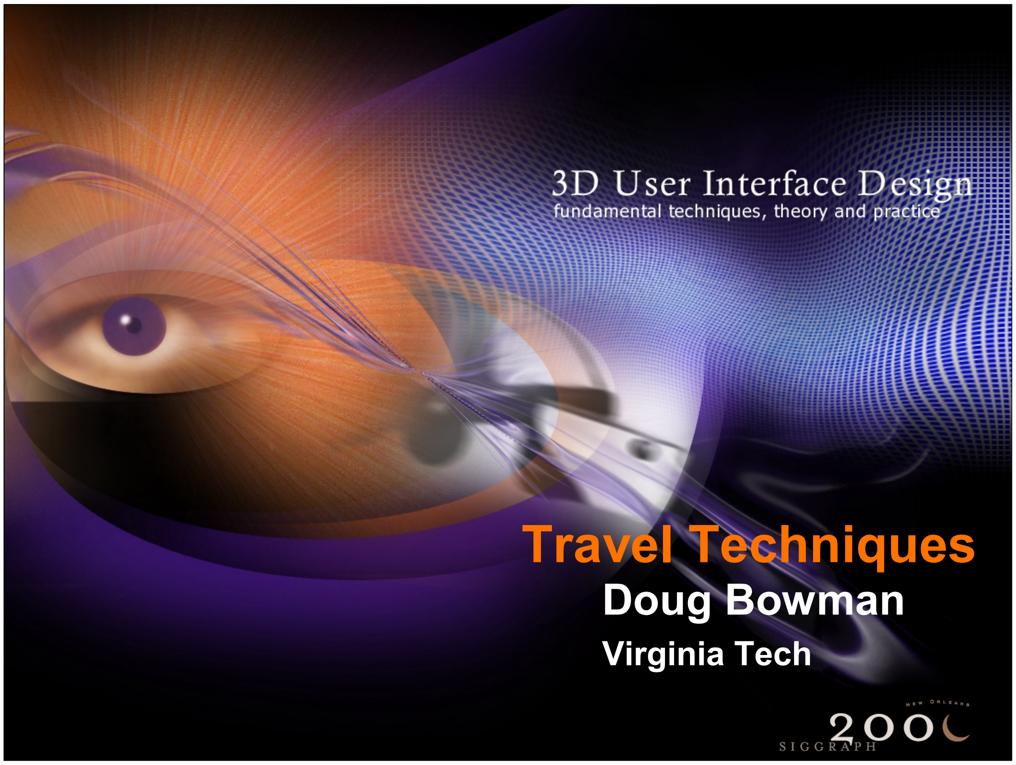

Travel techniques

Presented by Doug Bowman (bowman@vt.edu)

This is the first of the lectures on interaction techniques, to be followed by presentations on wayfinding, selection and manipulation, and system control.

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What is travel?

- the motor component of navigation
- movement between 2 locations, setting the position (and orientation) of the user's viewpoint
- the most basic and common VE interaction technique, used in almost any large-scale VE

