

VR Interaction

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Interaction and Navigation

- ❑ In Fish Tank VR, old HMDs, the user is typically sitting with a limited space to move in.
- ❑ With more **modern HMDs** (newer Oculus Rift, VIVE) or **CAVE** and **CAVE2**, the user has a larger space to move walk in, jump up, kneel down, lie on the floor etc.
 - Unseen Diplomacy pushes this navigation in a limited space to the extreme <https://www.youtube.com/watch?v=KirQtdsG5yE>
- ❑ But often you want to move further, or in effect move a different part of the virtual world into the area that you can easily move through.
- ❑ Common ways of doing this involve using a **joystick** or **directional pad** on the wand to **navigate** through the space as if you were in a first person video game.

Interaction and Navigation

- ❑ A simple option is using a wand to **point** to where you want to go and **teleporting** from one place to another within the virtual world, which is what most current consumer HMD games use.
 - Fallout 4 VR
https://www.youtube.com/watch_popup?v=S0D0N2SYHII
- ❑ Another option is to use large **gestures** such as **swinging** both your arms (holding two wands) up and down as though you were **jogging** to tell the system you want to **walk**, or pointing in the direction you want to go if you have **hand and finger tracking**.
 - VR Dungeon Knight uses the jogging metaphor
<https://www.youtube.com/watch?v=TTolJoKUcks>
 - Oculus Rift DK2 + Leap Motion Orion
<https://www.youtube.com/watch?v=LJPxyWM9Ujg>

Interaction and Navigation

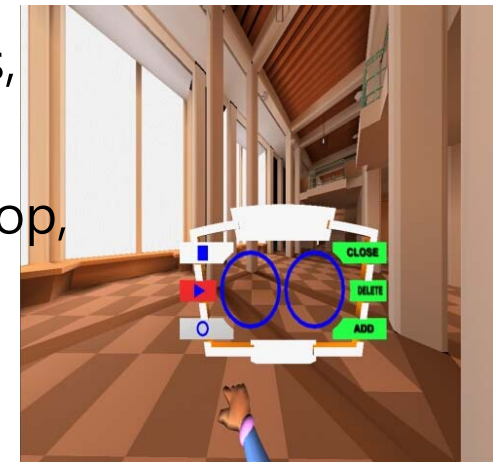
- ❑ If you have super human capabilities as in Megaton Rainfall VR, you can have the full Superman/Captain Marvel flying experience.
 - https://www.youtube.com/watch_popup?v=rD0QR2YPzv8
- ❑ Other **specialized options** as discussed include real device like **bicycles, treadmills, car interiors** where you drive the virtual car with the actual controls, plane interiors where you fly the virtual plane with the actual controls, trains, buses, trucks, etc.
- ❑ In Augmented Reality, you are limited to your actual physical movements (or the movements of a real car or a real bike) as the Augmented Reality world is anchored to the real world.

User Interaction with Virtual World

- A key ingredient of a VR experience
 - If the display of a virtual world does not respond to a **user's physical movement**, then it is not considered VR.
 - Interacting with a computer-generated environment occurs when **user inputs** are responded to by corresponding actions of the computer.
- Design the system that meets the needs of its user
 - Not natural for the novice user
 - Fortunately humans can be trained
- Use widely adopted **basic interface metaphors**
 - The basic interface for most cars is the same, such as a wheel, pedal, and transmission interface.
 - No additional training required

User Interface Metaphors

- Use of *metaphors* as a means of providing the user a context in which they can learn new techniques
- Relating a new interface technique to something with which they are already familiar
- Design new interface that adopts the metaphors of previous media if the existing metaphors have become ubiquitous in the society
 - Desktop metaphor on a computer: files, folders, trash can
 - Video/audio player's control metaphor: play, stop, rewind, fast forward



Some Pitfalls with User Interface Metaphors

- ❑ Erroneous mapping of the original concept onto the instantiated interface
- ❑ When the developer and the user have different expectations for how the interface should react based on the metaphor
- ❑ The user may learn to use the interface only as suggested by the metaphor, perhaps missing out on other available interactions not immediately suggested by the metaphor
 - e.g. Find function for search

Ultimate Interface

- Use real-life interactions as the metaphor by which a user interacts with a virtual world
- Knowledge of how to move a small object in the physical world enables the participant to move a small virtual object in the virtual world
 - e.g. reach out, grasp, pick up, and place
- Simplify the interface in VR
 - user may want to grab an object and pick it up and move it to somewhere **regardless of the distance**, without traveling while designing a room layout
 - move an heavy object without getting the help from others

Key Interactions in VR

□ Selection & Manipulation

- allows the user to select and then modify the world and the objects

□ Navigation

- allows the user to make their way through the world

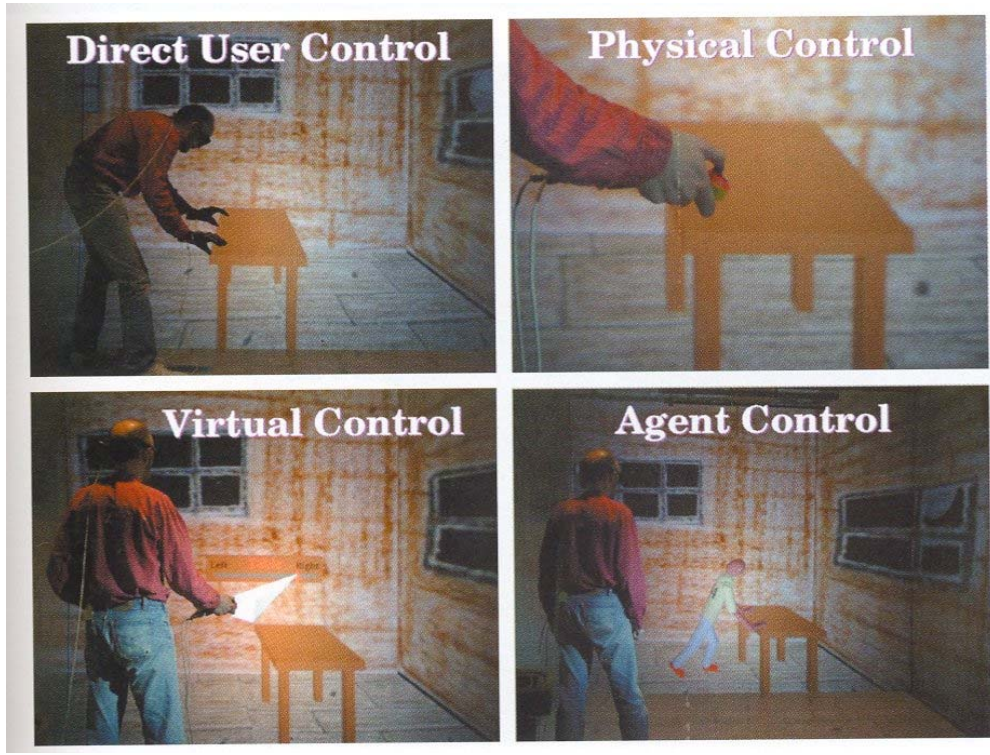
□ Communication

- allows the user to talk to either other users or with agents within the virtual world

Manipulation

- **User interaction with objects in the virtual world**
- In the desktop computer interface metaphor
 - users can *manipulate* a machine's file and operating system through the use of windows, icons, menus, and pointing devices (**WIMP interface**)
- In VR, most *manipulations* operate in two phases:
 - first, ***selection*** is made
 - and then an ***action*** is performed
 - sometimes these two operations can be performed simultaneously

Manipulation Methods



- Four ways in which most forms of manipulation can be performed within a VR experience [Mark Mine]
 - Direct user control
 - Physical control
 - Virtual control
 - Agent control

Direct User Control

- Participant interacts with virtual objects just as they would real objects (e.g. **grabbing**)
- Many direct user interactions combine the object selection process with the actual manipulation
- Use *gesture* or *gaze* to make a selection
- Example:
 - *grab with fist* interaction that causes the virtual object collocated with the hand
 - gesture action, such as the hand's movement

Direct User Control



Physical Control

- Using a real-world **apparatus**
 - Real buttons, switches, sliders, dial valuator, joysticks, trackballs, spaceball, etc
- By putting the interface in the real world, user receive **passive haptic feedback**
- Controls mounted on prop can act independently or integrating the prop's position
 - Buttons on a wand that can be used to scroll forward and backward through a menu by clicking on the right or left button and using the middle button to select the desired menu option
 - Point the prop at an object and press a button to select it
- Work better if there is a real-world metaphor between a physical control and the manipulation it performs

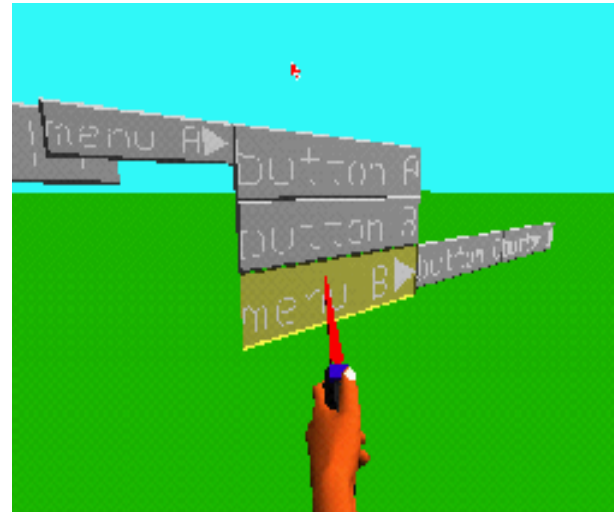
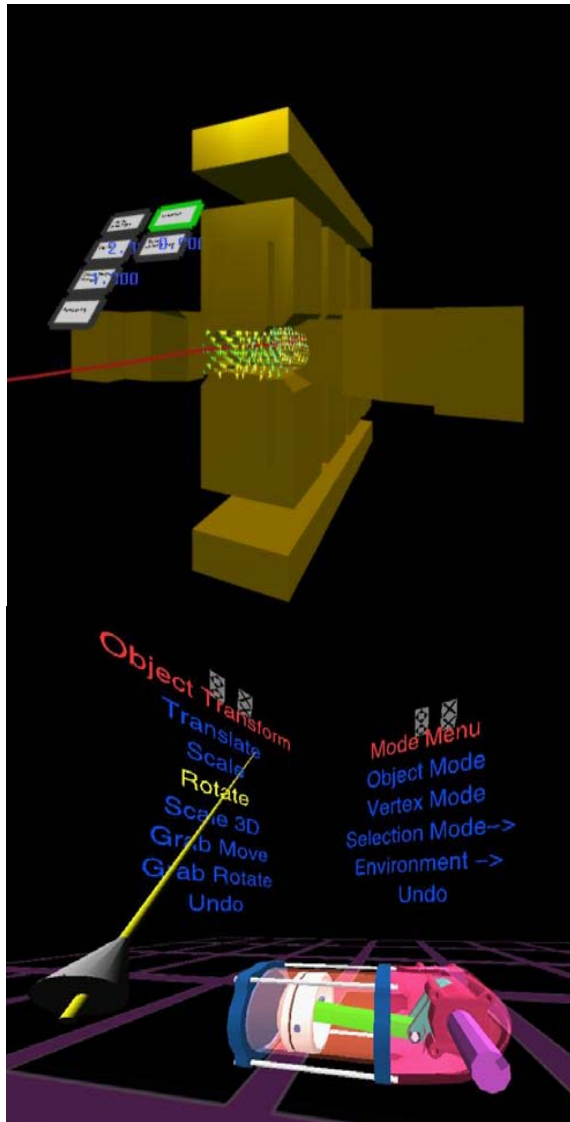
Physical Control



