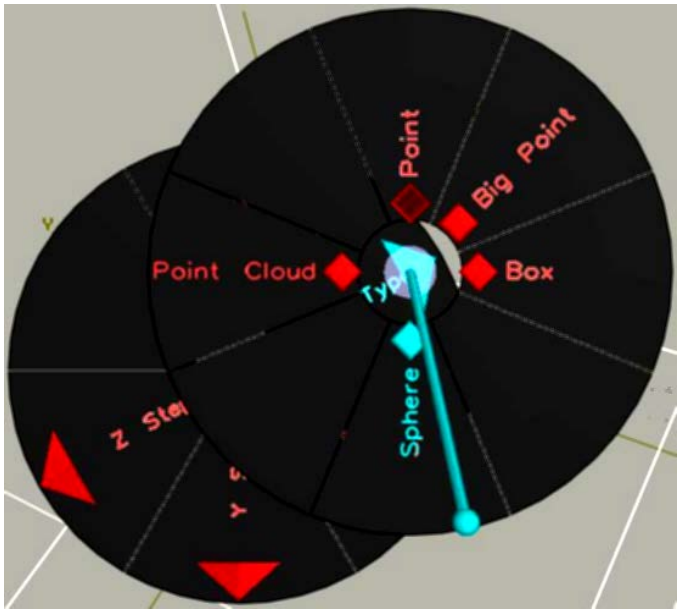
Floating menus in 3D

- Requires user knowledge
- Can occlude environment
- Using 3D selection for a 1D task
- Can be difficult to find
- Better than Heads-up-Display (HUD) but still very bad design – AVOID!



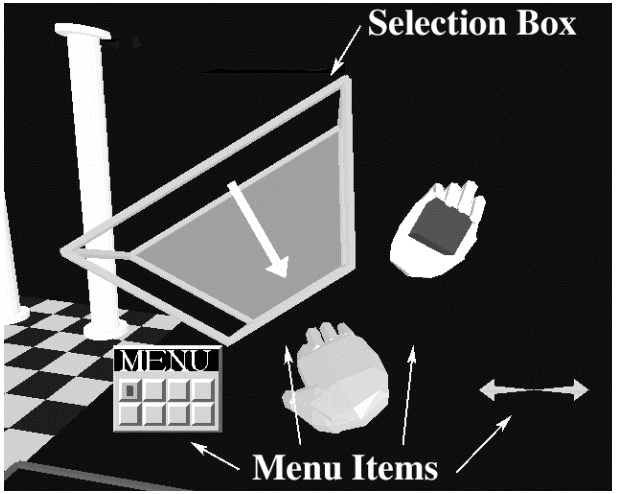
Pop-Up Menus - Radial

- Sundial
  - Pie menu with 3D selector
  - User rotates “Shadow stick” to occlude desired segment
- Example: iOrb



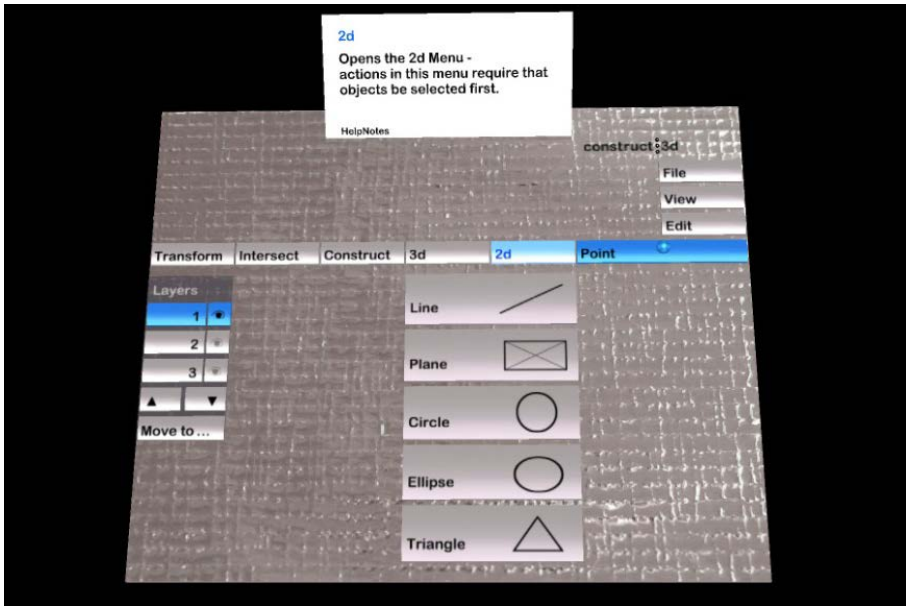
1 DOF menu

- Correct number of DOFs for the task
- Can be put away
- Only one menu level at a time