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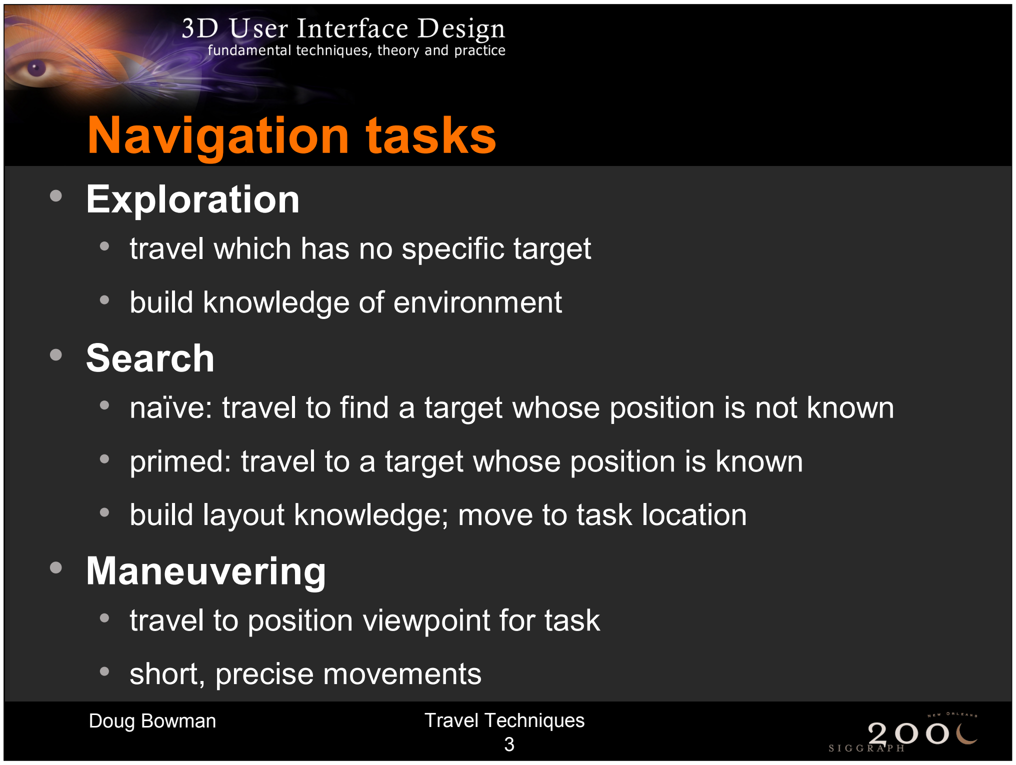
Travel refers to the actual movement through space, and not the planning, decision-making, or cognitive aspects (wayfinding). Can we really separate these 2 tasks? I would claim that you can have travel techniques which do not address wayfinding, but the best travel techniques will integrate **aids** to wayfinding.

We normally only consider setting the viewpoint position when designing travel techniques for immersive VEs, since orientation will be taken care of with head tracking. In non-immersive situations, travel techniques must consider orientation, making them more complex (e.g. navigation in a VRML browser).

Travel is truly a universal interaction task, except in VEs in which all user interaction is local.



The user tasks for travel are the same as those that will be presented for wayfinding, with the exception of maneuvering.

Exploration tasks have no explicit goal of the movement. The user is simply exploring or browsing the 3D space, usually to build knowledge of the environment or to see what the interesting features might be. Travel techniques for exploration should be almost thoughtless – you want the user to be able to simply move about with little restriction.

Search tasks involve traveling to a specific target location in the environment. Psychologists have further subdivided this task into naïve search, in which the position of the target is not known, and primed search, in which the position of the target is known (to some degree) and the task is to find that location again. See Darken & Sibert, CHI ’96, for use of these tasks in a VE.

Maneuvering tasks usually involve short, precise movements where the goal is to change the viewpoint slightly in order to do a particular task. For example, in a surgery simulation, the doctor might need to move to the other side of the operating table in order to get a good view of the procedure he is performing. In some cases, maneuvering can be allowed simply by letting the user move physically. However, due to limited tracker range, cable tangling problems, etc. you sometimes have to use an explicit travel technique for maneuvering.

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"Natural" travel metaphors

- **Walking techniques**
  - Large-scale tracking
  - Walking in place (GAITER)
- **Treadmills**
  - Single-direction with steering
  - Omni-directional
- **Bicycles**
- **Other physical motion techniques**
  - VMC / Magic carpet
  - Disney's river raft ride

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Many people have worked on naturalistic travel techniques – that is, techniques that use physical motion and some real-world or pseudo real-world metaphor for travel. Obviously such techniques are useful for applications such as training, where you want the user to move about as she would in the physical world to make the VE as lifelike as possible. However, as we will argue for all of the interaction tasks, naturalism is not always the best choice. We present here a few of the natural travel metaphors, but will focus for the remainder of this section on "virtual" or "magic" travel techniques where little or no physical motion is involved.

Naturalism also brings up the issue of realism in general. Too often it is asserted that VEs need to be realistic, without defining what type of realism one means. There is visual realism vs. realism of interaction, for example. Within interactive realism, it might be the case that ITs for certain tasks need to be realistic, while others do not. This issue is of importance, and will be covered in more detail in the lecture on the art of design.

Examples

-Walking techniques: these try to emulate physical walking to allow full use of the vestibular and kinesthetic senses. A brute-force way to allow this is simply to expand the area being tracked. Work on camera-based tracking at UNC takes this approach. There are also efforts to in some way analyze the user's motions as he's walking in place to determine direction, speed, etc. The GAITER project at the Naval Research Labs (Jim Templeman) is one example. Also, Iwata's work (e.g. Iwata & Fujii, 1996) has looked at different ways to allow a more natural walking motion while not physically translating, such as roller skates or slick shoes on a slick floor.