Virtual Control

- Controls that are manifested entirely in the virtual world
- Many virtual controls are merely computer-generated representations of similar physical counterparts
 - buttons, sliders, steering wheel, etc
- ***Allows a limited number of physical controls to be used to interact with a large number of virtual controls***
- May lose haptic feedback
- Often a physical control device is used to activate virtual controls within a virtual world
 - allows a physical device with only a few input signals to have a wider range of uses by creating an interface with numerous virtual controls similar to a mouse

Virtual Control - Menus

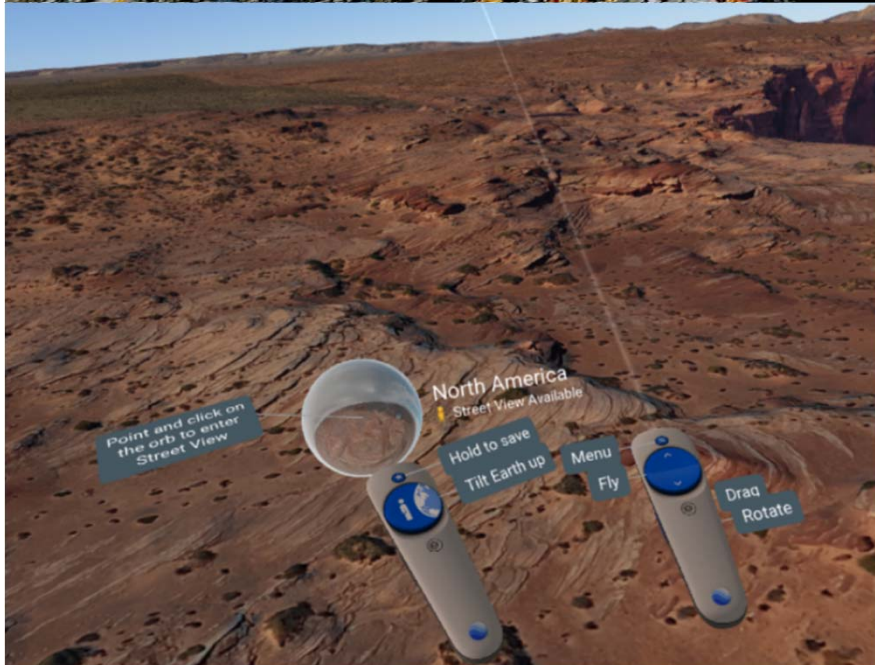


Head-Up Menu used in CALVIN

Virtual Control - Menus



Skyrim – traditional menu

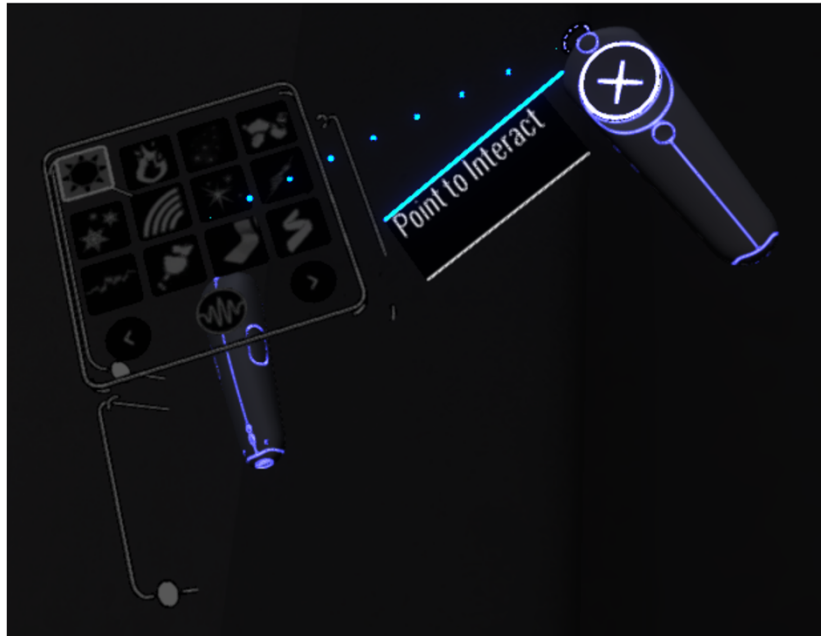


Google Earth VR
- buttons on controller with tooltips

Virtual Control - Menus



Vanishing realms - UI at user's waist

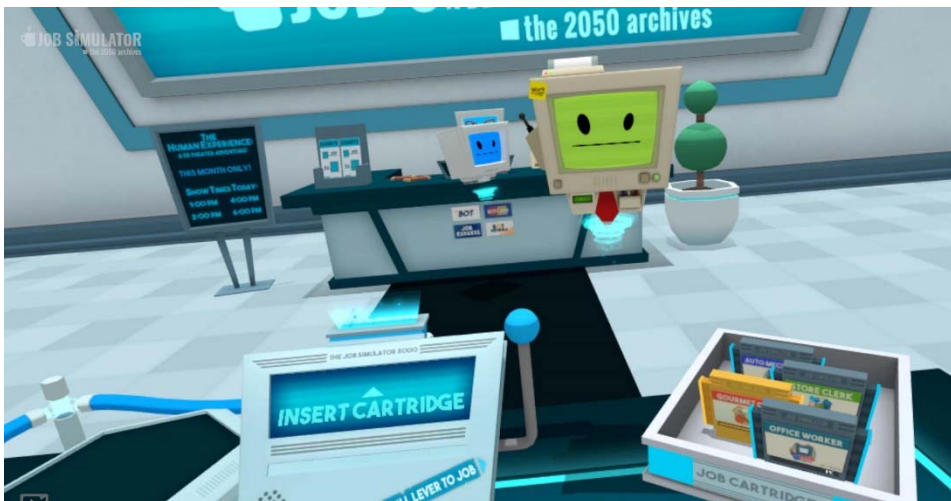


Tilt Brush – 2 handed 3D UI

Virtual Control - Menus

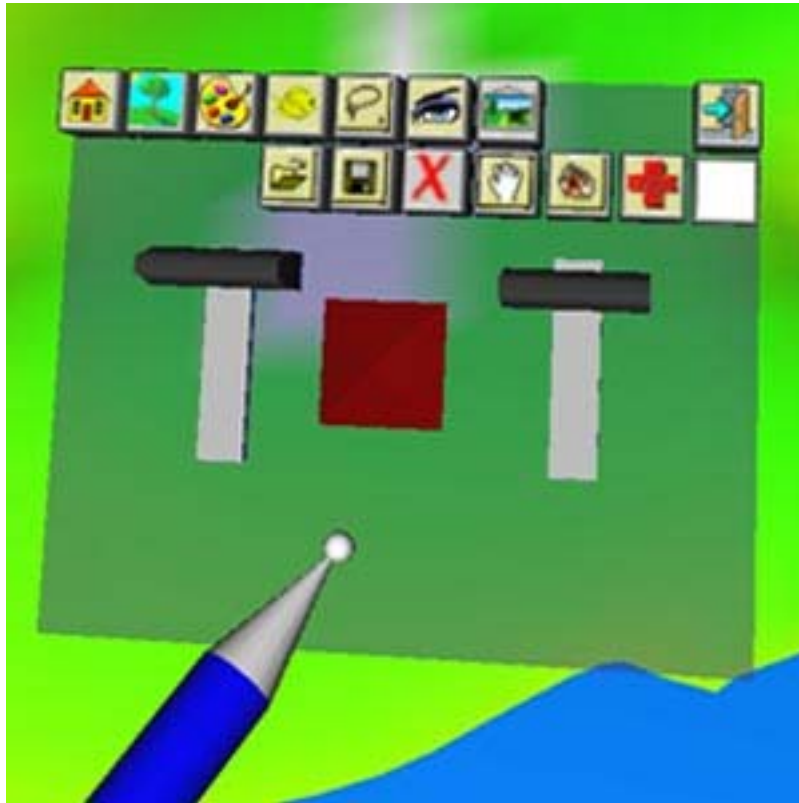


Bridge Crew
- press buttons with your hands
(controller)