Hannes
Kaufmann

Pen & Tablet Interaction



Pen & Tablet Interaction

Tablet = real object:

- Can put away
- Handwriting input possible
- Can be used as a clipboard
- Constrained surface for input
- Usability: People are used to 2D input
- Combine 2D/3D interaction
- Use any type of 2D interface, not just menus

Pen:

- Direct manipulation
- Magic Lens Metaphor

2D interaction in a 3D world

- Quite useful for appropriate tasks
- Can integrate seamlessly with 3D
- If presence is important, the 2D interface should be *embedded*, not *overlaid*

Applications - Examples

- Real applications always **combine** interaction techniques

Examples:

- Projection Screen Interaction e.g. ArsBox
- Volumetric Displays e.g. Perspecta3D
- ARToolkit Interaction: Mozart MagicBook
- Handheld HMD
- Outdoor AR modeling: Tinmith

Philosophies of Interaction Design

- Artistic approach
  - Intuition about users, tasks
  - Heuristics, metaphors
  - Aesthetics
  - Adaptation
- Scientific approach
  - Formal analysis
  - Formal evaluation
  - Performance requirements

Own Experience:

Combination of both gives best results!

AR
Interaction Techniques

Hannes
Kaufmann

IT Comparison VR – AR

	Virtual Reality / 3DUI	Augmented Reality
Selection	Raycasting, virtual hand, world scaling	same
Manipulation	Everything can be manipulated.	Distinction between *real / virtual* objects
Navigation	Viewpoint can be controlled freely.	Only *passive* hints
System control, Symbolic input	Menus, voice, gestures	same

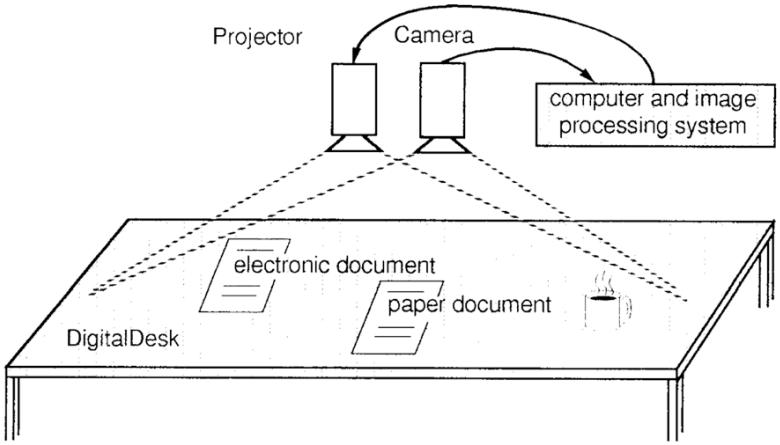
Manipulation

- Direct VR Style
- Augmented Environments / Surfaces
- Tangible Interaction

Hannes
Kaufmann

Augmented Surfaces

- Touch leads to surfaces
- Often using projection
  (e.g. Digital Desk [Wellner93]
- Treat paper and electronic documents as the same



