
Overview

- Navigation
- Wayfinding
- Travel

Further information:
Navigation

- is how we move from place to place within an environment

- is the combination of travel with wayfinding
  - wayfinding: cognitive component of navigation
  - travel: motor component of navigation
  - travel without wayfinding: "exploring", "wandering"

- is a common interaction tasks in VEs
  - except when all user interaction is local

Navigation Tasks

- **Exploration**
  - travel which has no specific target
  - build knowledge of environment

- **Search**
  - naïve: 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 / viewpoint for task
    - e.g. doctor moving to other side of the table in surgery simulation
  - short, precise movements
Additional Navigation Task Characteristics
to be considered when choosing or designing navigation techniques (I)

- Distance to be traveled
  - e.g. short-range travel using natural motion only
  - mid-range travel requires virtual travel technique but may not require velocity control
  - long-range should use techniques with velocity control or the ability to jump between locations

- Amount of curvature or number of turns in the path
  - e.g. steering based on torso direction appropriate when turning is infrequent
  - when path involves many turns, methods based on pointing more comfortable

- Visibility of the target from the starting location
  - many target-based techniques depend on visibility of target
  - e.g. gaze-directed steering inappropriate when user needs to search for target visually while traveling

Additional Navigation Task Characteristics
to be considered when choosing or designing navigation techniques (II)

- Number of DOF required for the movement
  - terrain-following is a useful constraint in many applications
  - when navigation task requires motion in horizontal plane only, the travel technique should not force the user to also control vertical motion

- Required accuracy of the movement
  - e.g. map-based target selection is often inaccurate (due to scale of the map, imprecise hand tracking, etc.)
  - if accuracy is important, travel techniques should allow for easy error recovery (e.g. backing up when target was overshot)

- Other primary tasks that take place during navigation / travel
  - often, navigation is a secondary task in a virtual environment
  - navigation techniques should be unobtrusive, intuitive, and easily controlled
Navigation

- Frames of reference
  - egocentric: self-view of the world (e.g. left/right)
    - "turn right at the intersection"
  - exocentric: external view of the world (e.g. north/south)
    - "go north at the intersection"

- Axes of translation
  - egocentric: longitudinal, lateral & vertical axes of a body
  - exocentric: world longitude, latitude & altitude
  - exocentric: Cartesian X, Y & Z

- Axes of rotation
  - egocentric: pitch, roll & yaw
    - a.k.a. elevation, roll & heading
  - exocentric: Cartesian X, Y & Z

Wayfinding

- The means of
  - determining (and maintaining) awareness of where one is located (in space and time),
  - and ascertaining a path through the environment to the desired destination

- Problem: 6DOF makes wayfinding hard
  - human beings have different abilities to orient themselves in an environment, extra freedom can disorient people easily

- Purposes of wayfinding tasks in virtual environments
  - Transferring spatial knowledge to the real world
  - Navigation through complex virtual environment in support of other tasks
Wayfinding - Cognitive Maps

- **Mental models (cognitive maps)**

  Types of *spatial knowledge* in a mental model
  - landmark knowledge
  - procedural knowledge
    - sequence of actions required to follow a certain path
  - map-like (topological) knowledge

  Creating a mental model
  - systematic study of a map
  - exploration of the real space
  - exploration of a copy of the real space

- **Problem:** Sometimes perceptual judgments are incorrect within a virtual environment
  - e.g., users wearing a HMD often underestimate dimensions of space, possibly caused by limited field of view

Wayfinding Support

- **User-centered**
  - make use of characteristics of human perception

- **Environment-centered**
  - design virtual world to support wayfinding
  - legibility techniques
    - landmarks, districts with a unique style, streets, rivers, …
  - can learn from architectural design
  - artificial cues, e.g., compass, signs
User-centered wayfinding support

- Allow a wide field of view
  - with small field of view, repetitive head movements are required to understand spatial information
- Provide motion cues
  - motion parallax
  - supply a minimum of vestibular (real motion) cues, match proprioceptive feedback with optical flow
- Audio could enhance visual spatial perception
  - direction and distance cues
- Support sense of presence: it could strengthen the construction of a cognitive map

Environment-centered wayfinding support

Legibility Techniques

- Divide a large-scale environment in parts with a distinct character
- Create a simple spatial organisation in which the relations between the parts are clear
- Support the matching process between the egocentric and exocentric reference frames by (visual) cues, including directional cues
- Building blocks for legible environments:
  - paths, edges, districts, landmarks
Environment-centered wayfinding support

Legibility Techniques

- **Landmarks**
  - Any obvious, distinct and non-mobile object can serve as a landmark
  - A good landmark can be seen from several locations (e.g. tall)
  - Audio beacons can also serve as landmarks

