Module IN 2018

3D User Interfaces
- Dreidimensionale Nutzerschnittstellen -

Prof. Gudrun Klinker

Interaction Techniques: Travel
SS 2023

Agenda

1. 3D travel tasks
2. Travel techniques
3. Design guidelines

1. 3D Travel Tasks

1.1 Exploration

- No explicit goal for movement
  - Browse the environment
  - Obtain information about objects and locations
  - Build up knowledge of the environment
- Used at the beginning of an interaction with an environment
- Spontaneous movements
- UI Requirements
  - Allow for continuous, direct control of viewpoint
  - Interrupt animated viewpoint control
  - Little cognitive load on user w.r.t understanding the technique

1.2 Search

- Travel to a specific goal or target location within the environment
  - Naive search

    Exploration
    ↔ Directed search (wayfinding aids)
  - Primed search

    Incomplete starting knowledge of environment
    ↔ Complete survey knowledge
- UI options
  - Goal-oriented approaches
    - Specify destination on map
      (inefficient if destination is not explicitly shown on map)

1.3 Manoeuvering

- Small, precise movements in a small area
  - Reposition local viewpoint
- Can cost users precious time and cause frustration
- UI requirements
  - Great precision of motion
  - Very fast
  - Tight feedback loop

1.4 Additional Travel Task Characteristics

- Distance to be traveled
  - Short-range: high precision
  - Medium-range
  - Long-range: velocity control, tele-portation
- Amount of curvature or number of turns in the path
  - Little curvature: steering based on torso-direction
  - Much curvature: pointing-based travel
- Visibility of the target from the starting location
  - Visible target: gaze-based techniques

1.4 Additional Travel Task Characteristics

- Number of DOFs required for the movement
  - Motion in horizontal plane (driving, terrain-following)
  - Motion in 3D (flying)
- Required accuracy of the movement
  - High accuracy: technique that allows for
    - Fine control of direction, speed, target location
    - Easy error recovery
  - Medium/low accuracy: map-based techniques
- Other primary tasks that take place during travel
  - E.g., count the number objects in an environment
  - Travel technique must be
    - Unobtrusive
    - Intuitive
    - Easily controlled

Agenda

1. 3D travel tasks
2. Travel techniques
3. Design guidelines

2. Travel Techniques

2.1 Technique Classifications

- Active vs. passive techniques
  - Active: movement of viewpoint controlled by user
  - Passive: viewpoint controlled by the system
    - if travelling is secondary task
  - Mixture: route planning (user plans, system executes)
- Physical vs. virtual techniques
  - Physical: user's body physically translates/rotates
    - Physical motion via locomotion device
  - Virtual: user's body is stationary/irrelevant
    - desktop VEs
  - Mixtures:
    - Physical rotation (head tracking) + virtual translation

	active	passive
physical	user motion	user-initated, then system-animated?
virtual	desktop UIs	animated

2.1 Technique Classifications

- Example: VR Roller Coaster

  Animated ?
  - Mostly passive ?
    viewpoint controlled by the system
  - Mixture physical/virtual ?
    user‘s body is stationary
    (position fixed in the MOVING car,
    head rotation not fixed)

https://www.schloss-thurn.de/attraktion/vr-achterbahn/

	active	passive
physical	user motion	user-initated, then system-animated?
virtual	desktop UIs	animated

VR Roller Coaster

2.1 Technique Classifications

Classification using task decomposition [Bowman et al 97]

- direction/target selection
  - gaze-directed steering
  - pointing/gesture steering (including props)
  - discrete selection
    - lists (e.g., menus)
    - environmental/direct targets (objects in the virtual world)
  - 2D pointing
- velocity/acceleration selection
  - constant velocity/acceleration
  - gesture-based (including props)
  - explicit selection
    - discrete (1 of n)
    - continuous range
  - user/environment scaling
  - automatic/adaptive
- input conditions
  - constant travel/no input
  - continuous input
  - start and stop inputs
  - automatic start or stop

2. Travel Techniques

2.2 Physical Locomotion Techniques

- Use user‘s physical exertion
- Intended for immersive VEs
- Used in
  - High-end video games

https://www.facebook.com/levrgalaxy/

  - Location-based entertainment systems

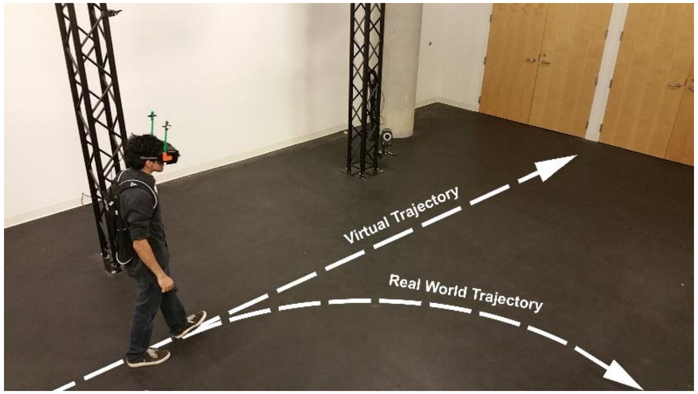
https://www.nintendo.de/Spiele/Smart-Gerat/Pokemon-GO-1112517.html

2.2 Physical Locomotion Techniques

2.2.1 Walking

Full gait techniques

- Real walking
- Redirected walking
- Scaled walking



2.2.1 Walking

- Approach
  - (Tracked) users physically walk in the VE
- Addressed human cues
  - Vestibular motion
  - Spatial understanding
- Problems
  - Limited „real“ range of the VE
  - Cables
- Experiments/extensions
  - VirtualPit experiments (UNC)
  - HiBall system (UNC)
  - Augmented Reality