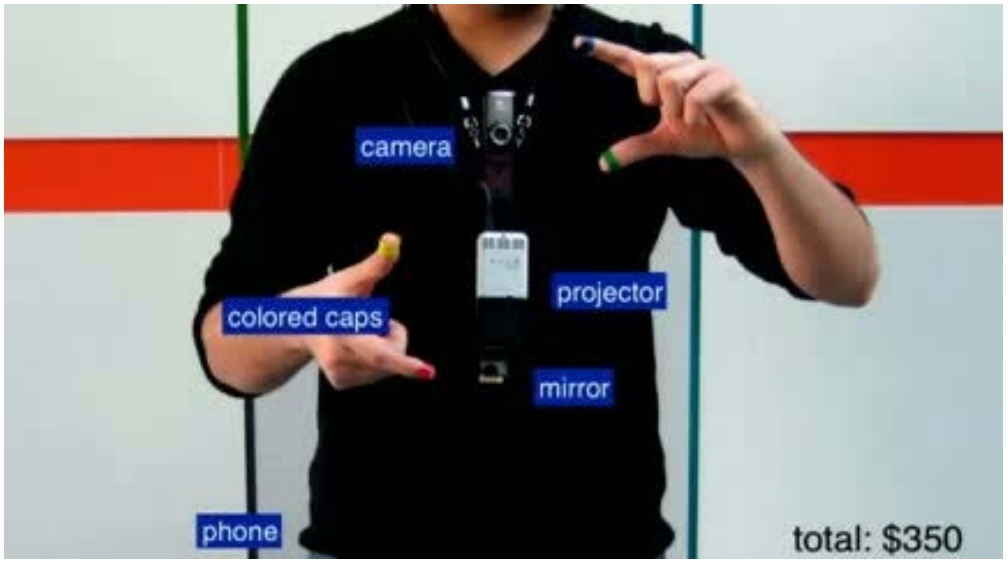
Touch Tables

Augmented Surfaces: Pros/Cons

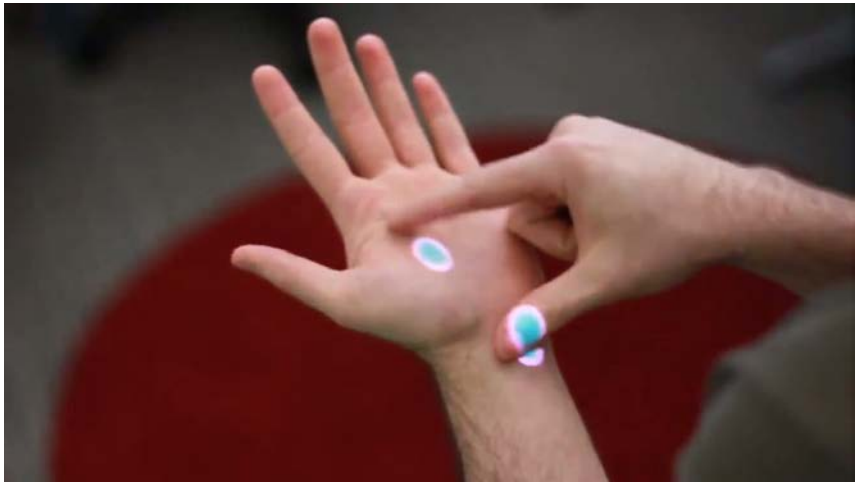
- Good
  - Intuitive interaction
  - Same modalities for real + virtual objects
- Bad
  - only 2D
  - creates a *spatial* seam

Projected AR Environments 1/2

- MIT 6th Sense



- Microsoft Omni Touch

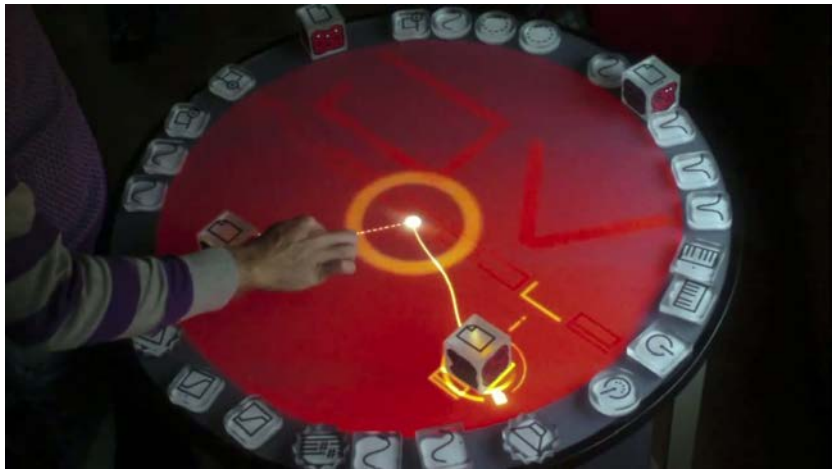


Projected AR Environments 2/2

- Microsoft Augmenting Indoor Spaces

Tangible Interaction

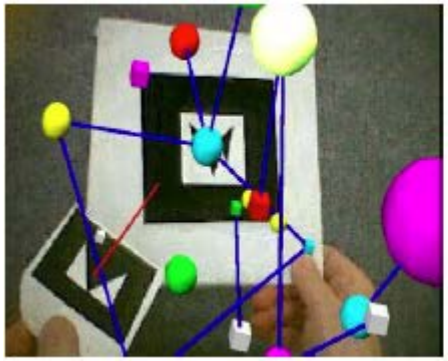
- Use real placeholder to manipulate virtual content
- Full 6DOF manipulation
- Popularized through ARToolkit