-Treadmills: also designed to allow physical walking or running, but using a bigger, more expensive device. Brooks and colleagues at UNC were one of the first groups to use a standard exercise treadmill outfitted with some steering apparatus for movement in a VE. Noma and colleagues at ATR international developed a treadmill combined with a motion platform which actually changes the orientation/heading of the treadmill when the user changes walking direction (Noma, Sugiharo, & Miyasato, IEEE Virtual Reality, 2000, pp. 217-224). The next slide shows the omni-directional treadmill, which allows walking in any direction on the horizontal plane. A similar device is the Torus treadmill (Iwata, IEEE Virtual Reality, 1999, pp. 286-293).

-Bicycles: have been used to simulate real motion based on pedaling and force feedback. In order to be realistic, you need to feel as if you're on a real bicycle, and simulate turning properly.

-Virtual Motion Controller (VMC) – shown in the picture. This is a project from the HIT lab at the Univ. of Washington. The VMC has sensors built into it that sense the user's weight and thus which part of the platform he's centered over. Direction of motion is controlled by stepping in that direction on the device. Speed is controlled by distance from the center.

-Magic carpet – this was a student project at Georgia Tech very similar to the VMC. Physically, it was a board on which the user stood. 9 regions were painted on the board allowing the user to go in any of the 8 compass directions or stop (by standing in the center).

-River raft ride at Disney Quest – In this ride, guests sit in a rubber raft on top of an inflatable membrane which can simulate the water's motion. Motion is controlled by a combination of the motions of all the guests' paddles, allowing steering, speed control, etc.

The image shows the omni-directional treadmill, developed by SARCOS corporation, which allows the user to walk in any direction on the horizontal plane. It works very well for slow, controlled walking, but has usability problems during sudden stops and starts, quick changes of direction, etc. due to the fact that it must actively try to keep the user near the center of the device. See Darken, Cockayne, & Carmein, UIST 1997, pp. 213-221 for more details.

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Common virtual travel metaphors

- **steering: continuous specification of direction of motion**
  - gaze-directed
  - pointing
  - physical device (steering wheel, flight stick)
- **target-based: discrete specification of goal**
  - point at object
  - choose from list
  - enter coordinates

Doug Bowman Travel Techniques 7

A very large number of different virtual travel techniques (where there's little or no physical motion by the user) have been suggested and/or implemented by researchers and application developers. Most of these techniques fall into four categories or metaphors.

The steering metaphor implies continuous control of the direction of motion, as when you steer a car.

Examples

-gaze-directed steering: look in the direction you want to go

-pointing: point in the direction you want to go

-using physical props such as a steering wheel, accelerator, and brake

The target-based metaphor lets the user choose the end goal of the motion, then the system actually performs the movement in between the two points.

Examples

-point at the object to which you want to travel

-a menu or list of choices from which you make a selection

-enter the coordinates of the point to which you want to move

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More common travel metaphors

- **route planning: one-time specification of path**
  - place markers in world
  - move icon on map
- **manual manipulation of viewpoint**
  - “camera in hand”
  - fixed object manipulation

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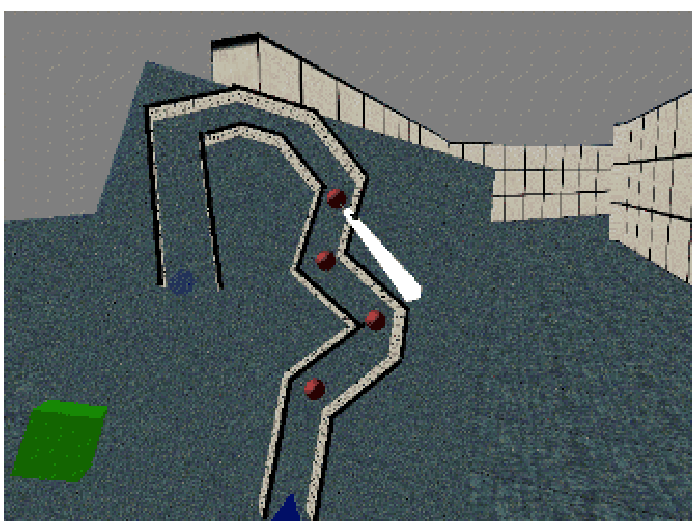
Route planning is a compromise between steering and target-based metaphors: the user specifies the end goal and also some intermediate path information. (These first 3 metaphors are on a continuum of the relative amount of control by the user and system.)