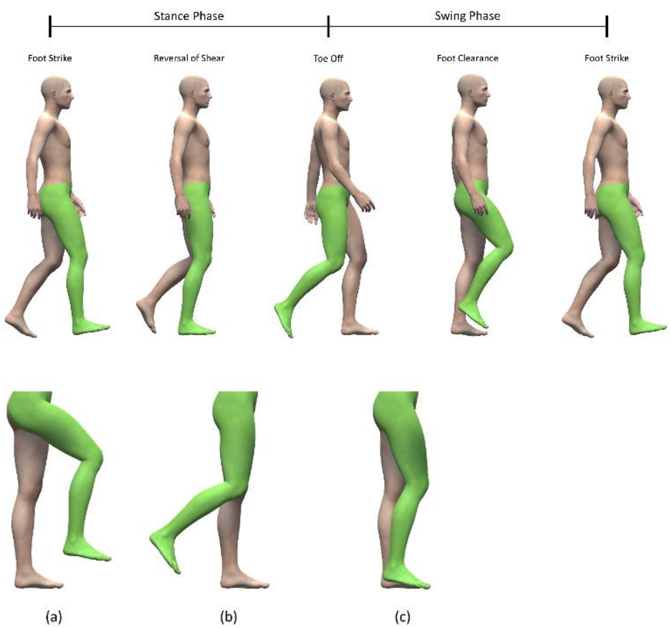

University of Northern Carolina (UNC)

Columbia University (CU)

2.2.2 Walking in Place

Partial gait techniques

- Walking in place

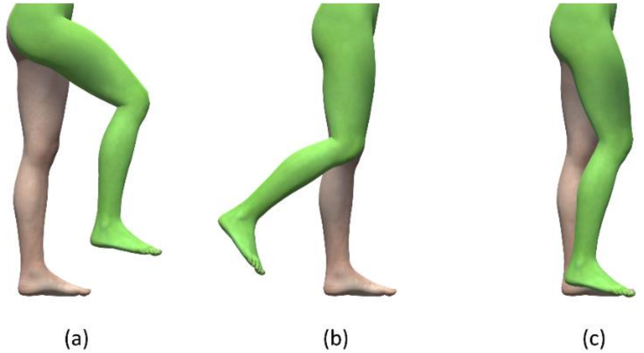


- Human joystick

VMC, Wells 96 (HIT Lab)

2.2.2 Walking in Place

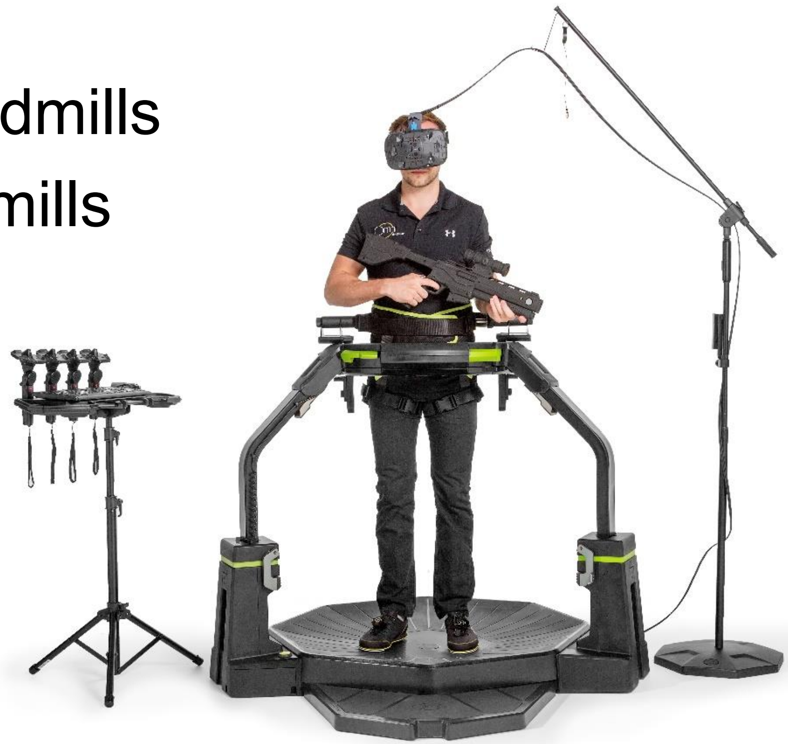
- Approach
  - Move feet to simulate walking (without real translation)
- Addressed human cues
  - Physical exertion
- Problems
  - Users cannot walk infinitely far (takes too long, users get tired)
- Experiments/extensions
  - Relative tracking of moving feet
  - Sense of presence: Walking > walking in place > virtual travel in VEs (flying) [Usoh 99]
  - Efficiency, task performance: virtual travel > walking in place



2.2.3 Devices Simulating Walking

Gait negation techniques

- Treadmills
- Passive omnidirectional treadmills
- Active omnidirectional treadmills
- Low-friction surfaces
- Step-bases devices



Low-friction surface
Virtuix

2.2.3 Devices Simulating Walking

- Approach
  - Use special locomotion devices (treadmills, …)
- Problems
  - How can users rotate on a treadmill?
- Experiments/extensions
  - Joystick or head tracking for rotations
  - Treadmill on a motion platform
  - Omnidirectional treadmill (ODT), Torus treadmill
  - GaitMaster
    (detection of walking motion via force sensors in a „ground surface“ attached to each foot)

Torus Treadmill
Tzukuba University, Iwata 1999

GaitMaster2
Tzukuba University, Iwata 2001

2.2.4 Cycles

- Approach
  - Vehicle-based approach
    - Bicycle (pedal-driven)
- Pro
  - Mechanically less complex
- Problems
  - Not as believable as real walking