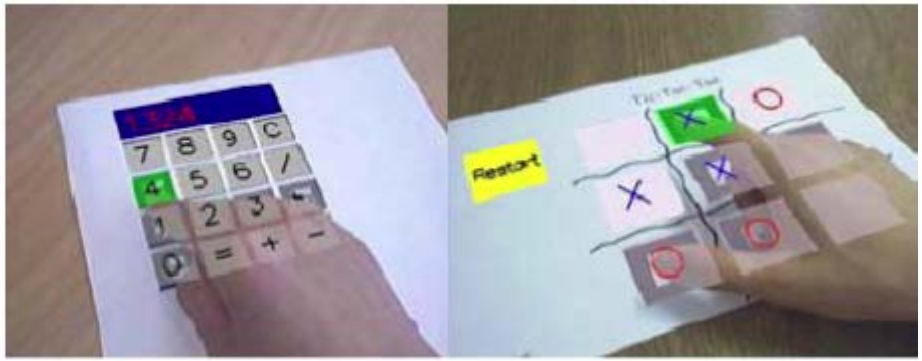


ReacTable

Tangible User Interaction

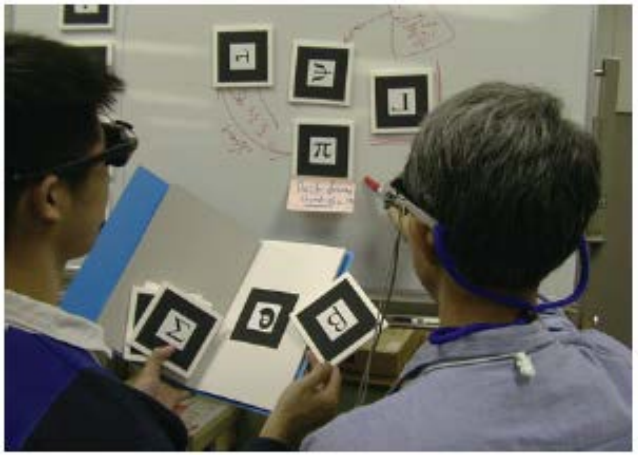
- Virtual Buttons
- Toggle buttons using Markers
- Proximity

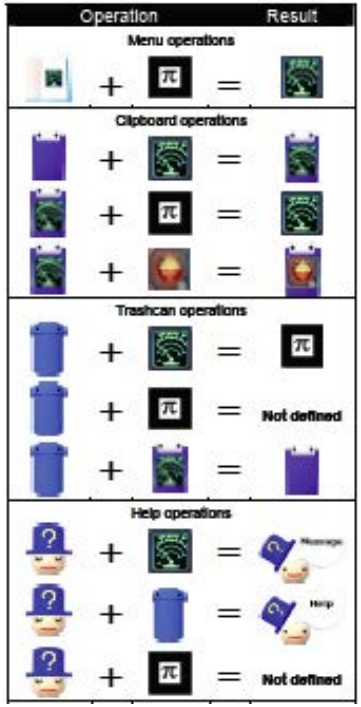




Tangible: Tiles

- Tangible markers
  - data
  - operations
- Integration with real world
  - annotations
- See through HMD
- Collaborative

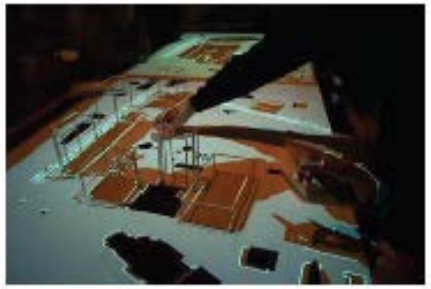


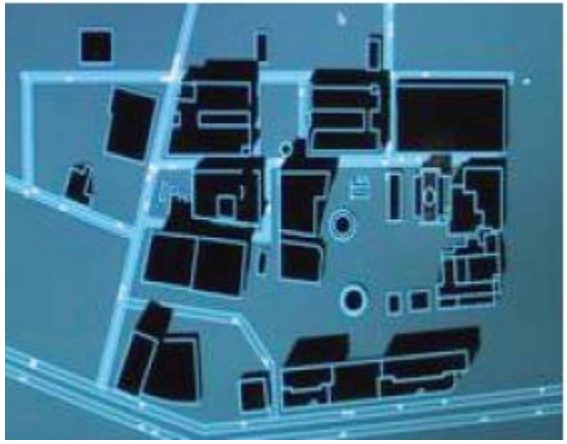


Hannes
Kaufmann

Luminous Tangible Workspace

- Urban planning tool
  - Tangible building models
  - Interactive simulations
    - Wind
    - Sunlight / shadows
    - Traffic patterns





Navigation

- Moving mobile device is a natural navigation interaction technique
- Zoom/Pan might be over-accelerated
- Mobile device movements relative to target are used for input