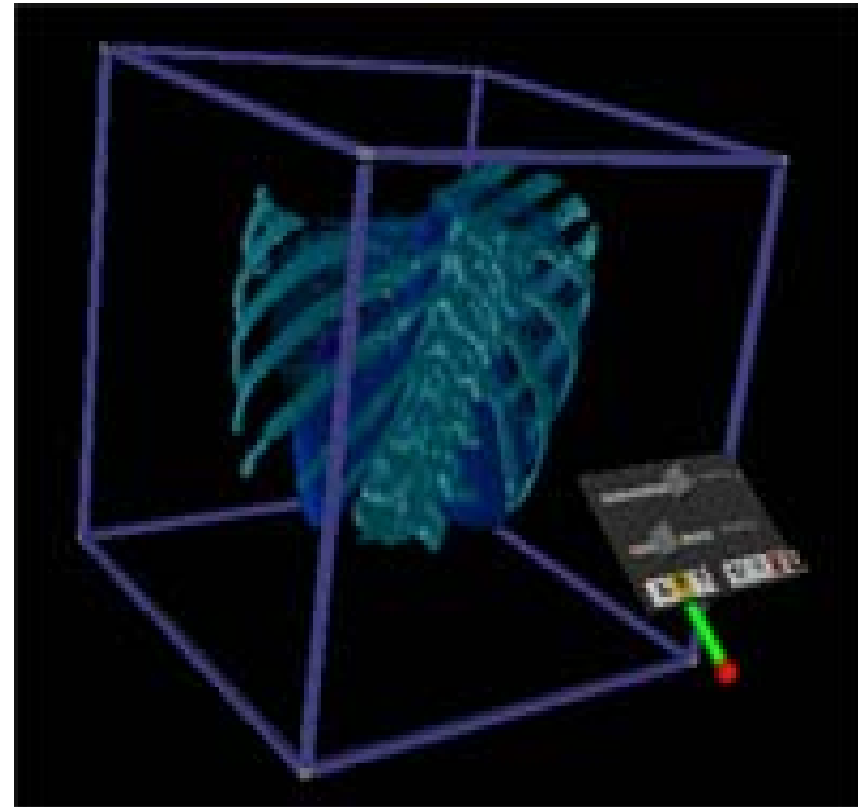


Job Simulator
- UI object manipulation

Virtual Control - Slider



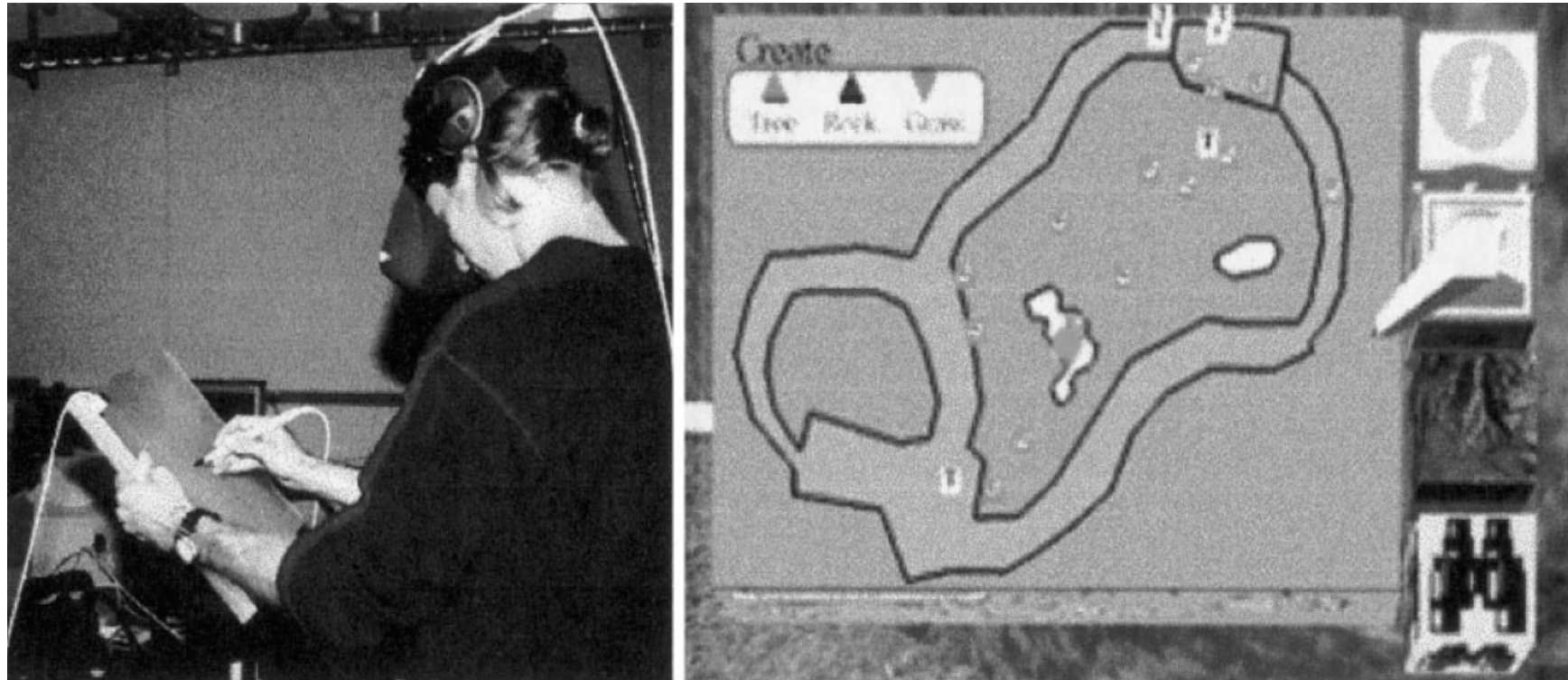
VR Landscape Design



VR² Viz

Virtual Control

– Virtual Controls Mapped on a Physical Device



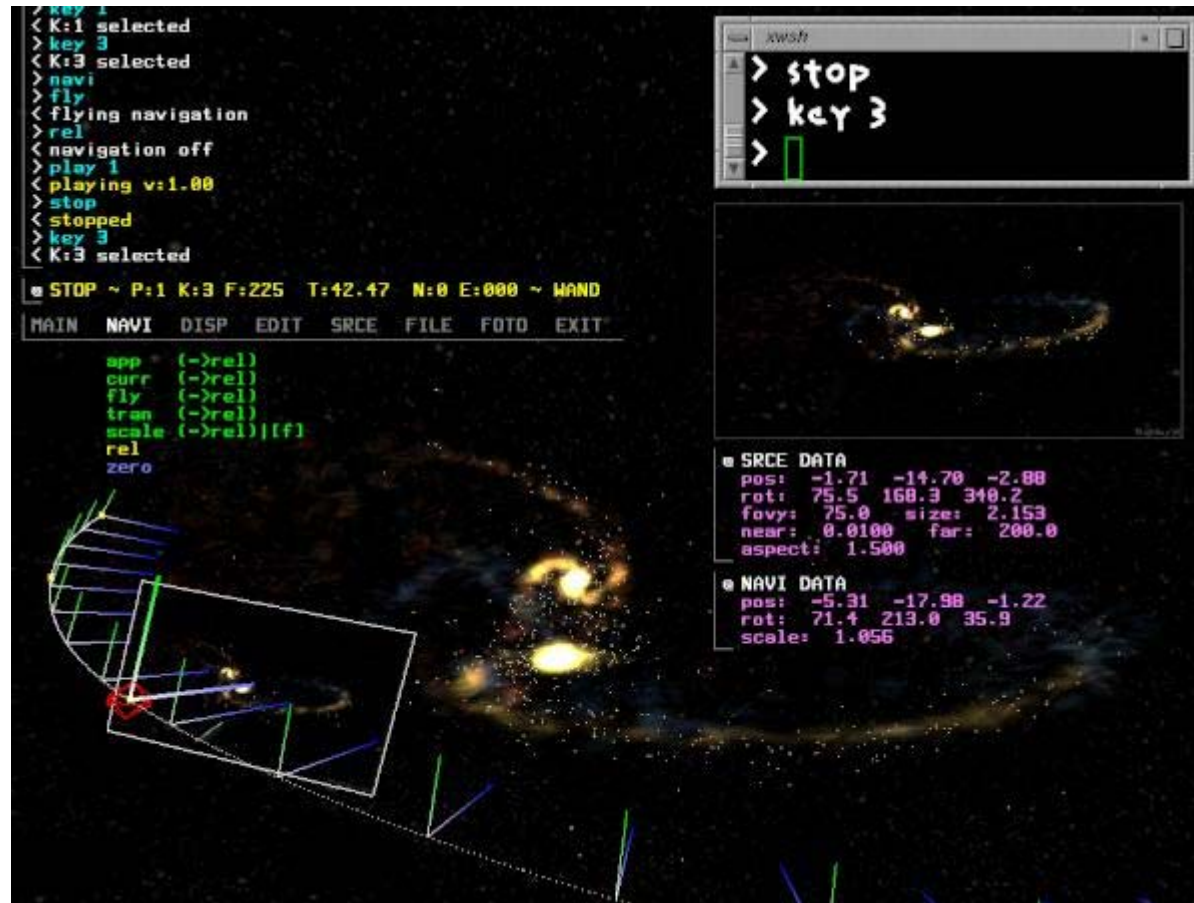
Physical devices used in the pen and tablet interaction metaphor, used in Virtual Reality Gorillas Exhibit

Agent Control

- Tell an “intelligent” agent to perform the action
- The agent can be a person or a computer-controlled entity
- Communication with the agent can take the form of voice (the norm) or gestures
- Gesture communication might be simple body language commands

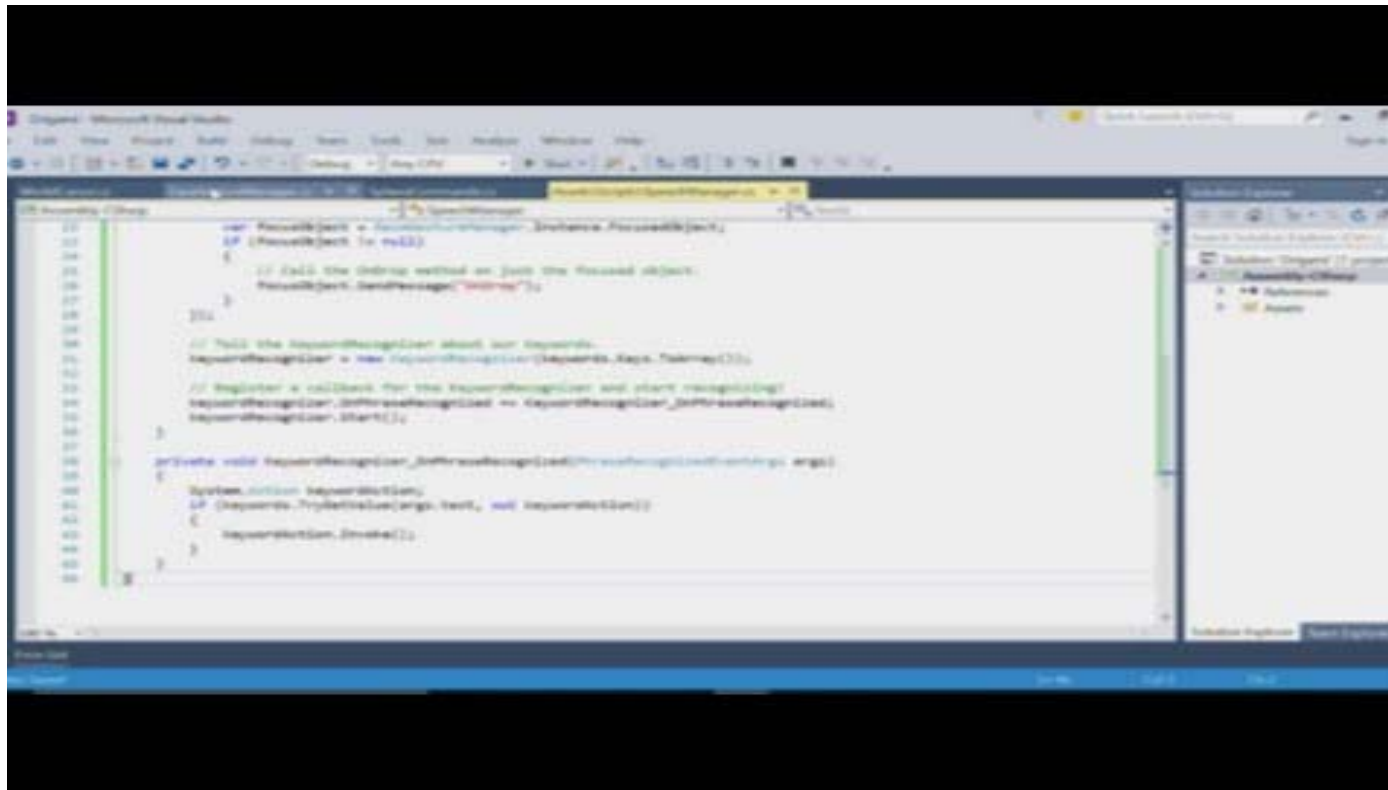
Agent Control

- ❑ In the case of VR applications like the Virtual Director from the 90s, **voice control** was the only convenient way to get around a very complicated menu system