Oculus Quest 2

Peloton bike

2. Travel Techniques

2.1 Technique classifications

2.2 Physical locomotion techniques → 行走

→ 2.3 Steering techniques 转向

2.4 Route-planning techniques

2.5 Target-based techniques

2.6 Manual manipulation techniques

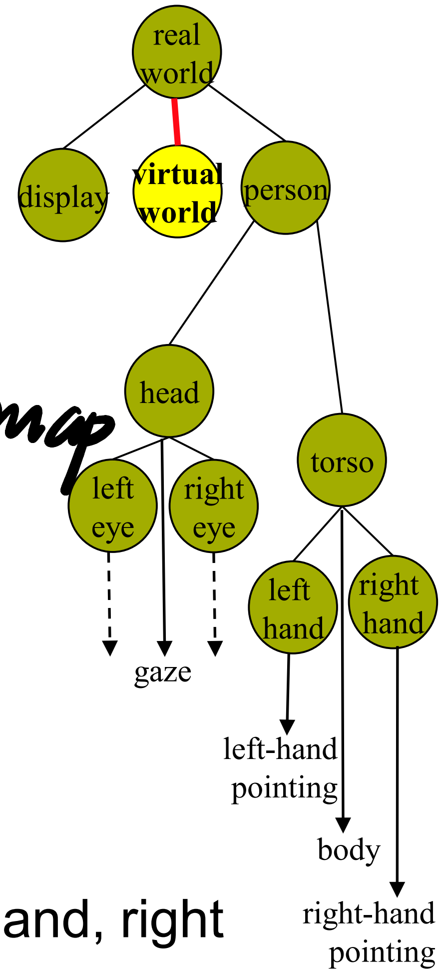
2.7 Travel-by-scaling techniques

2.8 Viewpoint orientation techniques

2.9 Velocity specification techniques

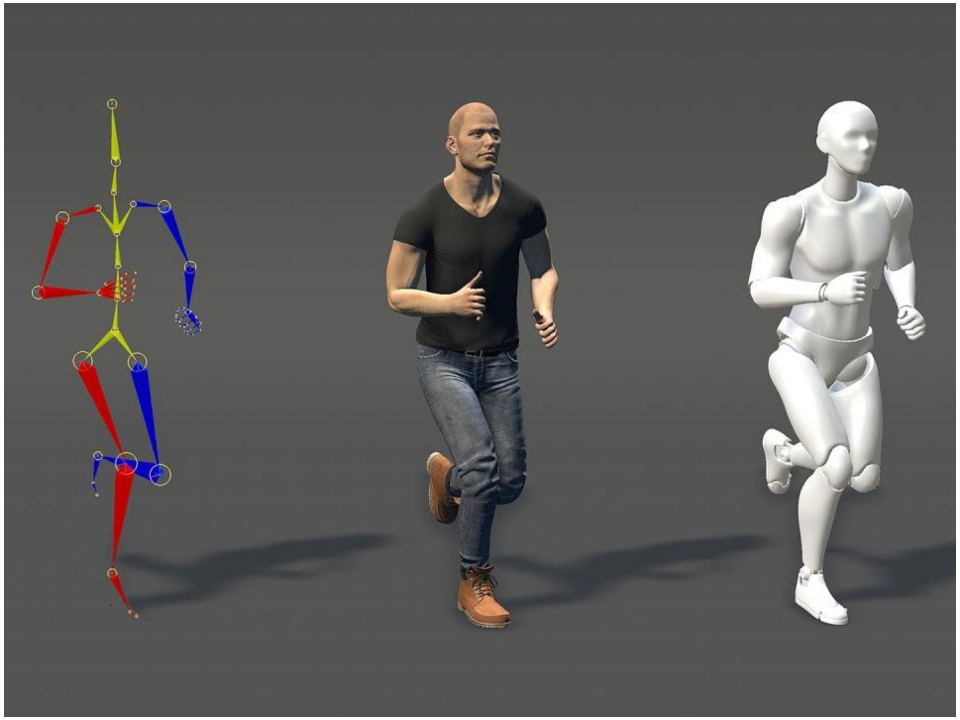
2.10 Integrated camera controls for desktop 3D environments

2.3 Steering Techniques



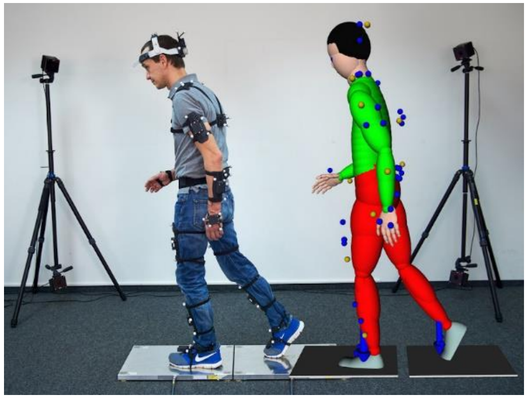
- Virtual travel techniques (immersive, desktop-based)
- Continuous control of the *direction* of motion
  - Absolute (north, west, east, south) → 前提：有map
  - Relative (left, right, forward, backward) → 更自然
- Coordinate systems:
  - World-based (absolute)
  - Person-based (relative: „ego“-x)
  - Large number of interlinked coordinate systems
    - Positions: head, left eye, right eye, torso, left hand, right hand
    - Orientations: gaze, body, hand pointing (left, right)

2.3 Steering Techniques



https://www.3dart.it/en/how-to-transfer-mocap-data-from-the-content-browser-over-to-a-character-in-c4d/