Navigation Support

- Direct Overlays
  - Information registered to Environment
  - Easy to interpret
  - Small field of view
  - No overview no knowledge build-up
- Map integration
  - Provides overview
  - May require mental rotation to align
  - Occludes display

Hannes
Kaufmann

Examples

Example Navigation Apps

- Wikitude Drive

- ACrossAir Nearest Tube

Hannes
Kaufmann

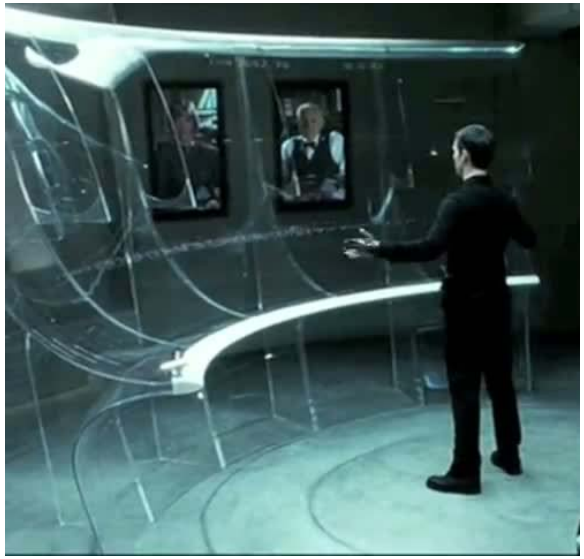
Maps

- Map and spatial knowledge
- Rules for good map design
  - Provide you are here marker
  - Provide grid
  - Choose either north-up or forward-up map
  - Try mixing local and global maps
- Often as World-in-Miniature