Examples

-using some manipulation technique, put markers in the world to denote your path

-place markers on a map of the space (see picture)

-move an icon representing yourself on a map of the space (e.g. World-in-Miniature, Pausch, Burnette, Brockway, and Weiblen, 1995)



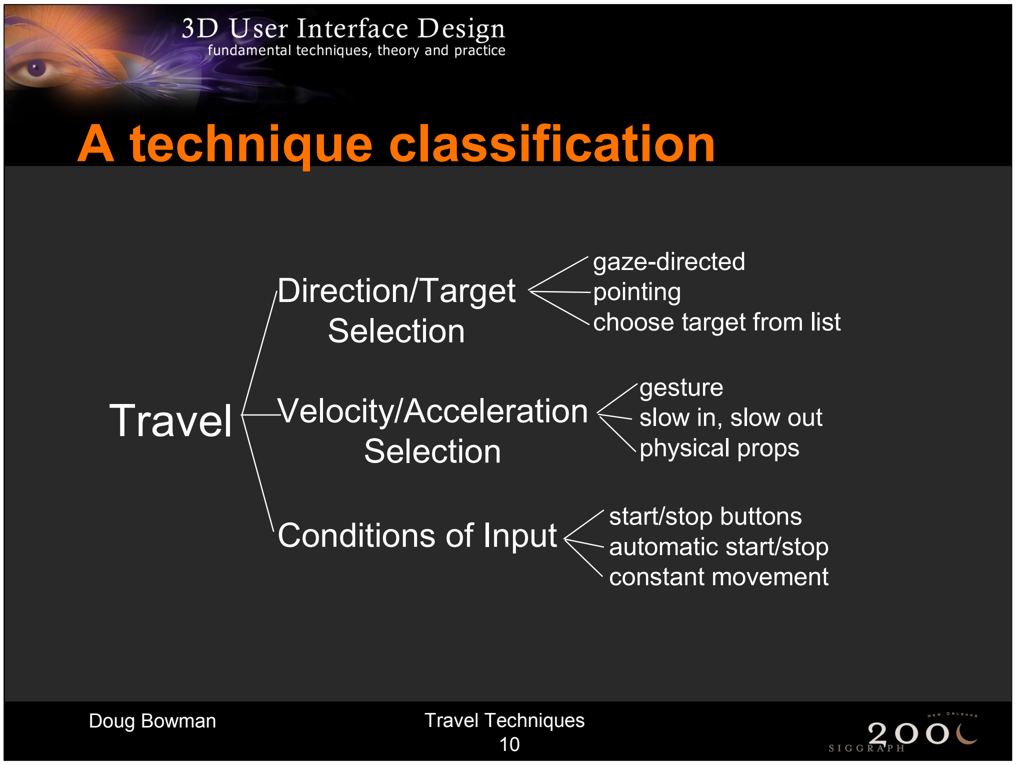
Something different is manual viewpoint manipulation, in which the user's hand motions are mapped in some way to viewpoint motion.

Examples

-camera in hand: the user moves his hand over a map of the space, with his hand acting as the camera though which the 3D space is viewed

-fixed object manipulation: the user selects an object and moves his hand as if to manipulate the object's position. Here, however, the object stays fixed and the user moves about the object. The real-world analog of this is grabbing a flagpole: when you move your hand, the flagpole stays put and you move about it.