AzureKinect, Assetstore.unity.com

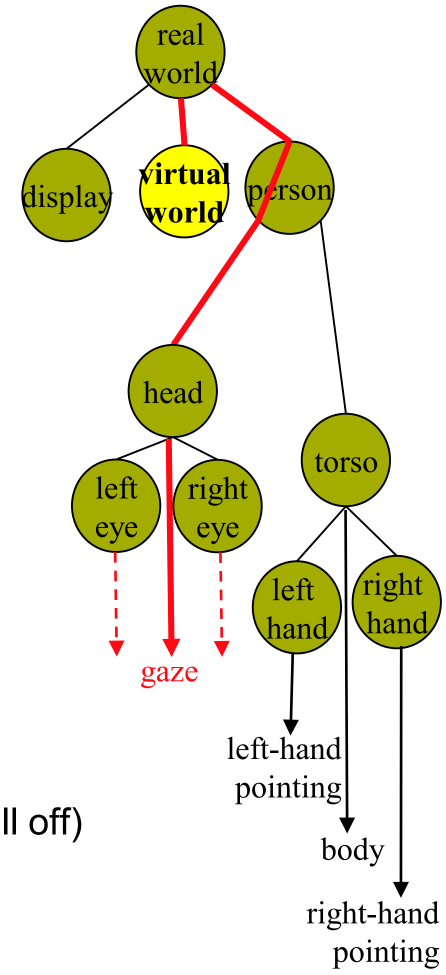


https://ar-tracking.com/en/product-program/motion-capture

2.3 Steering Techniques

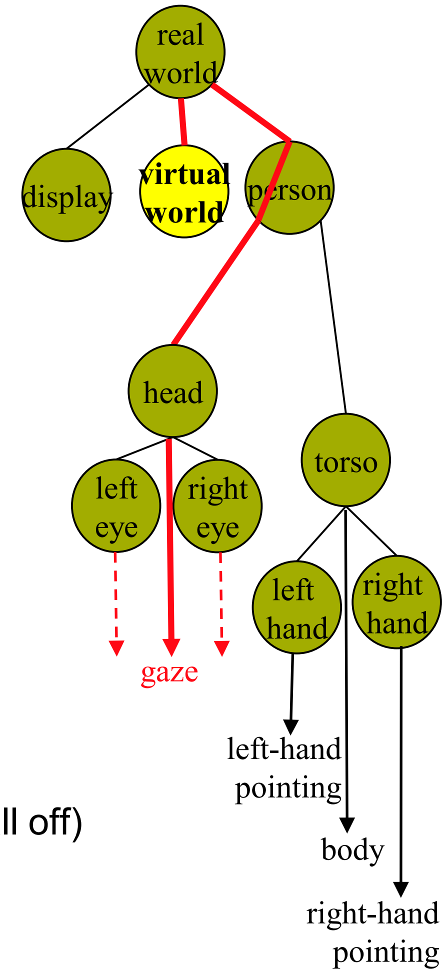
- → 2.3.1 Gaze-directed steering
- 2.3.3 Pointing
- 2.3.3 Torso-directed steering
- 2.3.4 Lean-directed steering
- 2.3.5 Camera-in-hand technique
- 2.3.6 Physical steering props
- 2.3.7 Virtual motion controller
- 2.3.8 Semi-automated steering

2.3.1 Gaze-Directed Steering



- Approach
  - Travel along viewing direction
    - Directional component:
      - Orientation of head tracker
      - Viewing direction of eye tracker (if available)
      - Desktop: Ray from virtual camera position through center of window
    - Translational component (slider or joystick with button-press)
      - (Scaled) additive amount (position change)
      - Multiplicative amount (speed)
- Pro
  - Easy to understand for users
  - Modest hardware requirements
- Problems
  - „Flying“ hard to realize
    - Horizontal motion: head has to be exactly upright
    - Lifting up from the ground = looking up to the ceiling (HMD may fall off)
  - Coupling of gaze direction with steering direction
- Experiments/extensions
  - Strafing (motion orthogonal to viewing direction)

2.3.1 Gaze-Directed Steering



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- Experiments/extensions
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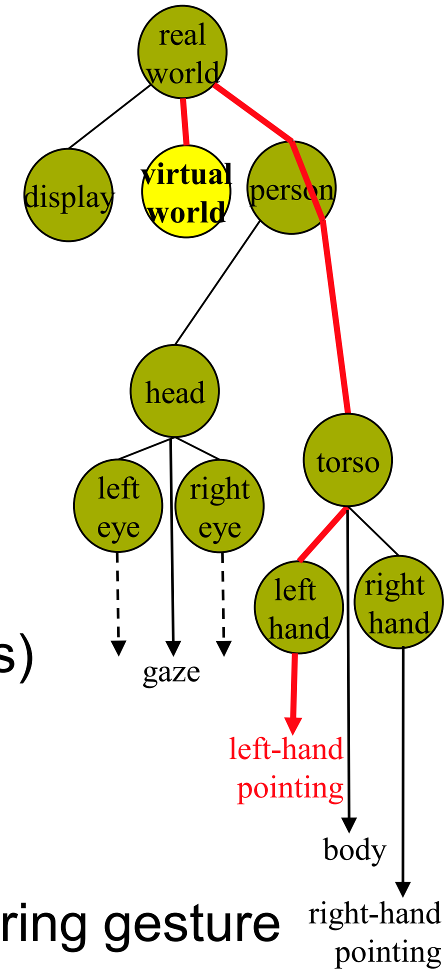
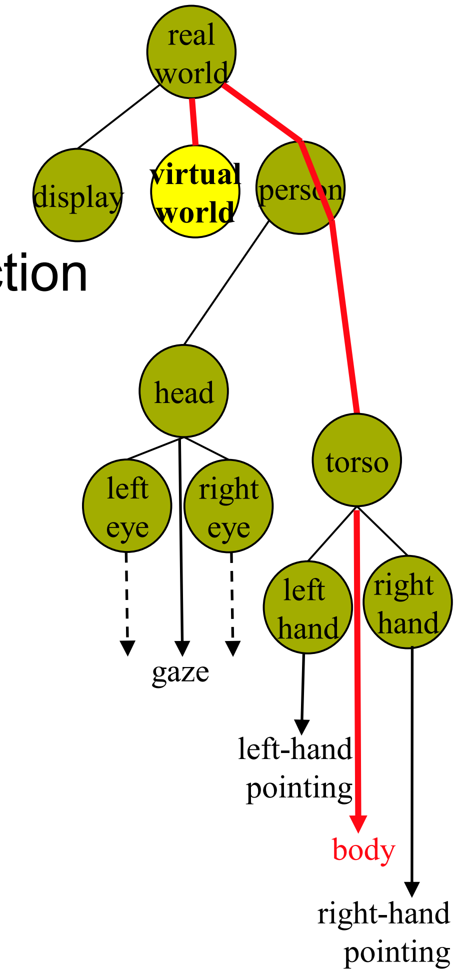
2.3.2 Pointing

- Approach
  - Use hand to point in travel direction
  - Desktop: keyboard for travel, mouse for gaze
- Addressed human cues, Pros
  - Proprioceptive sense (of own hand motion)
  - Good for acquisition of spatial knowledge
- Problems
  - More complex (simultaneous control of two values)
  - Higher levels of cognitive load
- Experiments/extensions
  - Two-hand pointing
  - Extension: using pinch gloves for initiation of steering gesture
    - motion direction
    - optionally: also speed