Examples: Gestural Interaction

- Oblong Industries

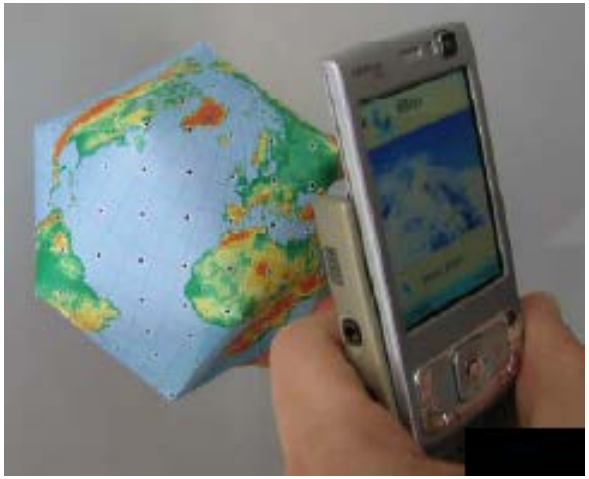
- Movies / Visions

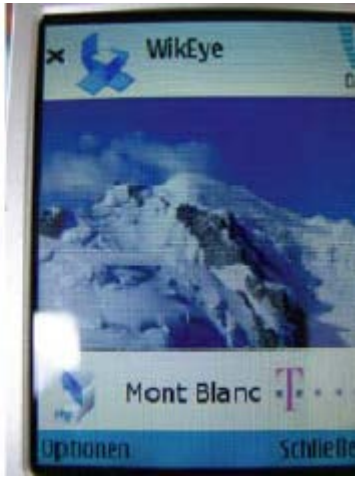


Interaction Techniques for Smartphones / Tablets

Crosshair Selection

- Crosshair and „Button“ press -> Selects specific spot

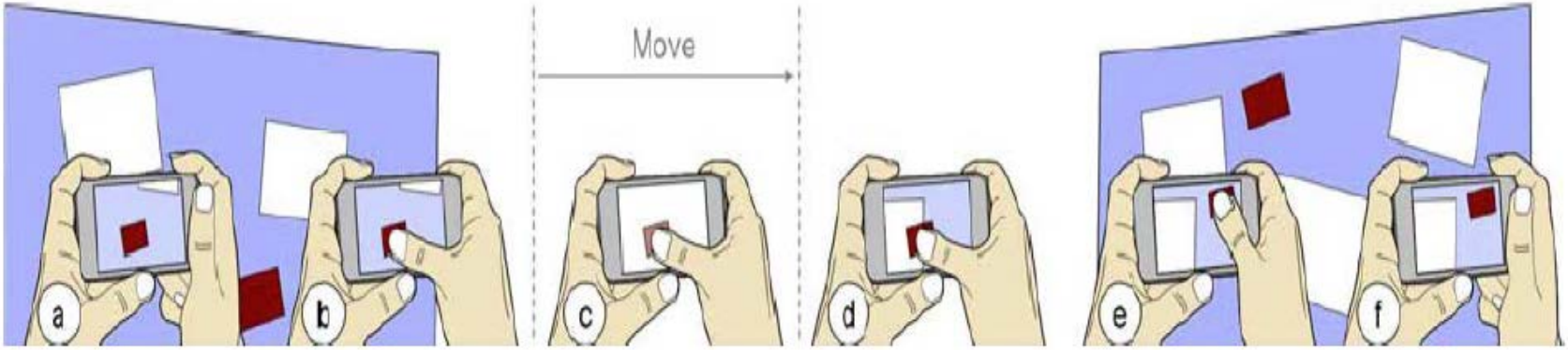




Hannes
Kaufmann

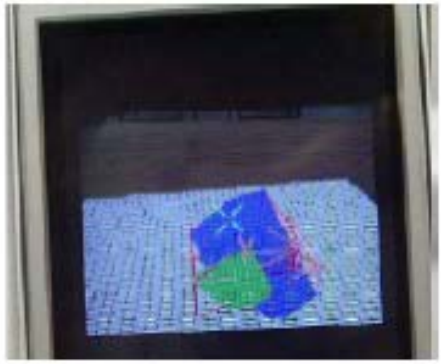
Point, Grab, Move, Release

- Relative to target 2D



- Relative to „world“ 3D

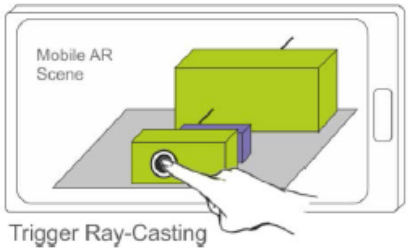


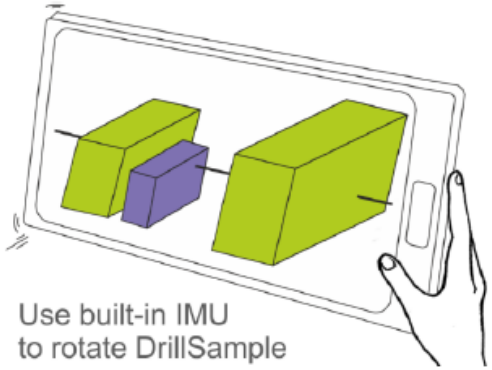


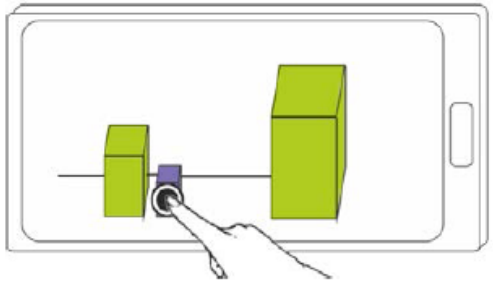