HoloLens Voice Input

- HoloLens makes effective use of voice to rapidly move through the menus without needing to look and pinch.



https://youtu.be/LxbOhnd2_GM

Selection

- Three different selection methods
 - Choosing a *direction* (e.g., pointing)
 - Choosing an *item*
 - Direct input of *numeric* or alphabetic *values*
- Two can be combined, such as when an item selection is carried out by pointing (a direction selection) at the desired choice (e.g., in a menu, on a map, in the world)

Direction Selection

- Useful as a method of item selection (objects or places) and as a directional indicator for travel control (navigation)
- Items can be selected whether they are within reach or not
- Several ways
 - Pointer-directed
 - Gaze-directed
 - Crosshair-directed
 - Torso-directed
 - Device-directed
 - Coordinate-directed
 - Landmark-directed

Direction Selection

□ Pointer-directed Selection

- Selection *by pointing* uses some form of hand posture or gesture to indicate a direction
- Tracking of the hand position or through the use of a prop designed to indicate which way the user is pointing
- An object might be highlighted as the pointer points in its direction
- A visible indicator of a pointer-directed beam showing the scope that is encompassed is useful

□ Gaze-directed Selection

- Selection *by gaze* depends on the visual attention of the participant, making use of the direction the user is looking
- It is actually the direction of the head because most VR systems do not yet track the actual movement of the eyes

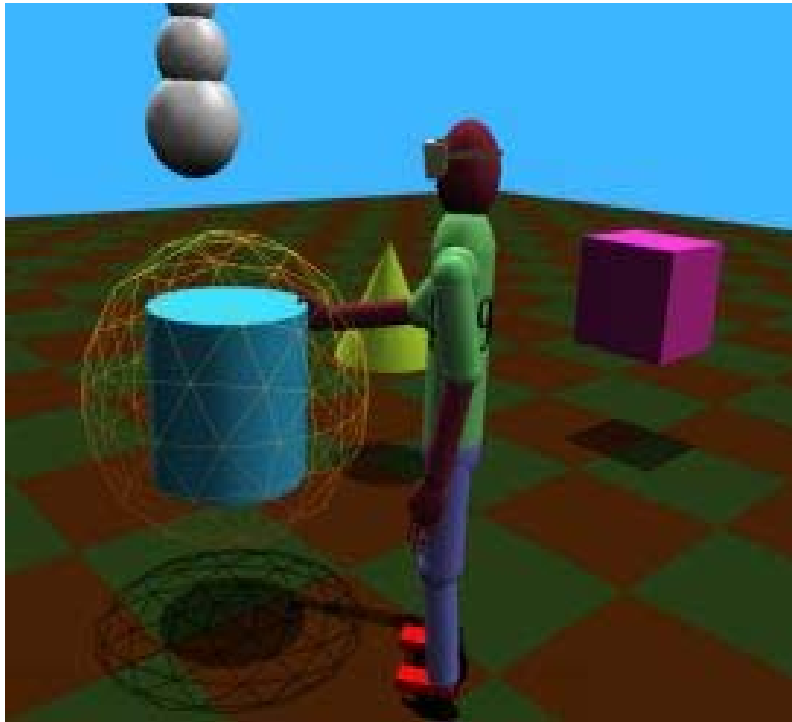
Direction Selection

- ❑ Crosshair-directed Selection
 - Requires use of both the head and the hand
- ❑ Torso-directed Selection
 - Good for indicating the direction of travel
- ❑ Device-directed Selection
 - Uses a physical control
 - May be relative to an absolute reference (e.g. north) or to current direction (e.g. turn left)
- ❑ Coordinate-directed Selection
 - Uses coordinates (e.g. 30 degrees east of north or turn left 45 degrees)
 - Input by a value-selection technique (e.g. voice)
- ❑ Landmark-directed Selection
 - Requires some means of indicating the landmark or object in the environment (e.g. toward the water tower)

Item Selection

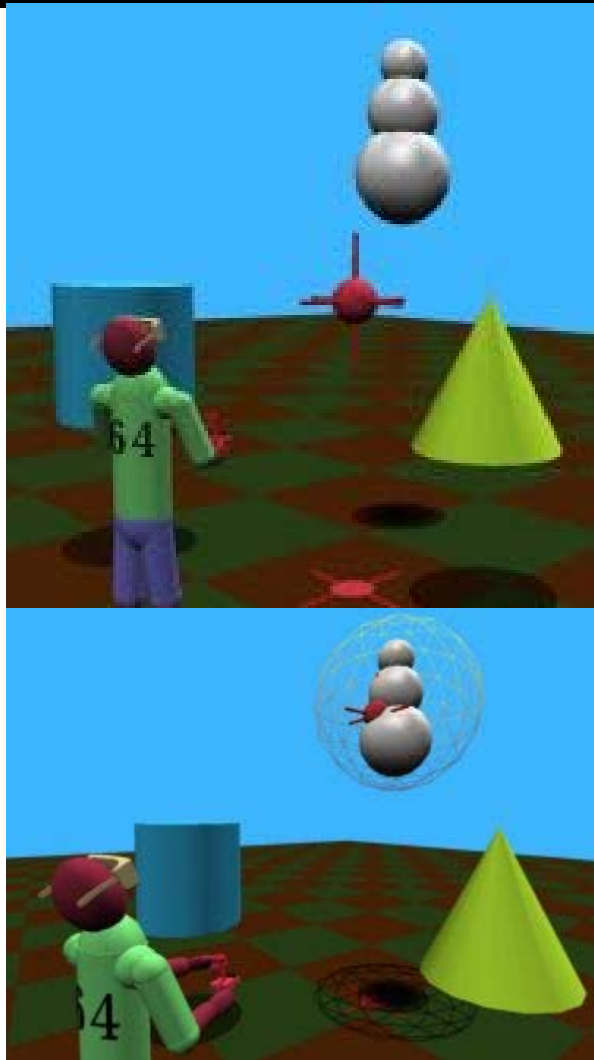
- ❑ Generally applicable to VR of all purpose but can be customized to meet the needs of a particular application
- ❑ The items in a list can appear as individual objects in the world, groups of objects, or even as locations
- ❑ Several ways
 - Contact select
 - 3D-cursor select
 - Menu select
 - Point to select
 - Name to select
 - Select in mini world
 - Aperture select

Item Selection



- Selection by contact
 - Part of the avatar of the user must contact with the desired object
 - Contact itself may automatically activate an action, or the user may need to separately trigger activation
 - Object contact feedback can come in many forms (e.g. a visual highlight, an aural signal, or kinesthetic resistance)

Item Selection

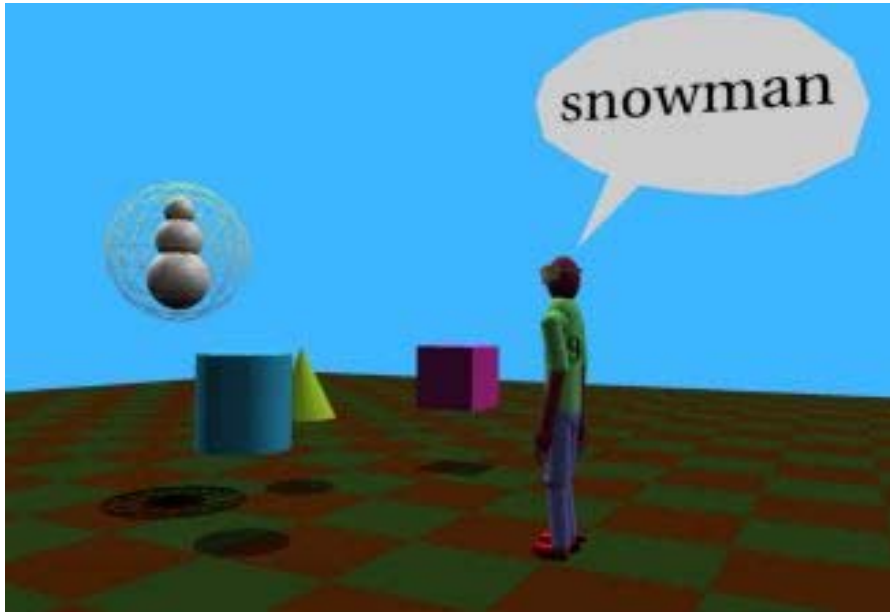


- Selection by 3D cursor
 - User controls a 3D cursor by some means (e.g. flown by joystick)
 - Selected when the cursor comes in contact with an object
 - If cursor is attached to a handheld prop, then this is very similar to selection-by-contact

Item Selection

- Selection by menu
 - Familiar to most computer users
 - Requires a list of all possible items from which to select an item
 - Menus can be made with texts, graphics, 3D representations of objects
 - Requires means of input to indicate the a menu choice is selected
- Selection by pointing
 - Use direction of pointing to indicate an object
 - Similar to contact-selection, but object can be out of reach (e.g., point with a prop or via the user's gaze)
 - Typically, a second action must be performed by the users to designate the candidate as their choice