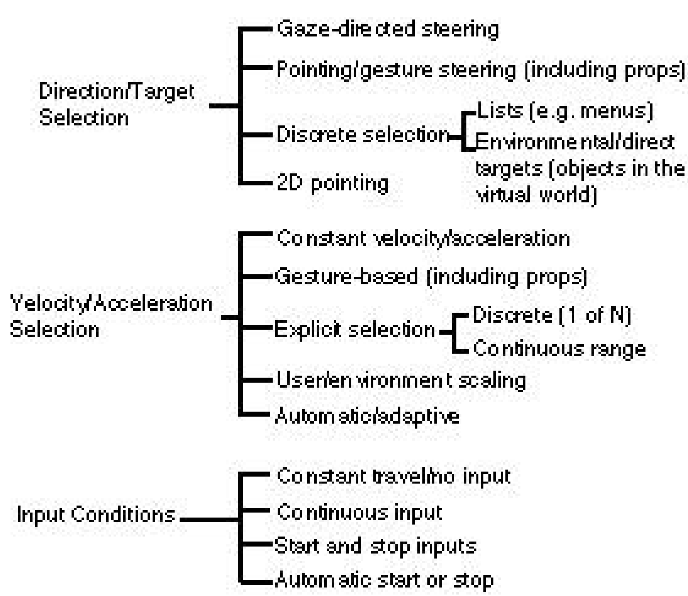
-grabbing the air: grab anywhere in the air or on the world, and move the world relative to yourself rather than moving yourself relative to the world. The real-world analog of this is pulling yourself along a rope. This was used in Multigen's "SmartScene" software.

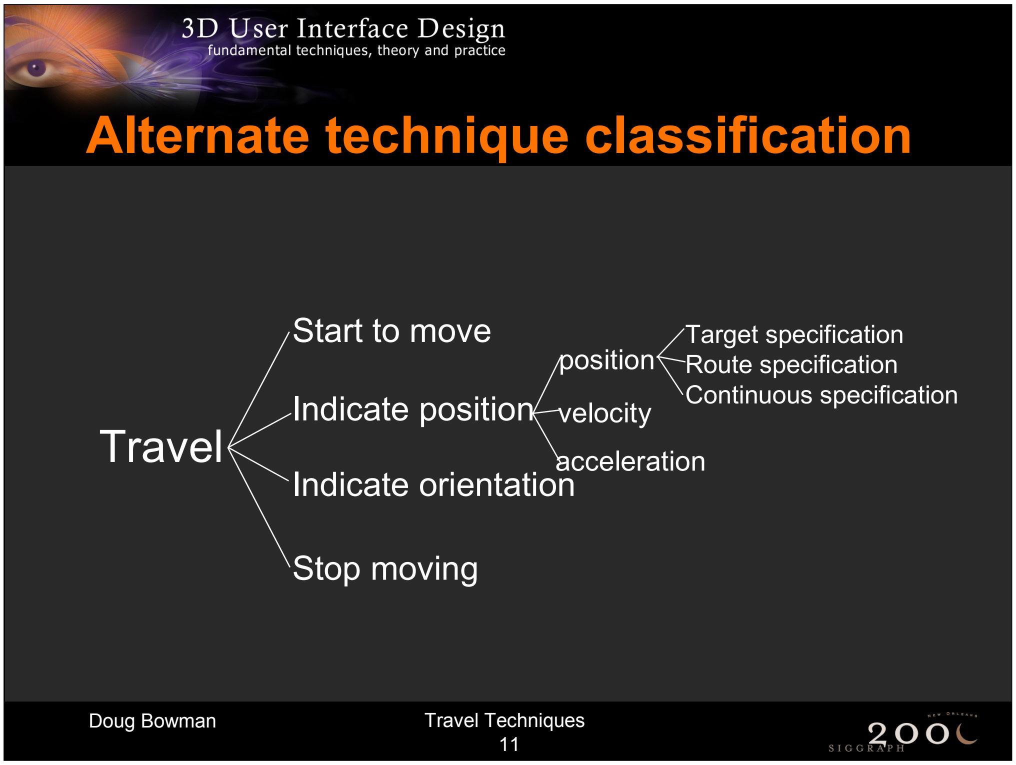


This is one possible classification of travel techniques, based on three parts of the overall task of travel. Only a few possible techniques for each of the sub-tasks are listed for simplicity (full taxonomy below).

This taxonomy is an example of a pure component-based taxonomy. See the lecture on the Science of 3D Interaction for more details.

Bowman, Koller, and Hodges, Travel in Immersive Virtual Environments. IEEE VRAIS '97