2.3.3 Torso-Directed Steering

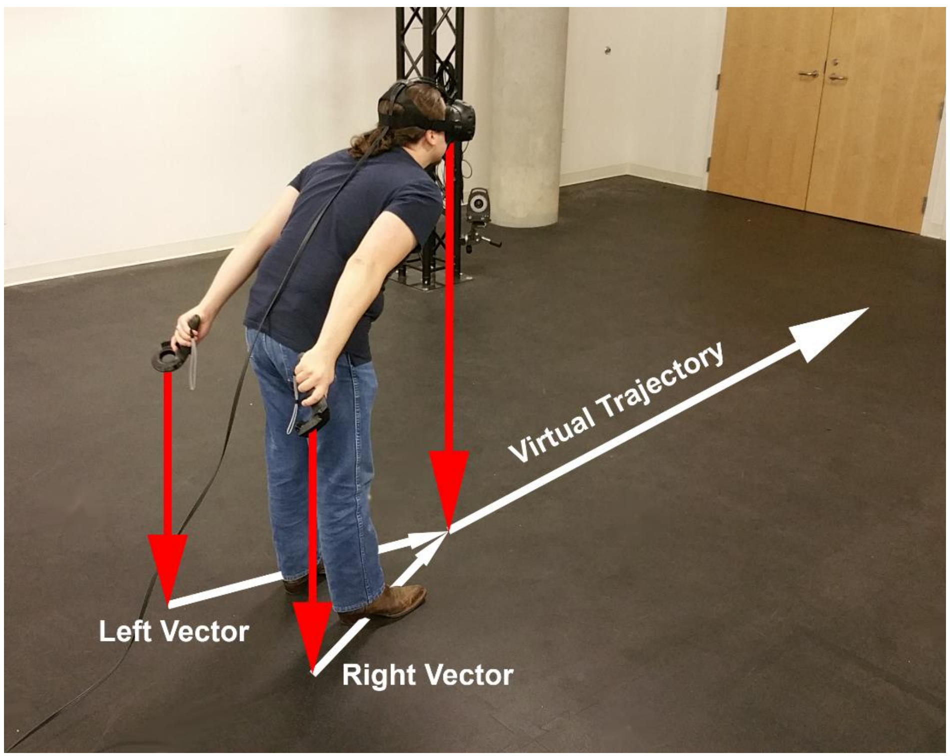
躯体

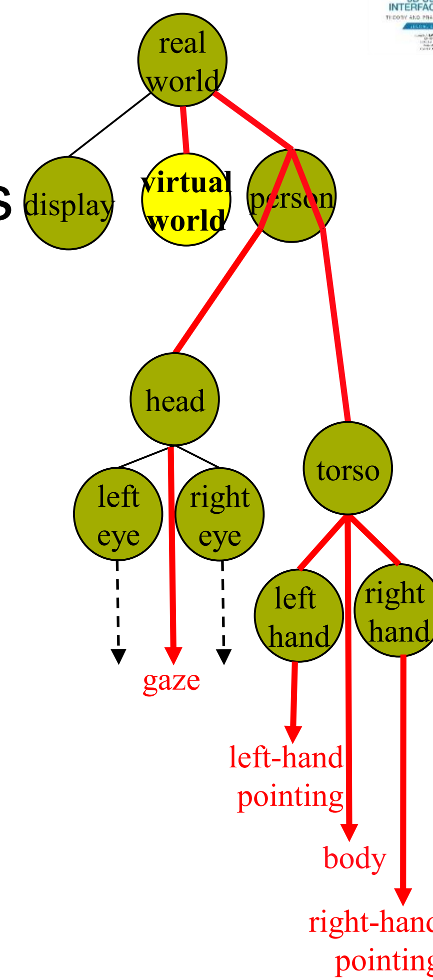


- Approach
  - People naturally turn their bodies in walking direction
  - Tracked torso (waist)
- Addressed human cues
  - Decoupling of motion and gaze
  - More natural than pointing (less cognitive load)
  - Hands are left free for other tasks
- Problems
  - Only usable for horizontal motions
  - Additional tracker (target) required

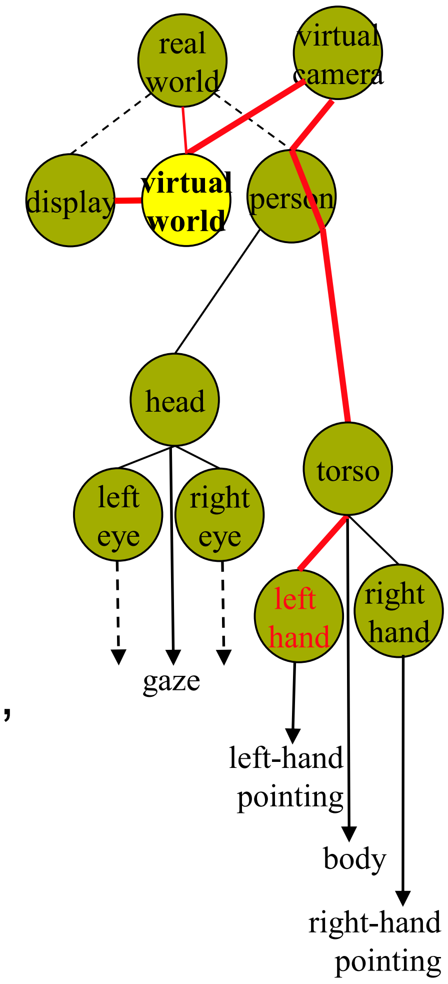
2.3.4 Lean-directed Steering

Combination of several body-based techniques





2.3.5 Camera-In-Hand Technique



- Approach
  - For desktop VE (with position trackers)
  - Tracker in hand = virtual camera
- Addressed human cues
  - Proprioceptive sense of hand motion
- Problems
  - Confusing due to exocentric control of workspace, drawn from an egocentric perspective
- Example: Magic Lens
  - Drone, steered by thumbs on tablet
  - Drone, steered by tracked tablet
  - Tablet relative to head

2.3.6 Physical Steering Props

- Approach
  - „Near-field haptics“ approach
  - Use specialized steering devices
    - In cars: steering wheel, gas pedal, brake
    - Ships, tractors, aircrafts
- Metaphors, Pros
  - Vehicle metaphor
  - Usable without training
- Problems
  - User has to be seated
  - Potentially unrealistic user expectations of realistic control and system response
- Examples
  - Virtual jungle cruise, DisneyQuest: collaborative control of a virtual raft with physical oars
  - Pirates of the Caribbean: virtual ship
  - Arcade games: motorcycles handlebars, skateboards, skis, …