- **Guidelines for landmark design**
  - distinguish landmarks by color and form
  - place landmark at prominent place

Wayfinding support

Artificial Cues

- **Maps**
  - A common wayfinding aid from the real world
    - Maps can be used as a visualization tool rather than for wayfinding
  - Egocentric (e.g. view-direction-up) vs. exocentric maps (e.g. north-up)
    - (most are the latter)
  - World-in-miniature is a form of a map (with additional features)
    - avatar as user locator

"You-are-here" maps
Wayfinding support
Artificial Cues – Map Design Guidelines

- Use you-are-here maps
  - map & you-are-here marker
- Consider multiple map at multiple scales
  - global map for world reference
  - local map to communicate direct surroundings
- Carefully choose the orientation of the map
  - cognitive load for mental rotation when map is not aligned with environment
- Use appropriate map size and placement to reduce occlusion of the environment

Environment-centered wayfinding support
Artificial Cues

- Memorable place names
  - A location without a distinct physical landmark can be used as a reference point
  - E.g. Picadelli Circus
  - When combined with a "put-me-here" method of travel can be very easy to use
Environment-centered wayfinding support

Artificial Cues

- **Path following**
  - Easy method of wayfinding
  - Multiple paths through a single space may be denoted by colors
  - For example, hospitals that use colored lines to indicate how to get to certain locations.

- **Bread crumbs (leaving a trail)**
  - Leaving a trail of markers - like Hänsel and Gretel
  - Allows participant to know when they've been somewhere before
  - Having too many markers can make the space be overly cluttered

- **Compass**
  - May also be other form of direction indicator (e.g. artificial horizon)
  - May specify directions in 2D space or 3D space
Environment-centered wayfinding support
Artificial Cues

- **Instrument guidance**
  - instrument that actively indicates whether on or off course, and how to correct if off course.
  - very common in aircraft and marine navigation systems; navigation systems for cars

- **exocentric view**
  - a peek at where you are standing in the world
  - may be a temporary shift in viewpoint, or a constant view of the world (e.g. WIM)
  - maintaining visual context when switching between egocentric and egocentric view is important

- **coordinate display with orthogonal grid structure**
  - text string that displays numeric location (x,y coordinates) to the user
  - requires a means of relating those numbers to the world
  - visual grid helps to serve this purpose
Environment-centered wayfinding support

Artificial Cues

- **reference objects**
  - inclusion of objects of well known size in environment as aid for judgment of size and distances
  - e.g. chair, human figure

- **artificial landmarks**
  - if environment does not contain natural landmarks, consider adding artificial landmarks
  - e.g. poles

- **audio and olfactory cues**
  - e.g. use speech to explain route to user, as in car navigation system
  - could use smell as unique object identifier

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Evaluation

Navigating Large Virtual Spaces.

Comparison of

- map
- grid
- map + grid
- no aid

Results

- navigational performance superior when maps are used
- grid provides superior directional information
- control condition, i.e. no aid, provided the worst performance

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Wayfinding – Myths and Reality

- Myth: Using a Virtual Environment will always improve wayfinding in the real world compared to using a map
- Reality: knowledge transfer is depending on multiple factors, support can also be counter-productive

- Myth: Wayfinding only includes visual perceptual factors
- Reality: Wayfinding also includes other factors

Travel

- The ability to move through and explore a space
- The most basic and common VE interaction technique, used in almost any large-scale VE
- Motor component of navigation
  - Immersive VR:
    - only consider viewpoint position; orientation is taken care of by head tracking
    - non-immersive VR (e.g. VRML browser): must also consider orientation
  - Control order:
    - displacement, velocity, or acceleration control
- Constraints
  - e.g. maintain vertical position: Fly-through v. walk-through
  - e.g. terrain following – user position always on proper height above floor
Travel - Physical locomotion

- Physical movement of the user
  - naturalistic travel technique

- Walking techniques
  - Maneuvering in CAVE
  - Large-scale tracking

- Walking in place
  - e.g. GAITER

- Devices simulating walking
  - Single-direction treadmill with steering
  - Omni-directional Treadmill
  - Gaitmaster

- Bicycles

Travel - Steering Techniques

- Steering: continuous specification of direction of motion

- Pointing
  - travel in direction of handheld tracker
  - dual-handed fly-through (see picture)
  - move from reference (see picture)
    - e.g. relative position of hand to body
      (+hand gesture) controls movement

- Gaze-directed
  - user cannot look around while traveling

- Torso-directed

- Camera-in-hand

- Virtual Motion Controller (VMC)
Travel – Steering (continued)