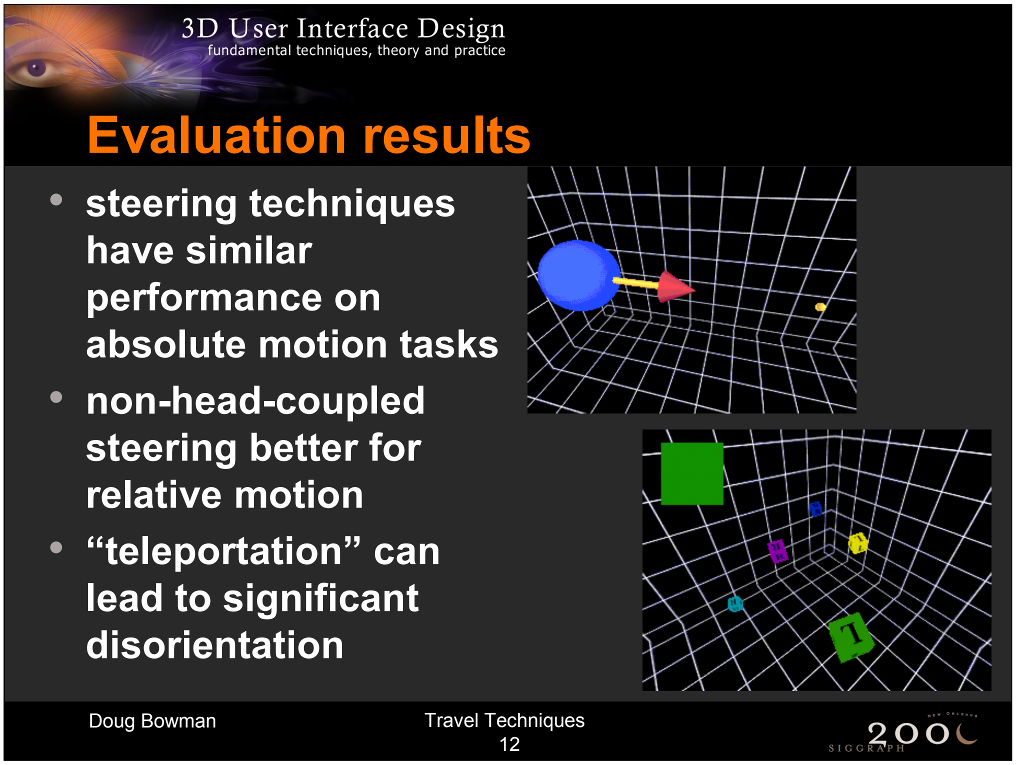


Here’s another possible classification of travel ITs based on the first three metaphors from the discussion of common travel metaphors. Note that techniques from the fourth metaphor have to be force-fit into one of the other three. For example, the camera in hand technique would be considered steering (continuous specification) since you are continuously controlling the direction of motion (using hand motion).

The complete taxonomy breaks down the task of travel into four subtasks, but here we are only interested in the position specification part of the taxonomy. Other issues, such as specifying velocity, or indicating orientation in non-immersive environments, are interesting but not represented here for conciseness.

This is an example of a hybrid taxonomy containing elements of both a component-based and metaphor-based taxonomy – see the lecture on the Science of 3D Interaction.

Bowman et al, Formalizing the Design, Evaluation, and Application of Interaction Techniques for Immersive Virtual Environments, Journal of Visual Languages & Computing, 1999



We've run six formal experiments to evaluate travel ITs in a general way. Here are some of the most salient results.

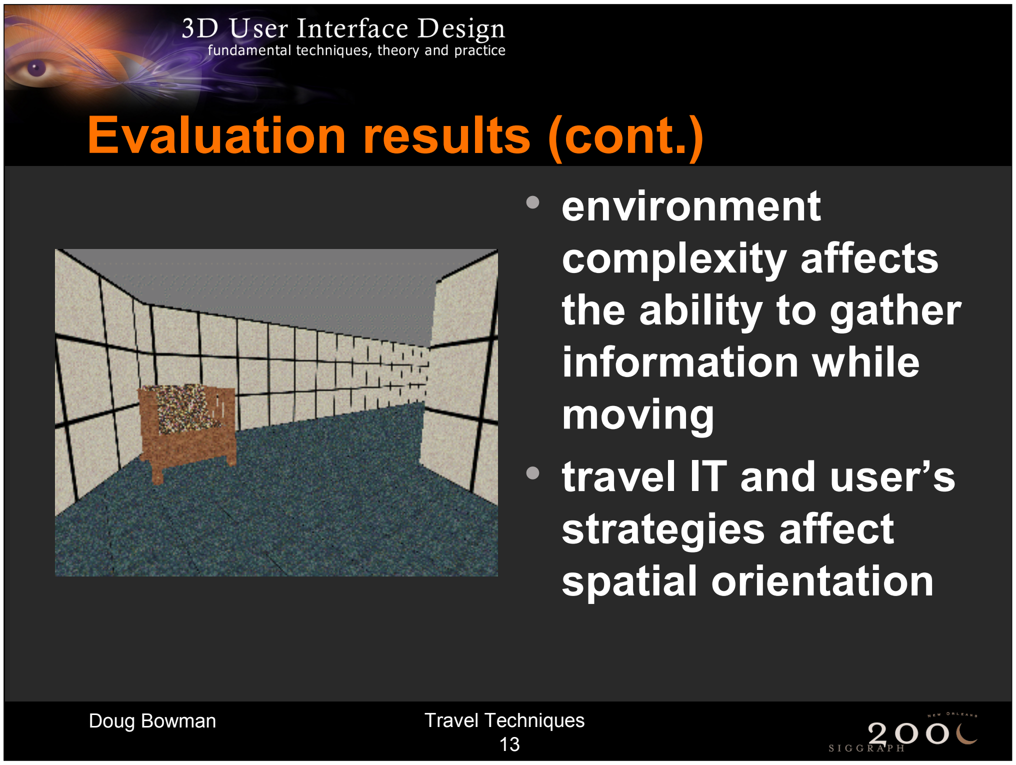
These first results are taken from:

Bowman, Koller, & Hodges, Travel in Immersive Virtual Environments, IEEE VRAIS '97.

We first studied an absolute motion task – move until you are inside of a virtual sphere. Gaze-directed steering and pointing had similar performance (time to complete task) results for this test.

We also studied a relative motion task – move to a position defined relative to a virtual object. The environment is shown in the first picture. The user was to move to a point along the line indicated by the pointer at a certain distance from it (indicated by the gold dot in the picture, but not visible during trials). Here, pointing was significantly faster, because the user's head is not coupled to the direction of motion – he can look in one direction and move in another.

The third experiment studied the impact of velocity on a user's disorientation. The environment contained 4 colored cubes (2nd picture). The user studied the locations of these cubes, then pressed a button. The system moved the user with different velocities (slow, fast, accelerate/decelerate, infinite velocity (jump to new location)) to a new position, at which time the user was asked to find one of the cubes with a colored stimulus and press a button based on the letter seen on that cube. Slow vs. fast velocity had no effect, but "teleportation" / jumping / infinite velocity caused significantly higher times than the other techniques.

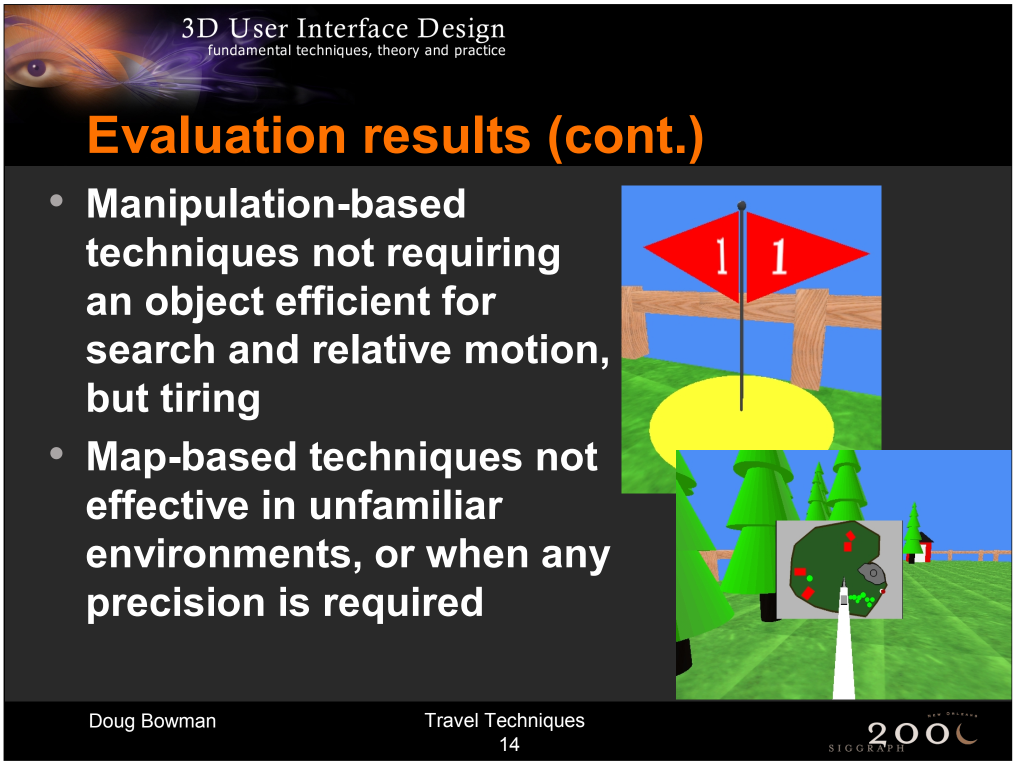