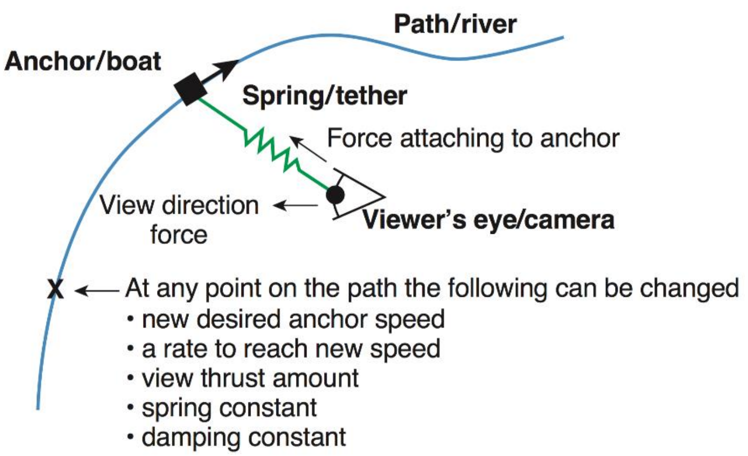
2.3.7 Virtual Motion Controller (VMC)


VMC, Wells 96 (HIT Lab)

- Approach
  - Platform with embedded pressure sensors along the rim of the platform
  - Center = stationary position
  - Rim = motion (direction + speed) in vector direction (center → rim)
- Addressed human cues
  - Natural proprioceptive, kinesthetic senses to maintain spatial orientation and understanding of movement
- Problems
  - Limited to 2D motions

2.3.8 Semi-Automated Steering

- Approach
  - System provides general constraints and rule on user‘s movement
  - User controls motion within given constraints
- Metaphors
  - River metaphor, virtual boat ride: the boat continues to negotiate its way down the river even when the user doesn‘t interact [Galyean 95]
  - User attached to a „controlled path“ by
- Examples
  - Magical story telling
    - Disney‘s Aladdin attraction: magical carpet rides [Pausch et al 96]



2. Travel Techniques

2.4 Route-Planning Techniques

- Two-step process:
  - User first specifies/plans a route
  - System then arranges travel along this route
- Applications:
  - Define a camera path for an animation
  - Focus on other tasks:
    - Information gathering
  - …to some extent…: surgery planning

2.4 Route-Planning Techniques

→ 2.4.1 Drawing a path

2.4.2 Marking points along a path

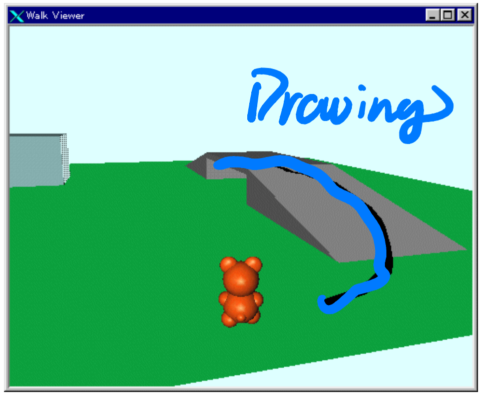
2.4.3 Manipulating a user representation

2.4.4 Transistions between different modes

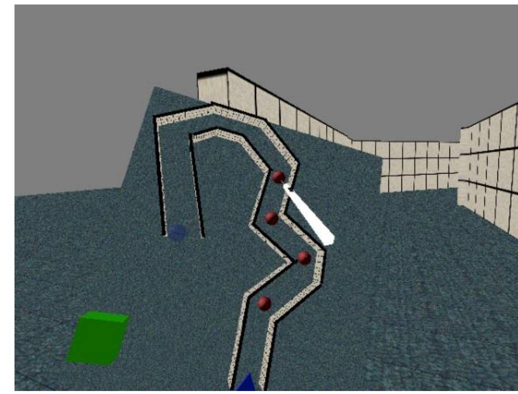
2.4.1 Drawing a Path

Approach

- Desktop 3D UIs: draw directly in the 3D environment with mouse (according to projected 3D world on screen)
  - Path at fixed height above ground
  - Intelligent path mapping through tunnels and valleys
- Immersive VE: draw into a 2D or 3D map of the virtual world



2.4.2 Marking Points Along a Path



- Approach
  - User places markers at key locations along the path
    - Directly in the environment
    - On a 2D or 3D map of the environment
  - System interpolates between markers
    - According to 3D environment map (straight line on surface)
    - Markers as control points for curves
- Issue
  - Feedback: how does the selection of control points influence the final path?

route plan

Columbia University, MARS System

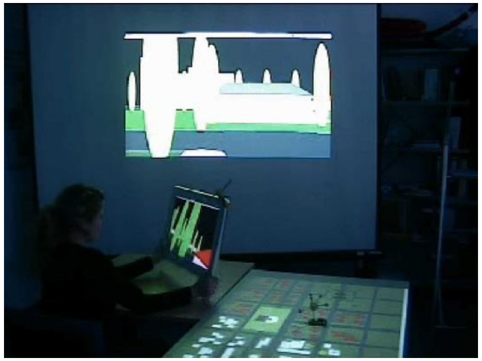
2.4.3 Manipulating a User Representation

- Approach
  - Two-phase approach:
    - Represent user by an avatar in a WIM-presentation
      - User: define motion path by controlling avatar
    - System: execute motion path in real-scale VE
  - Transitions large-scale VE ↔ WIM: „fly-in“, „fly-out“
- Pros
  - User representation (6 DOF)

2.4.3 Manipulating a User Representation

(Entity)

- Remote view control
  - Remote person completely controls the view of a VR user
  - E.g.: test situations in a driving simulator
    - Basic setup
    - Tangible Car UI

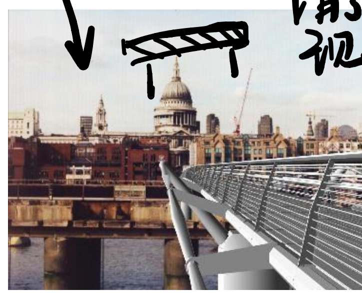


CAR (TU Munich)

2.4.4 Transitions between Different Modes

- Travelling in a mixed world (AR mixed with VR)
  - Consistent transitions
    Flying bridges

AR



增强现实

某定点模拟
VR

  - Leaving the real world behind: Magic book

2. Travel Techniques

2.5 Target-Based Techniques

- Go directly to a specific viewpoint in the VE
- Not necessarily „tele-portation“!
  - Decreases user‘s spatial orientation