- **Pilot-through (Physical steering props)**
  - any form of travel based on the control of some (virtual) vehicle
  - similar to fly-through, but with an extra layer of control (piloting controls are ostensibly mediated by the simulation of some vehicle)
  - typically uses manipulation of (physical or virtual) controls such as steering wheels, rudders, pedals, joysticks, etc.
  - often mimics real world vehicles, but not always
  - e.g. DisneyQuest Virtual Jungle Cruise

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Travel – Steering (continued)

Virtual Jungle Cruise
DisneyQuest

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Prof. B. Jung
Virtuelle Realität, WS 2006/07
**Travel – Steering (continued)**

- **Automated Travel: Ride-along**
  - simple and restrictive
  - user rides on a path controlled by the experience
  - mimics some real world experiences – e.g. roller coaster
  - limits how much of a virtual world needs to be created

- **Semi-automated steering: Tow rope**
  - slightly less restrictive than ride-along
  - user is still following a path, but can move within some envelope behind the path
  - analogous to a water skier (or car being towed)
  - also known as the *river-metaphor*
  - e.g. DisneyQuest: Aladdin's Magic Carpet

**Travel – Target-based techniques**

- **Put-me-here (target-based techniques)**
  - discrete specification of travel target
  - simplest form of travel to implement (other than physical locomotion)
  - jump the user to a particular position in the world
  - can occur instantaneously (*teleporting*; may be confusing), or over a period of time
  - real-world analog is to tell someone where to take you
  - specification of target
    - e.g. menu, speech, pointing, enter coordinates
    - e.g. map-based or WIM-based
  - **ZoomBack technique**
    - retain information about previous position; "back"-button
    - e.g. virtual museum applications (Zeleznik et al. 2002)
Travel – Route-based planning techniques

- One-time specification of path
  - using some manipulation technique

- Place markers in world
  - straight-line interpolation or curve
  - should provide interactive feedback to the user to indicate the planned path

- Manipulating a user representation
  - e.g. move user avatar in WIM
  - e.g. move icon on map
  - can define not just position but also orientation

Travel – Manual manipulation techniques

- Use hand-based object manipulation metaphors to manipulate the viewpoint (instead of an object)

- Grabbing-the-air
  - grab anywhere in the air or on the world, and move the world relative to yourself rather than moving yourself relative to the world
  - real-world analog of this is pulling yourself along a rope
  - e.g. used in Multigen’s “SmartScene”

- Fixed-object manipulation
  - user selects an object and moves his hand as if to manipulate the object’s position
  - the object stays fixed and the user moves about the object
  - real-world analog of this is grabbing a flagpole: when you move your hand, the flagpole stays put and you move about it
Travel - Viewpoint orientation techniques

- Head tracking

- Orbital viewing
  - *direction* of looking (orientation of head) 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 counterintuitive at first

- Non-isomorphic rotation
  - e.g. for CAVEs with no back wall
  - amplify head rotations

- Virtual sphere techniques
  - for desktop VR

Travel - additional techniques

- **Move-the-world**
  - fly-through from another perspective
  - instead of flying myself through the world, I manipulate how the world flies around me
  - very different feel

- **Scale-the-world**
  - for traveling large distances
  - also treats the world as an object
  - scale down about the current location, change reference points
  - scale back to original size
A travel technique classification
Bowman et al. 1997

Travel
Direction/Target Selection
- gaze-directed
- pointing
- choose target from list

Velocity/Acceleration Selection
- gesture
- slow in, slow out
- physical props

Conditions of Input
- start/stop buttons
- automatic start/stop
- constant movement

Alternate travel technique classification
Bowman, Davis et al. 1999

Travel
- Start to move
- Indicate position
- Indicate orientation
- Stop moving

specify position
specify velocity
specify acceleration

discrete target specification
continuous specification
one-time route specification
Guidelines for Designing Travel Techniques
adapted from Bowman, 2002

- Make simple tasks simple (discrete, target-based techniques for motion to an object, continuous motion specification techniques for search)
- Use physical head motion for viewpoint orientation if possible (e.g. don’t use joystick)
- Avoid the use of teleportation; instead, provide smooth transitional motion between locations
- Provide wayfinding aids (landmarks, compasses, …) to help the user decide where to move, and integrate those aids with the travel technique

Myths and Reality
Bowman, SIGGRAPH 2000

- Myth: There is one optimal travel technique for VEs.
- Reality: the best travel technique depends on the task, environment, and user.
- Myth: A “natural” technique will always exhibit more performance, usability, and usefulness than another technique.
- Reality: Unnatural, or “magic” techniques often exhibit more desirable characteristics than natural ones (e.g. walking). Natural techniques may be best if the goal is training a real world task, or to increase presence.
- Myth: Desktop 3D, workbench, and CAVE applications should use the same travel techniques as HMD-based VEs.
- Reality: The display modality must be considered when designing travel techniques (e.g. workbench exocentric vs. HMD egocentric view).