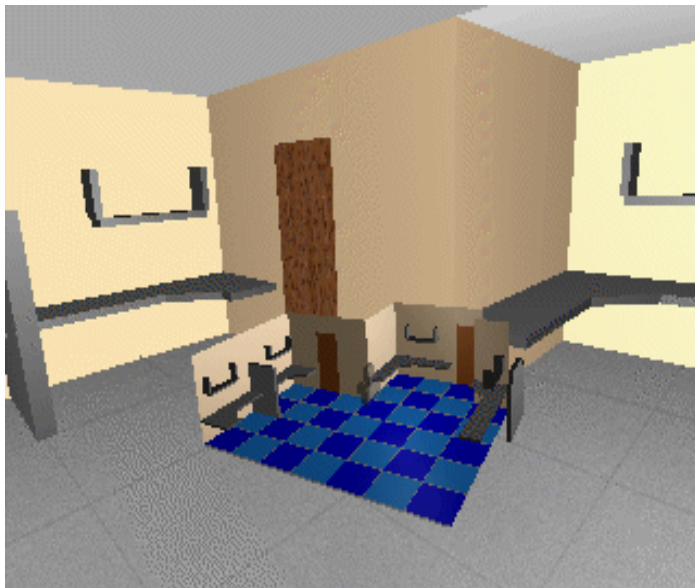
Item Selection



- Selection by naming
 - Very familiar to users
 - Require voice recognition
 - Need to verify that the computer "understood" what was intended (e.g. object could be highlighted momentarily before the action is taken, allowing the user a chance to cancel the operation)
 - Require that the user knows the exact name of the objects

Item Selection

- Selection in Miniature World
 - Provide smaller replicas of the world, I.e. World in Miniature (WIM)
 - Require means of selecting the menu choice
 - Also similar to contact-selection

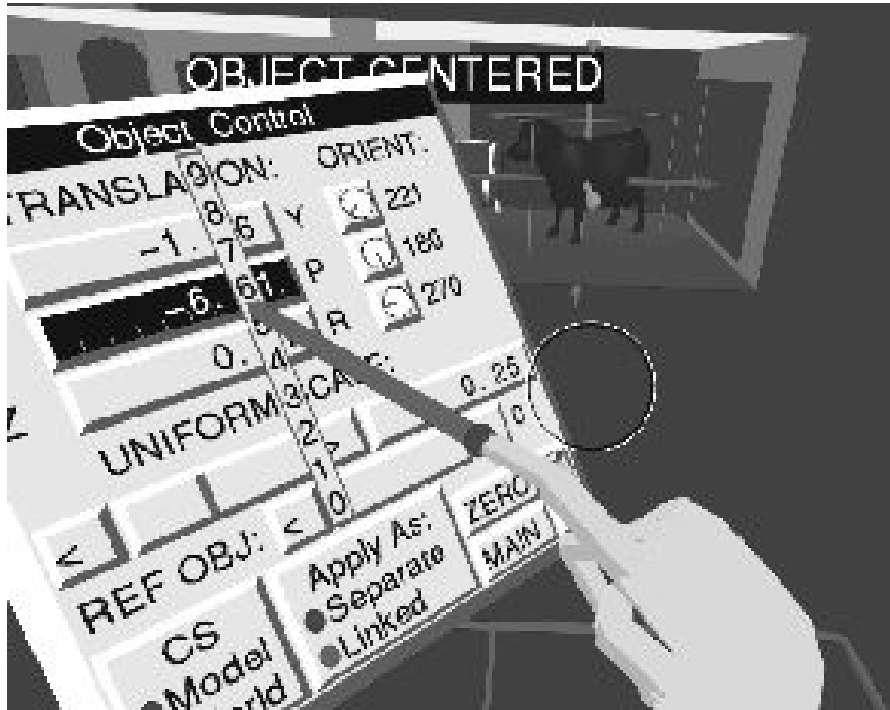


Item Selection



- Selection by aperture
 - Aperture is usually indicated with fingers of the user
 - Require tracking aperture (e.g. fingers)
 - Require tracking the eye location (e.g. head)
 - Require knowing which eye the user is using
 - Similar to direction selection using crosshairs

Value Selection



- Typically uses some form of physical or virtual control (e.g. dials, keyboard)
- May use a menu of pre-selected values
- May use voice input

Manipulation Operations

- ❑ Once the users have selected an object, they may want to manipulate it.
- ❑ Common forms of manipulation operations are:
 - Positioning and sizing objects
 - ❑ Any of the direct, physical, virtual, or agent control can be used
 - Exerting force on a virtual object
 - ❑ Pushing, hitting, and supporting objects
 - Modifying object or global attributes
 - ❑ Changing the parameters, such as transparency, color, light, reflectance, sound qualities, firmness, mass, density, growth rate, that control how an object (world) is rendered or behaves
 - Altering state of virtual controls or travel controls
 - ❑ The changed value of the virtual control may then be used to select, modify, or steer some other object in the world

Navigation



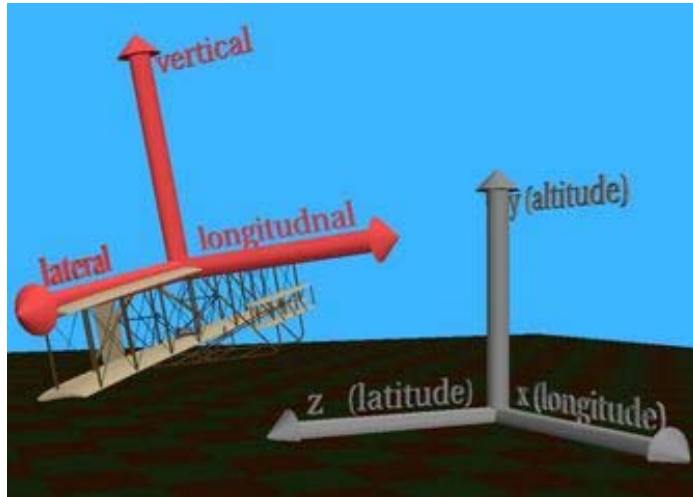
Navigation

- Navigation is how we move from place to place
- In the real world, we navigate as we walk, drive, ski, fly, skate, and sail through the world
- There are endless ways of navigating through VE
- Navigation is the combination of **travel** with **wayfinding**
 - **Travel: How a user moves through space (or time)**
 - **Wayfinding: How a user knows where they are and where they are going**

Why do we care about Navigation?

- ❑ Large scale virtual environments are more common.
- ❑ Users get lost in the virtual world.
- ❑ Users are unable to visit all places in the virtual world.
- ❑ Users are unable to revisit a place.
- ❑ Users do not understand the topology.
- ❑ Familiarization takes time.

Frames of reference



- Ego-centric reference frame
 - Self view of the world (e.g., left/right)
 - Translation: longitudinal, lateral, vertical axes of a body
 - Rotation: yaw, pitch, roll (aka heading, elevation, roll)

- Exo-centric reference frame
 - External view of the world (e.g. north/south)
 - Translation: Cartesian X, Y, Z
 - Rotation: world longitudinal, lateral, altitude

Navigation Tasks

□ Exploration

- No explicit goal of the movement
- User is simply exploring the space
- Usually to build knowledge of the environment or to see what the interesting features might be.

□ Search

- Traveling to a specific target location in the environment
- **Naïve search:** the position of the target is not known
- **Primed search:** the position of the target is known (to some degree)
- User builds layout knowledge
- User moves to task location

Wayfinding

- ❑ The means of determining (and maintaining) awareness of where one is located (in space or time) and ascertaining a path through the environment to the desired destination
- ❑ The goal of wayfinding is to help the traveler know where they are in relationship to their destination and to be able to determine a path to arrive there
- ❑ A major step in achieving this is through the development of a **cognitive map (or mental model) of the environment** through which one is traversing or plans to traverse
- ❑ In the domain of human factors studies, knowledge of one's location and surroundings is referred to as one form of *situational awareness* or sometimes as *navigational awareness*

Cognitive Map

- User build mental model of the space
- Wayfinding aids help
- Strategies
 - Divide & conquer
 - Global network
 - Progressive expansion
 - Narrative elaboration

Spatial Knowledge Acquisition

- During wayfinding, a person makes use of three kinds of **spatial knowledge** to build up a cognitive map of the space
 - Landmark knowledge
 - Route knowledge
 - Survey knowledge
- Acquisition
 - Information comes directly from the environment (primary)
 - Information comes from other source (secondary)

Wayfinding in the real world

- Follow paths, roads
- Use maps
- Use signs
- More difficult in natural environment
 - Use instruments (e.g. compass)
 - Orienteering

Wayfinding Aids

- ❑ An interface for navigating through an environment will often include tools to aid in the process of wayfinding
- ❑ Tools that provide procedural or pathway information (the location of key landmarks, distance measures, and mapping information) can greatly help the user to navigate the space and build a good mental model
- ❑ May include multiple aids (multiple intelligence)
- ❑ Some wayfinding aids are built directly into the environment, while others are tools the traveler always has at their disposal to help them discern information about the environment that cannot be perceived (e.g., compass)

Wayfinding Aids

- Path following
- Maps
- Landmarks
- Memorable place names
- Bread crumbs (leaving a trail)
- Compass
- Instrument guidance
- Exocentric view
- Coordinate display with orthogonal grid structure
- Constrained travel
- World Semi-transparency