以目的为导向
而非行为导向

2.5 Target-Based Techniques

2.5.1 Map-based or WIM-based target specification

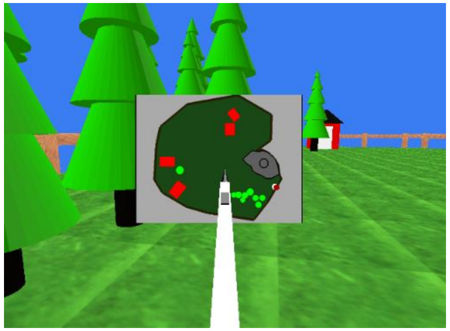
2.5.2 ZoomBack technique

See also: „cross-task“ target-specifications

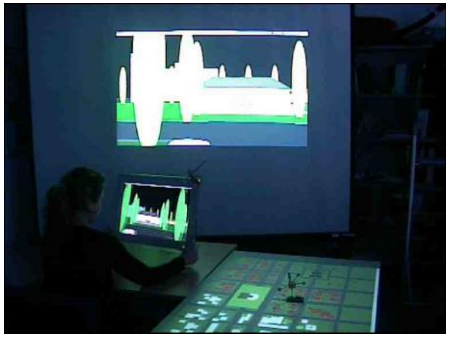
- Object selection/manipulation: travel to selected object
- Object selection/manipulation: travel to a newly positioned (manipulated) target
- Select a predefined target from a list or menu
- Enter 2D or 3D coordinates or location name, using text entry

2.5.1 Target Specification

Map-based or WIM-based



- Approach
  - User specifies target location in 2D map or WIM (e.g. by positioning an avatar with a virtual hand)
  - System generates a path from current to target location
- Details
  - How to relate position in the WIM to the position in the large VE
  - Interaction via stylus (or tracked tangible)
  - 3D path



2.5.2 ZoomBack Technique

- Approach
  - User selects an object in the environment (ray-casting)
  - System moves user to a position directly in front of the object
  - System remembers previous position
  - User can move back after inspecting the object
  - Implementation via „pop-through“ button
- Experiments/extensions
  - Virtual museum (step up to a virtual painting, step back to get an overview)

museum

zoom in

zoom back

2. Travel Techniques

2.1 Technique classifications

2.2 Physical locomotion techniques 移动

2.3 Steering techniques 转向

2.4 Route-planning techniques

2.5 Target-based techniques

→ 2.6 Manual manipulation techniques

2.7 Travel-by-scaling techniques

2.8 Viewpoint orientation techniques

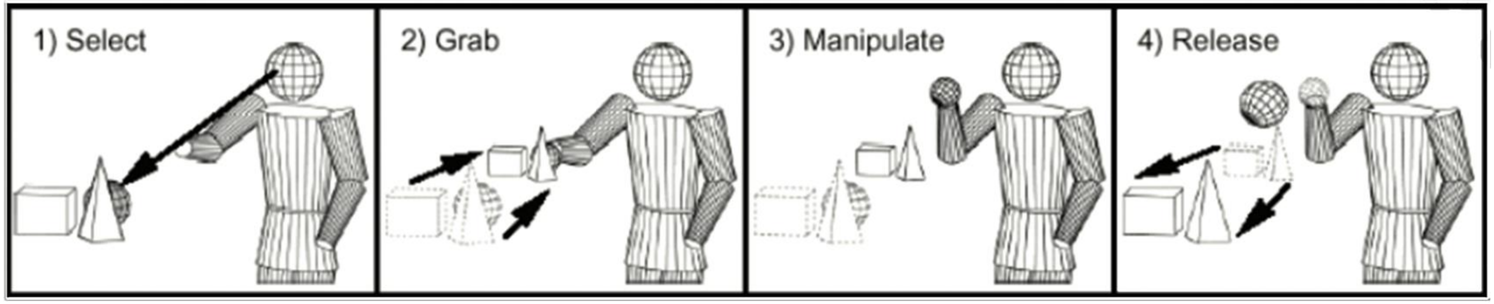
2.9 Velocity specification techniques

2.10 Integrated camera controls for desktop 3D environments

2.6 Manual Manipulation Techniques

Hand-based manipulation: HOMER, GoGo

Manipulate viewpoint instead of virtual object



Suitable for interspersed actions:
both travel and object manipulation

→ 2.6.1 Grabbing the air

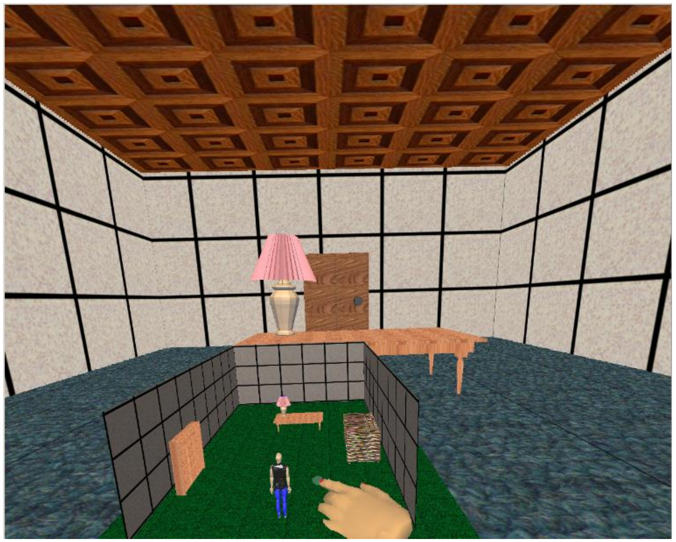
2.6.2 Fixed-object manipulation

2.6.1 Grabbing the Air

pointer – grab

- Approach
  - User: grabbing gesture „anywhere“ in the virtual world, followed by hand motion
  - System: move the entire world according to hand motion
- Problems
  - World motion ≠ hand motion!! (Ignore hand rotations)
  - Determine whether user wants to travel or to manipulate a virtual object
- Experiments/extensions
  - Use Go-Go concept to allow for faster/larger motions (to reduce clutching)