Hannes
Kaufmann

Intuitive Interaction for Handheld AR

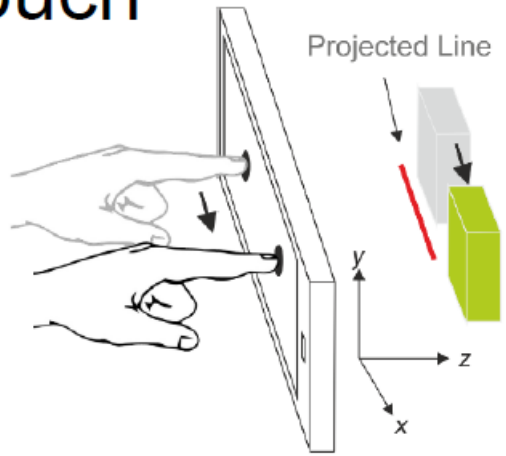
DrillSample



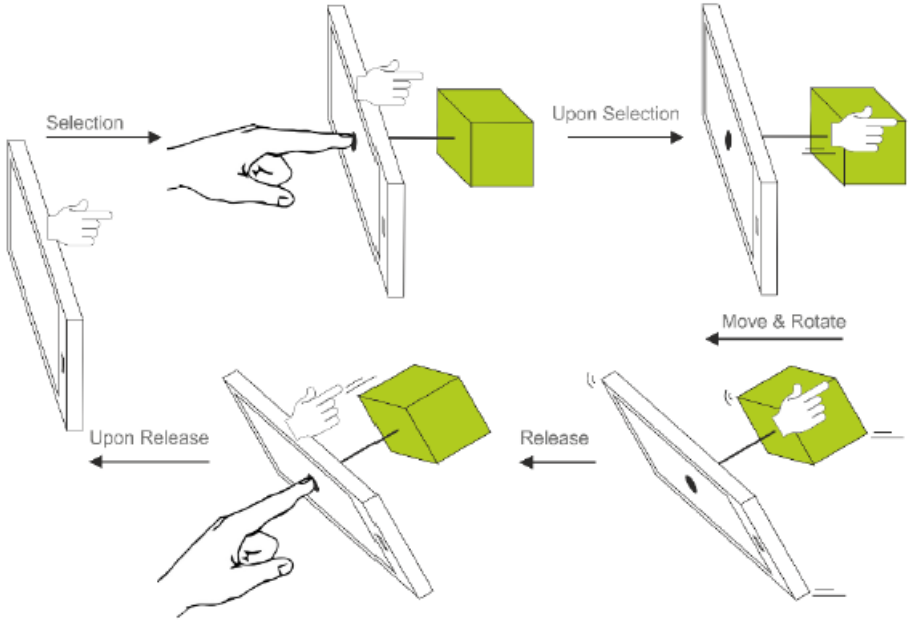




3DTouch

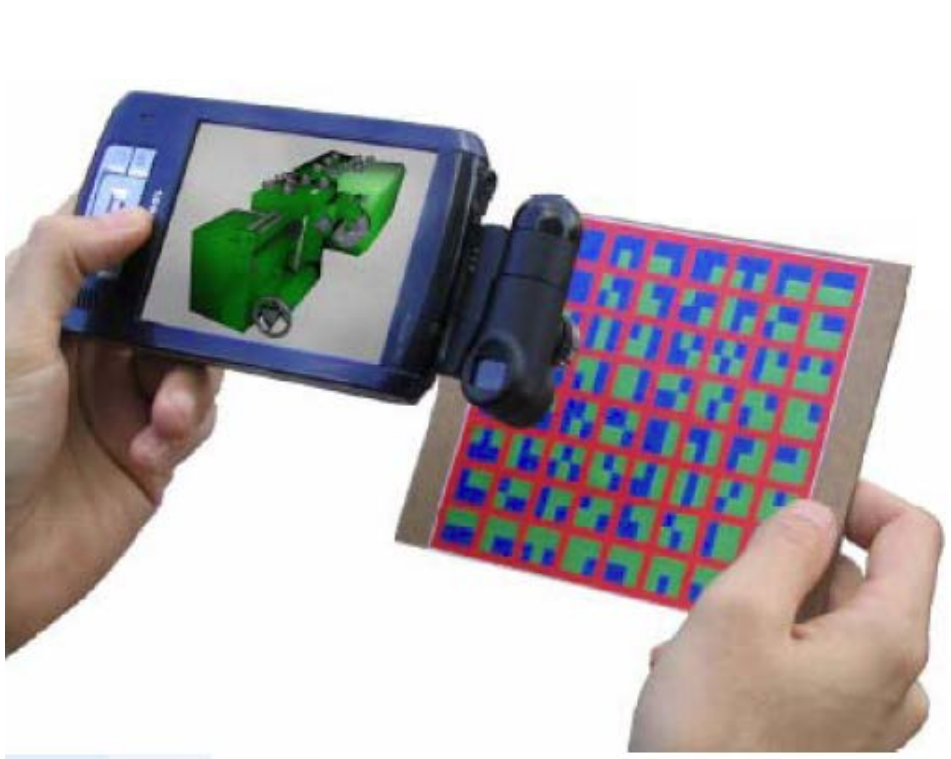


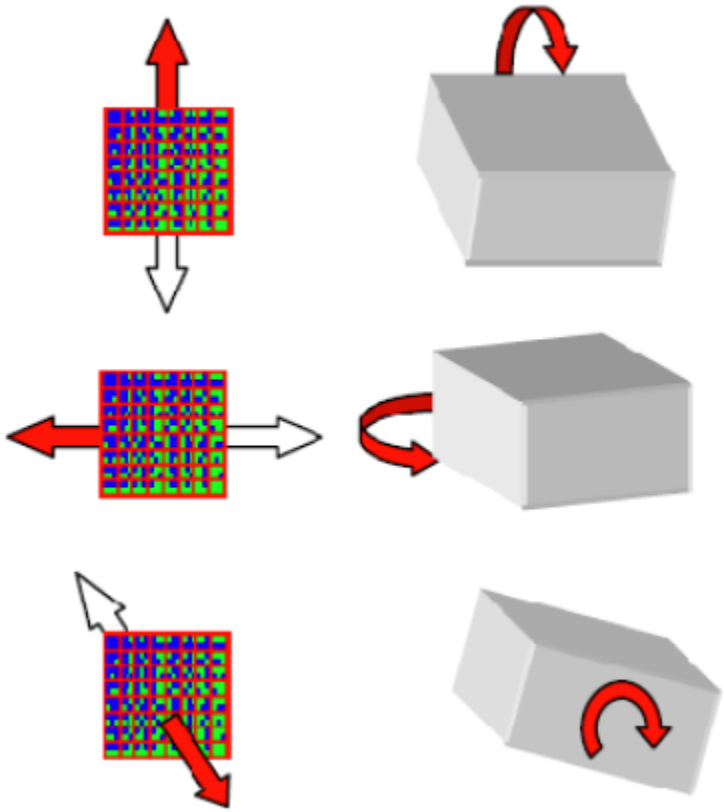
HOMER-S



Hannes
Kaufmann

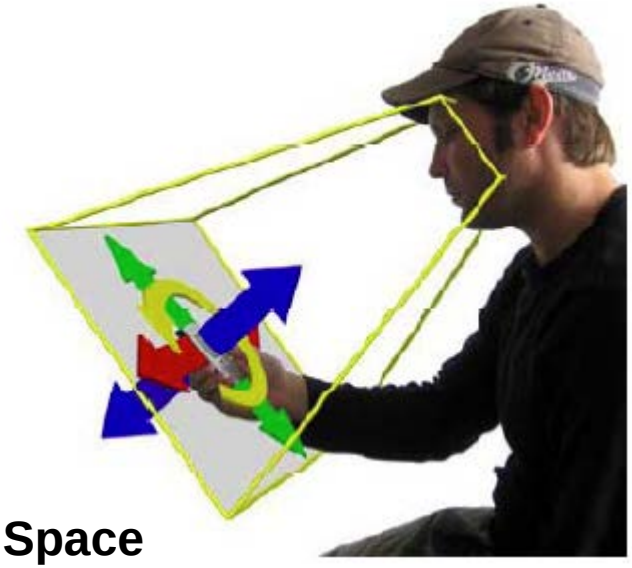
Indirect Object Manipulation via Target Movement





Layered Pie Menus

- Mobile device movements relative to head/target are used for menu selection
- Head movements relative to device

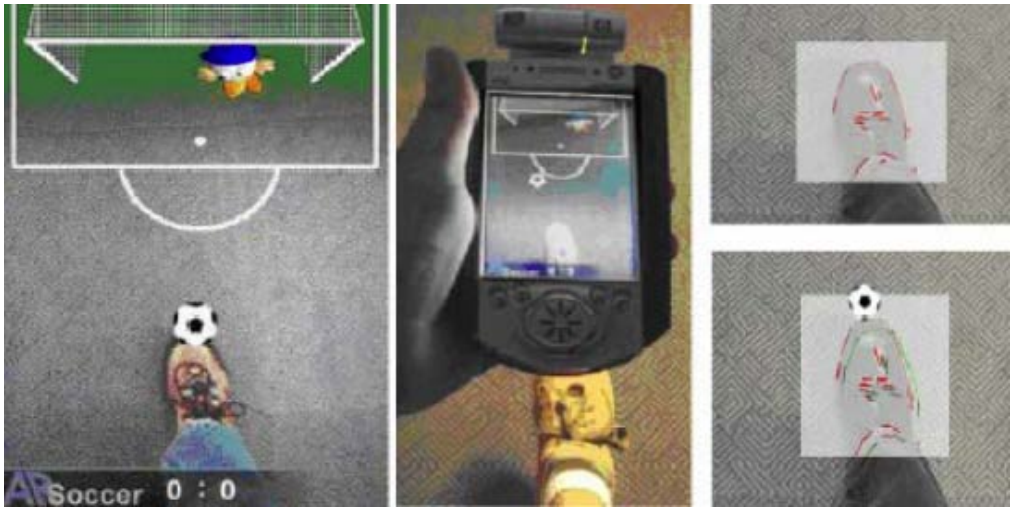


Mixed Interaction Space with face tracking

Hannes
Kaufmann

Direct Hand/ Foot Gestures

- Hand Interaction / Gesture
- Foot Interaction / Gesture



Social AR – A Vision ?

- Users create content & model the world
  - "YouTube" of AR
  - Supported with automated methods
- Situated social networks
- AR 2.0
- Same Place / Different Time

Oh,no,officer - it's not graffiti. it's an analog real-time augmented reality application.

Literature

- 3D User Interfaces – Theory and Practice Doug Bowman, Ernst Kruijff, J. LaViola, Ivan Poupyrev; Addison Wesley, 2005.

Thank you
for your attention!

Questions, Comments?