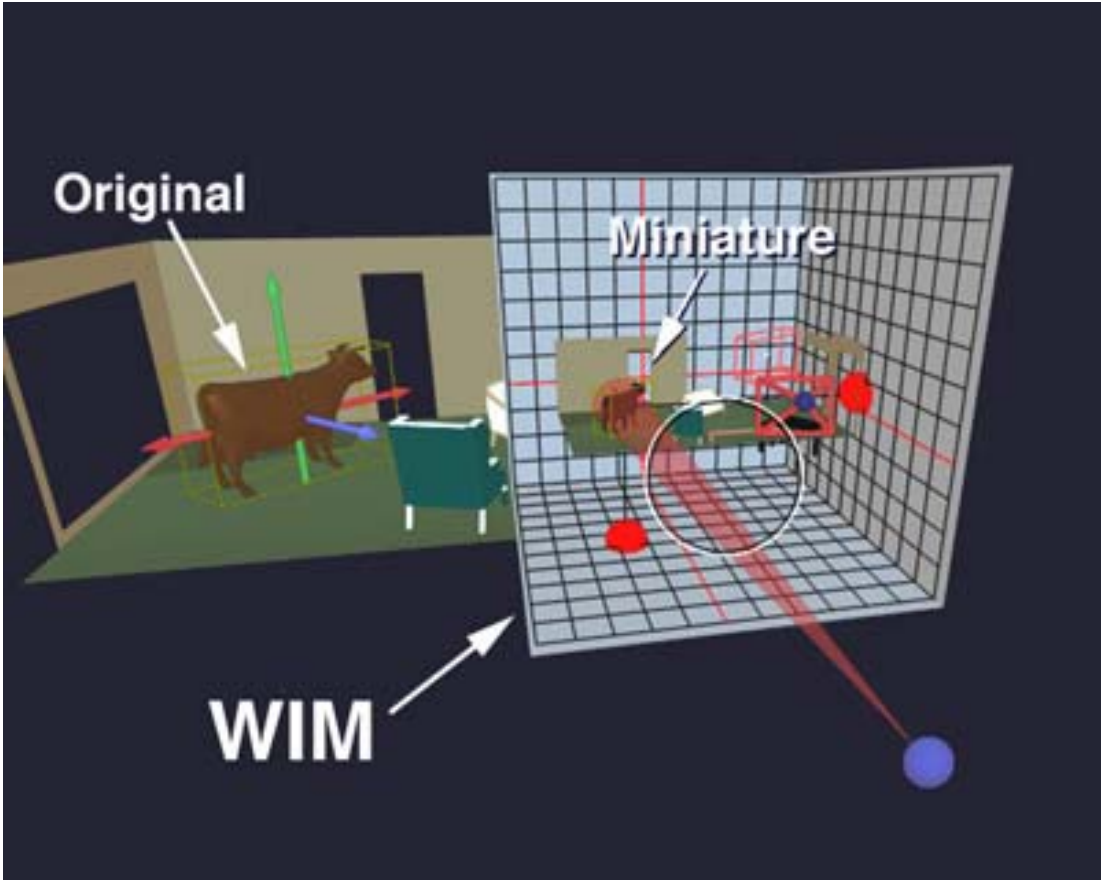
Path Following

- Easy method of wayfinding is to *follow a path* or *trail* within the environment itself
- A path might be marked by a continuous colored line that traces the route, e.g. hospitals colored line
- It might use discrete posts labeled to indicate progression along the path, frequently with an arrow leading to the next way point

Maps

- A common wayfinding aid from the real world
- A map is a graphical representation of any space
- Egocentric (e.g. view-direction-up) vs. Exocentric (e.g. north up) map depending on the task
- *"You are here"* map
- Translucent map
- World-in-miniature is a form of map
- Can be integrated into travel, e.g. the user could point at a location on the map and jump to the specified location

Maps

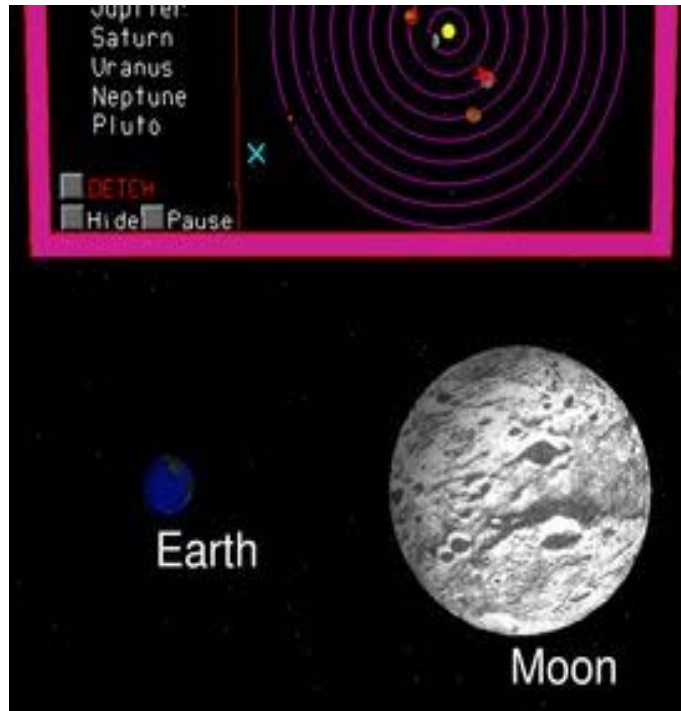


Landmarks



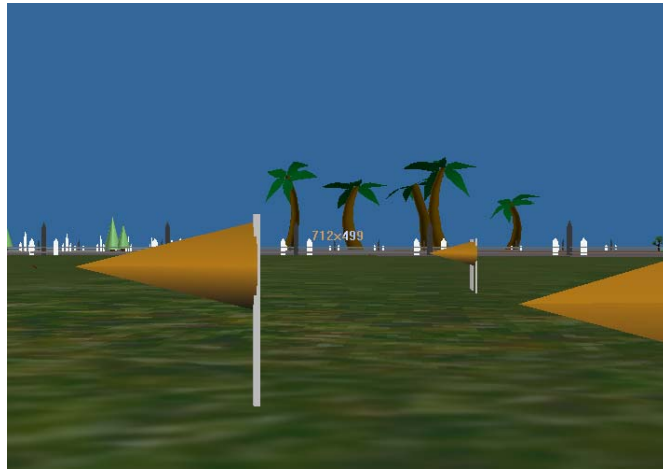
- Any obvious, distinct, and static object
- A good landmark can be seen from several locations and will also be helpful to a user in judging their distance from it
- Audio signals can also be used as landmarks, alone or in conjunction with a visual object

Memorable Placenames



- By assigning *memorable place-names* to locations in a world, the place itself can become a landmark
- Place-names can be used in conjunction with a map display to help a participant determine their current locations
- A *name to select* form of item selection can be used to indicate a travel destination
- Combined with “put me there” method of travel

Bread Crumbs



- ❑ Dropping *bread crumbs* (leaving a trail of markers) can be used as a means of allowing the user to see where they have been before
- ❑ Perhaps use the markers to retrace their “steps” to a previously visited location
- ❑ Hopefully makers will last longer than bread, though having too many markers can make the space be overly cluttered

Compass



- ❑ Serve the same purpose as those in the real world
- ❑ May also be other form of orientation indicator (e.g. artificial horizon)
- ❑ May specify directions in 2D or 3D space

Instrument Guidance



- ❑ Instrument that actively indicates whether on or off course, and how to correct if off course
- ❑ Very common in aviation and marine navigation systems
- ❑ Instrument wayfinding systems are now available for road vehicles – GPS, navigation aid system

Exocentric View

- A temporary shift in viewpoint from an egocentric view to an exocentric view can be used to aid a participant in determining their location within the environment
- For example, a user constrained to walking on the ground could be given the ability to have a temporary exocentric view. Their view could shift to a bird's-eye view above and behind them
- Also called wingman's view
 - Transition between both views
 - Connecting line
 - Wedge to indicate FOV

Exocentric View

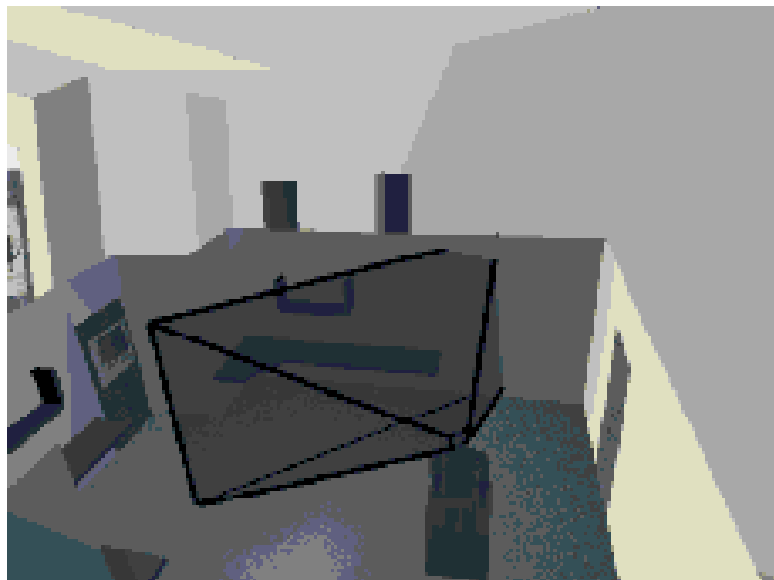
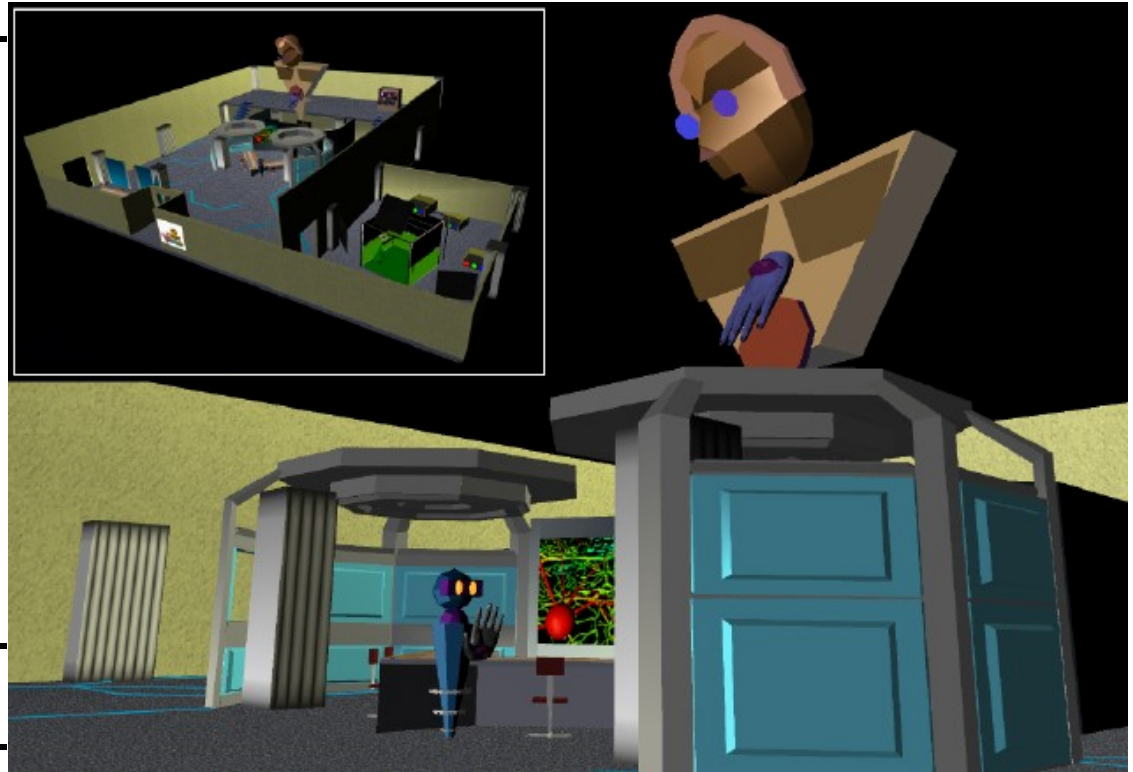
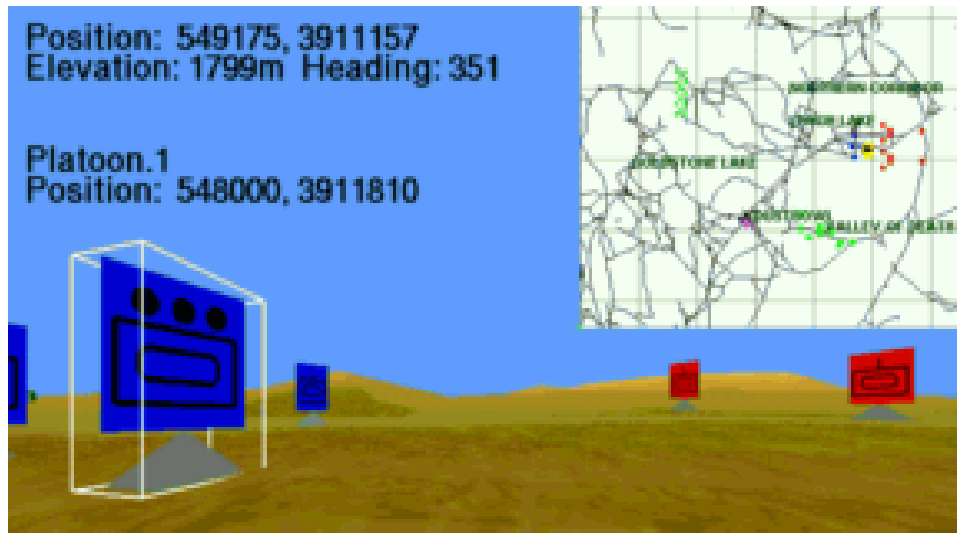