2.6.2 Fixed-Object Manipulation



- Approach
  - User selects an object, makes hand movements
  - System interpretes hand movements as travel instructions **relative to** selected object
  - Example: motion on slippery floor (ice dance)
- Examples
  - Move toward an object by pulling it close
  - Move around an object by rotating it

2. Travel Techniques

2.7 Travel-By-Scaling Techniques

- Approach
  - Arbitrarily scaled physical motion in virtual world
- Problems
  - User must understand current scale factor
    - Use virtual body of fixed scale
  - Danger of cyber sickness
  - Imprecise user movements (for large scale factors)
  - Additional interface component required to specify scale factor (e.g., pinch gloves)

2. Travel Techniques

2.1 Technique classifications

2.2 Physical locomotion techniques

2.3 Steering techniques

2.4 Route-planning techniques

2.5 Target-based techniques

2.6 Manual manipulation techniques

2.7 Travel-by-scaling techniques

→ 2.8 Viewpoint orientation techniques

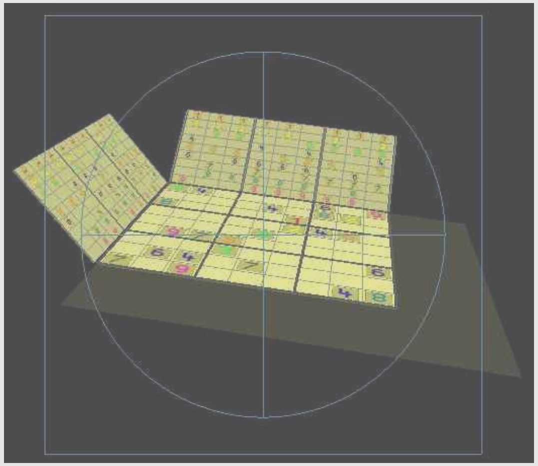
2.9 Velocity specification techniques

2.10 Integrated camera controls for desktop 3D environments

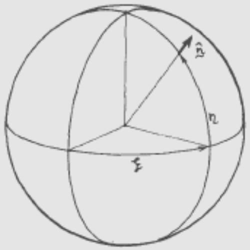
2.8 Viewpoint Orientation Techniques

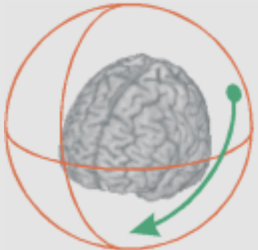
- Head tracking
  - Standard approach
- Orbital tracking
  - The user „flies“ on an orbit around a single object
- Non-isomorphic rotation
  - E.g., projected displays in which the displays do not completely surround the user
  - Amplified head rotations
- Virtual sphere techniques
  - For desktop VEs
  - E.g., ARCBALL

3.7.4 ARCBALL Technique

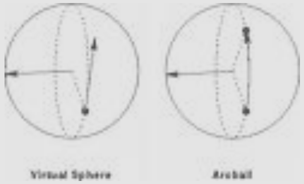


- Use spherical geometry to interpret 3D rotations



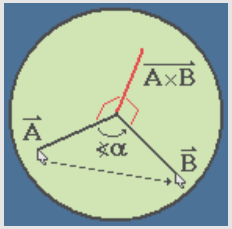


- Great circle (arc) on the sphere
  - arc lies on plane through sphere center

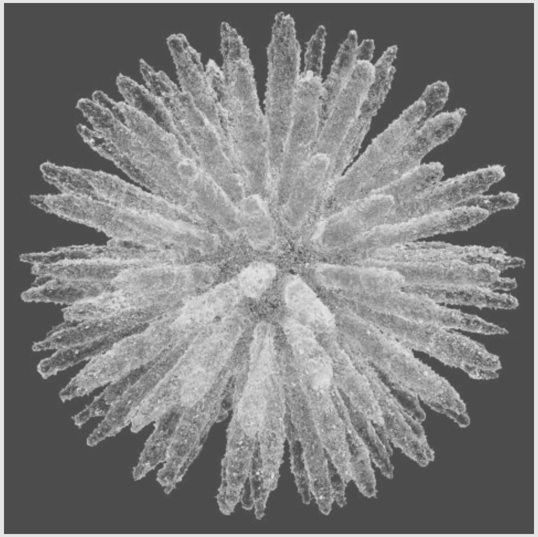


http://rainwarrior.thenoos.net/dragon/arcball.html

  - rotation around the axis perpendicular to the circle



http://www.sph.sc.edu/comd/rorden/3d.html



ICE Sphere by Christoph Welkovits
http://www.morphographic.com/Sphere.htm

2. Travel Techniques

2.9 Velocity Specification Techniques

- Approach
  - Adaptive speed depending on travel situation
    - Fast motion across large distances
    - Slow motion for detailed viewpoint adjustment
  - Velocity control methods
    - „Lean-based“ velocity: position of head relative to waist
    - Velocity defined by hand position (relative to body)
    - WIMP: buttons, menus, text input
    - Physical props: accelerator/brake pedals
    - Force-feedback joystick
- Problems
  - Additional complexity

2. Travel Techniques

2.10 Integrated Camera Controls on Desktop

- Approaches
  - Use of standard keyboard and mouse mapping: 2DOF input → 6 DOF camera control
  - VRML viewers, 3D modeling and animation systems (Blender, Unity etc):
    Several navigation modes, entry of numeric coordinates
  - Two-joystick technique (bulldozer technique)

Agenda

1. 3D travel tasks
2. Travel techniques
3. Design guidelines

3. Design Guidelines

- Match the travel technique to the application
- Consider both natural and magic techniques
- Use an appropriate combination of travel technique, display technique, and input devices
- Choose travel techniques that can easily be integrated with other interaction techniques in the application
- Provide multiple travel techniques to support different travel tasks in the same application
- Make simple travel easier by using target-based techniques for goal-oriented travel and steering techniques for exploration and search

3. Design Guidelines

- Use a physical locomotion technique if physical user exertion or naturalism is required
- Use graceful transitional motions if overall environment context is important
- Train users in sophisticated strategies to help them acquire survey knowledge
- Consider integrated (cross-task) interaction techniques if travel is used in the context of manipulation
- Desktop 3D navigation techniques should allow the user to accomplish the most common travel tasks with a minimum effort

Thank you!