Figure 2: A frustum which corresponds to the user's current view.



Coordinate Display and Orthogonal Grid Structure

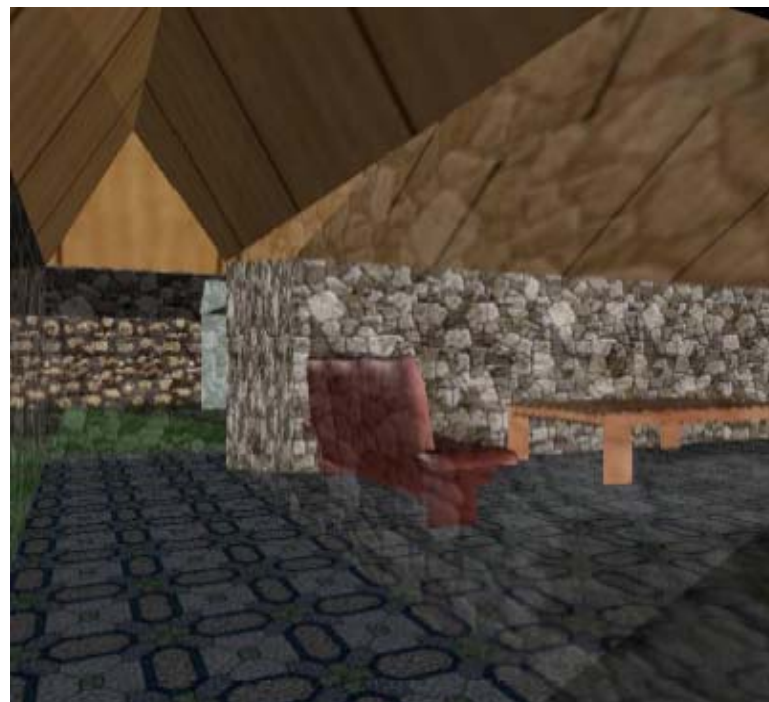
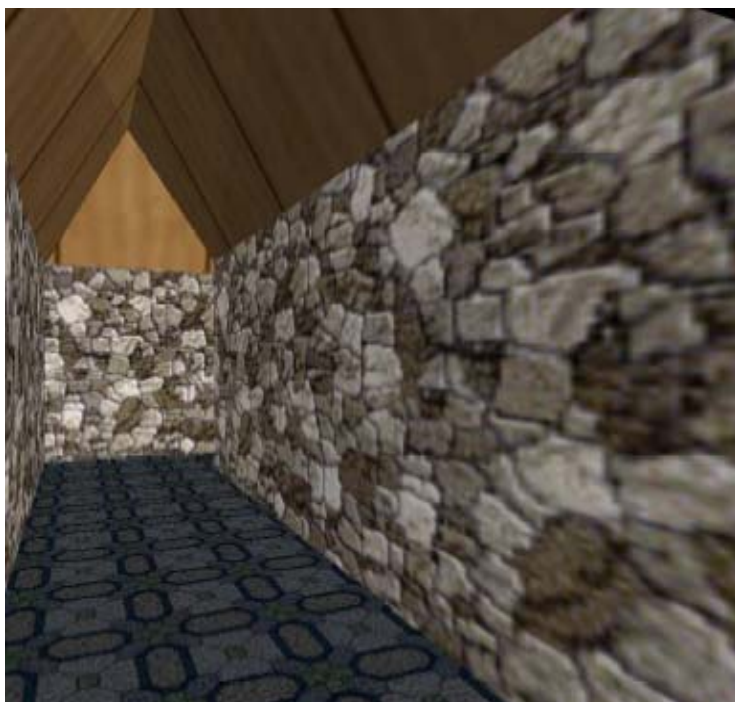


- Presented as text string that displays *coordinates* of user location information
- Requires a means of relating those numbers to the world
- Provides names of places
- Displays visual grid itself
- This can be used to give one's location to another participant or it can be stored for future reference to help return to the same location

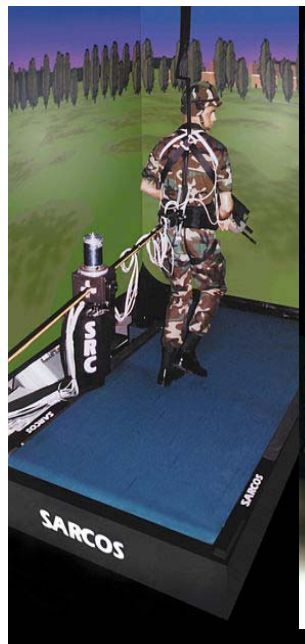
Constrained Travel

- ❑ One of the problems with moving freely through multidimensional space is that it can be very disorienting
- ❑ By restricting the number of ways and places a user can travel, their ability to become lost is reduced
- ❑ Typically built into the form of travel chosen

World Semi-transparency



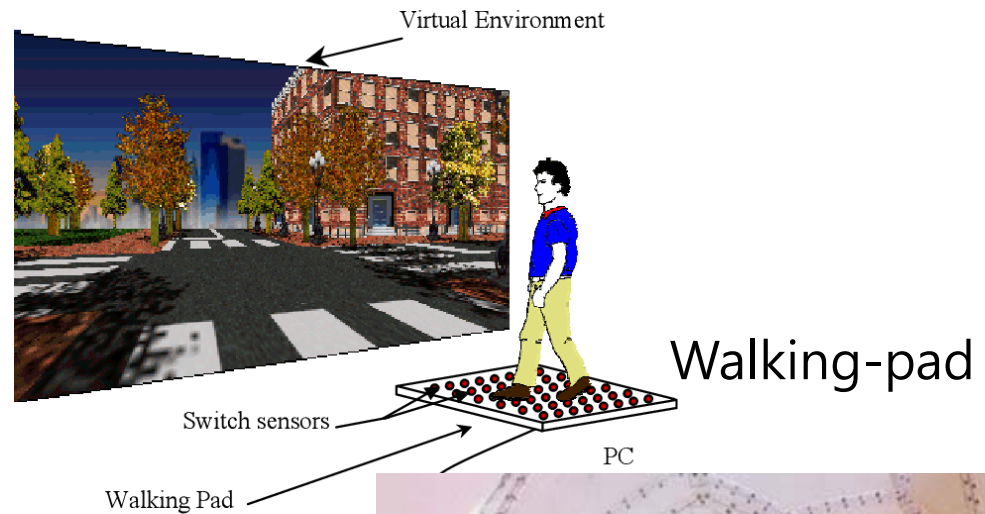
Travel



Travel



Virtuix Omni walking platform
In 5 Best VR Treadmills (2019)
<https://thetechinfluencer.com/best-vr-treadmill/>



VirtuSphere
<https://youtu.be/5PSFCnrk0GI>

Travel

- ❑ *Travel* is the crucial element that accords them **the ability to move through and explore a space**
- ❑ Some travelers learn to traverse the world via a joystick, riding in a motorized wheelchair
- ❑ Many more learn to use a joystick, button, or mouse to journey through computer-based worlds
- ❑ The choice of travel method and how to implement it may be based on the genre of the experience, on the I/O devices available to the developer, or on devices known to be available to the user

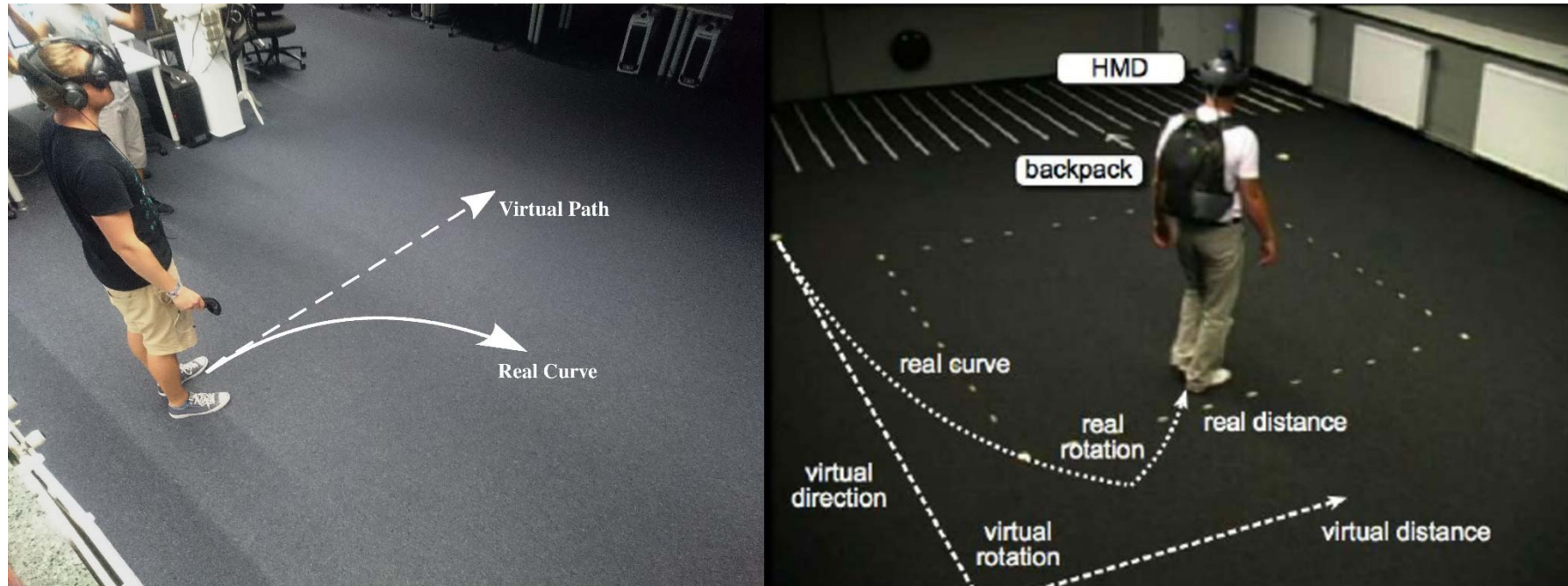
Travel Methods

- Physical locomotion
- Ride along
- Tow-rope (river metaphor)
- Fly-through (walk through)
- Pilot-through
- Move the world
- Scale the world
- Put me there
- Orbit viewing

Physical Locomotion

- Physical movement of the user is the simplest way to travel
- Requires that user's position in the real world be tracked, and used to position the user in the virtual world
- Requires that the user be allowed to walk in a space large enough to cover the virtual world (or **trick the user into walking in circles**)
- The scope of user movement is limited by the tracking technology (e.g., large-area trackers allow the exploration of larger worlds)
- Work in conjunction with many other forms of travel

Physical Locomotion - Redirected Walking (RDW)



Ride Along

- ❑ The user rides on a path controlled by the experience, and mimics some real world experiences – e.g. roller coaster
- ❑ Application developer can control the scope of the world that a participant can visit and can concentrate world modeling efforts on portions of the world that are more important to the overall experience
- ❑ The interface is simpler than more flexible travel paradigms, and thus requires less VR skill training

Two-rope



- Slightly less restrictive than ride-along
- The traveler is being towed through the environment
- The participant is able to veer away from the tow vehicle within the constraints of the towrope length, giving user freedom to move
- Speed is generally controlled by the pulling entity and not the user

Fly-through

- ❑ The most generic method of travel through a virtual space
- ❑ Walkthrough paradigm is basically the same, but with a terrain-following constraint applied to the traveler
- ❑ There are many ways to implement the control interface for fly-through travel:
 - Pointer-directed fly-through
 - Gaze-directed fly-through
 - Torso-directed fly-through
 - Dual-handed fly-through
- ❑ A common method of travel in many CAVE applications is to add yaw rotation to the use of the handheld wand prop for a pointer-directed walkthrough

Pilot-through



- ❑ Any form of travel based on the control of virtual vehicle
- ❑ Similar to fly-through, but with an extra layer of control
- ❑ Typically uses manipulation of (physical or virtual) controls, e.g. steering wheels, pedals, joystick
- ❑ Often mimics real world vehicles

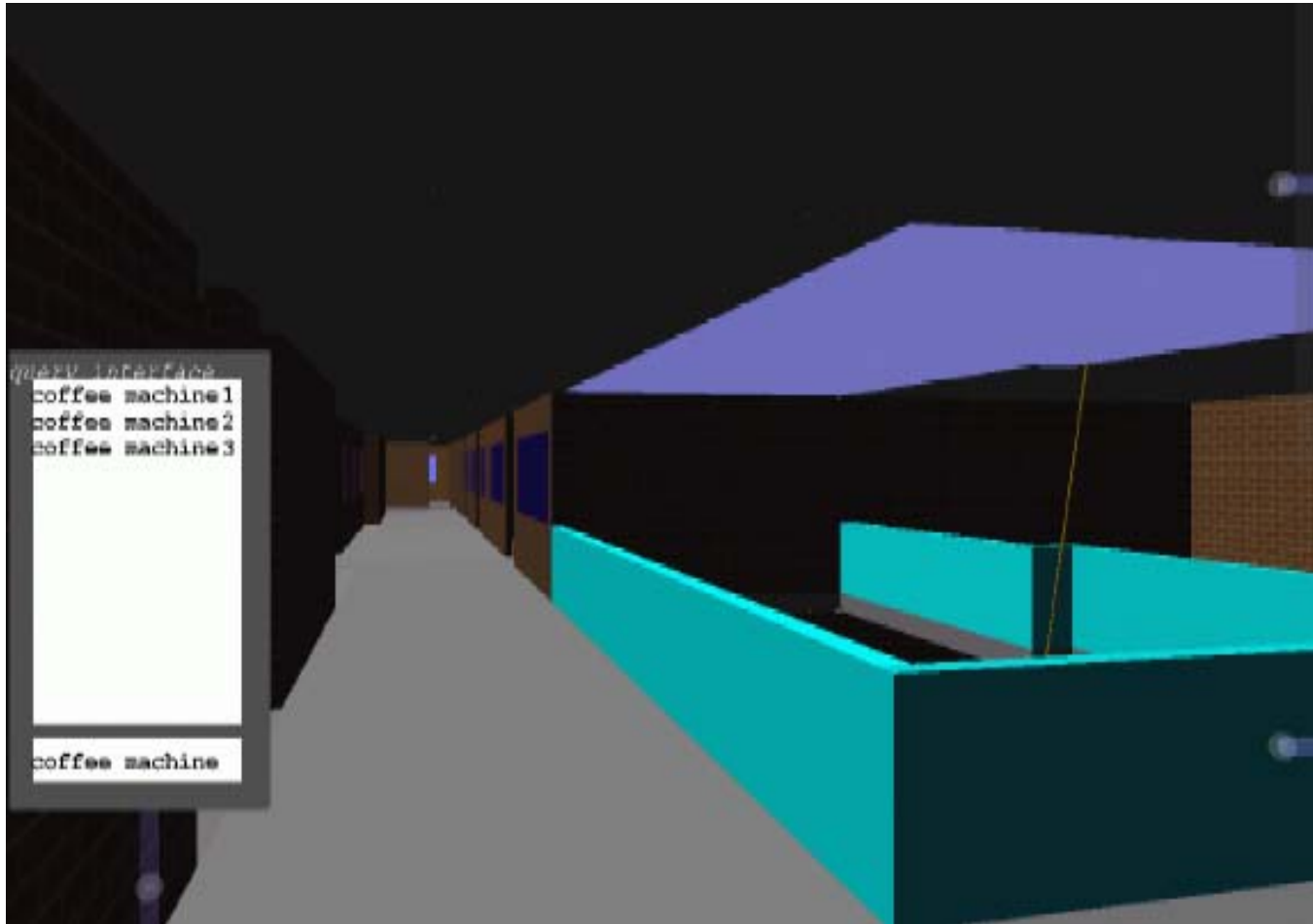
Move-the-world & Scale-the-world

- Move-the-world
 - Fly-through from another perspective
 - Instead of flying myself through the world, user manipulate how the world flys around me
- Scale-the-world
 - Also treats the world as an object
 - Travel is the result of two scale operations about a different reference point
 - Scale down about the current location, change reference points scale back to original size

Put Me There

- Simplest form of travel to implement and perhaps the easiest way to travel virtually
- The user specifies a destination and is taken to that place
- Can occur instantaneously or over a period of time
- Destination is generally chosen by some form of:
 - item selection (e.g., map selection, miniature world representation)
 - menu selection
 - voice selection
 - entering a portal (with a specific destination)

Navigation by Item Query and Selection



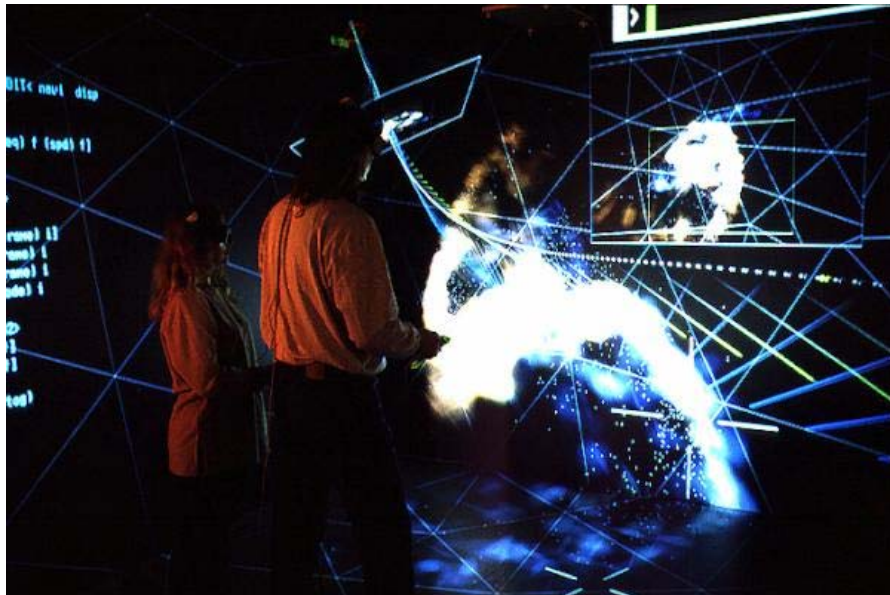
Navigation by Item Query and Selection



Orbital-viewing

- ❑ Direction of looking (head orientation) indicates at which side of an object to look
- ❑ In this case, the entire world generally consists of a single object
- ❑ Which ever direction you look, you see the other side of the object (i.e., as if the object were orbiting around your head)
- ❑ Can be counter intuitive at first

Time travel



- For scientific applications
 - Freeze time
 - Accelerate & Decelerate
- Clock style
- Time bar
- VCR controls

Reference

- <https://www.evl.uic.edu/aej/528/>
- <https://www.evl.uic.edu/aej/428/>