The next experiment involved gathering information (words and their locations) while traveling through virtual corridors. The travel technique used had no effect here (we tested gaze-directed steering, pointing, and torso-directed steering), but the complexity of the corridor's path was significant – it induced more cognitive load on the user to travel through a path traversing all 3 dimensions than one confined to a ground plane, for example.

Bowman, Koller, & Hodges, A Methodology for the Evaluation of Travel Techniques in Immersive Virtual Environments, Virtual Reality: Research, Development, & Applications, 1998

We next tested the three metaphors presented earlier (steering, route planning, and target-based travel) for their effect on a user's spatial orientation, as measured by his memory for the locations of objects (an example environment and object is shown in the picture). Here we found an interesting result. The complexity of the path was again significant, but also we found an interaction between the travel technique and the *strategies* we observed the users using. Steering was best if the user employed sophisticated strategies such as flying above the path to get a survey view or flying through walls to see what was on the other side. Target-based techniques were best if the user did not employ such strategies.

Bowman, Davis, Badre, & Hodges, Maintaining Spatial Orientation during Travel in an Immersive Virtual Environment, PRESENCE, 1999

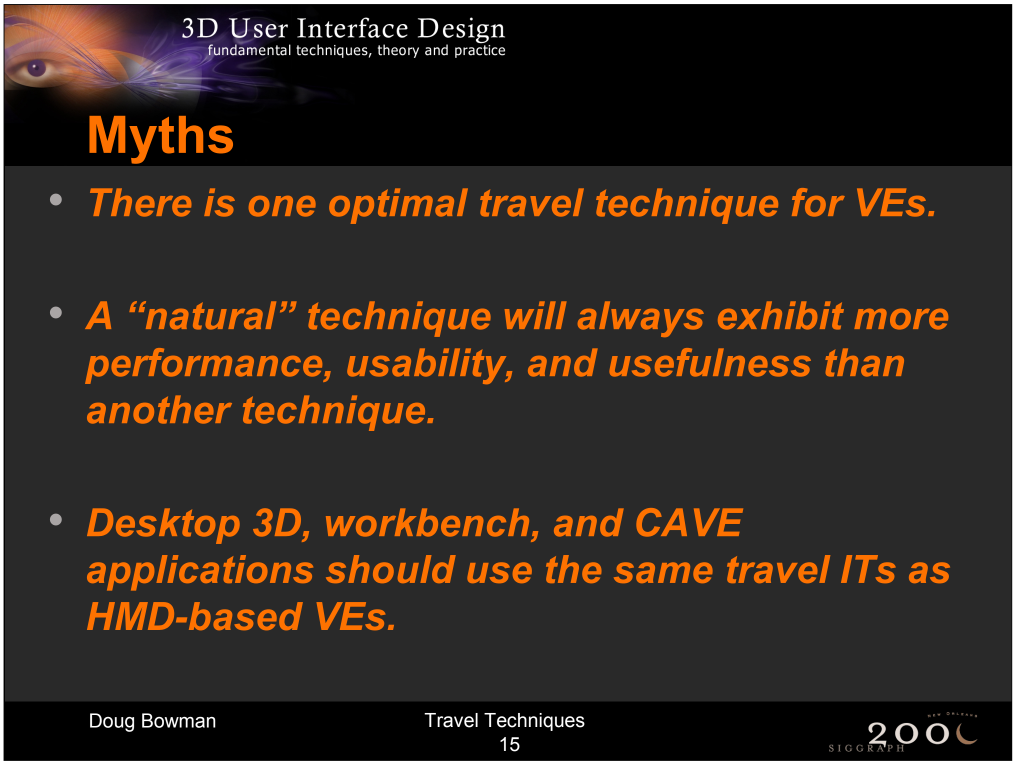


The final set of results are from a “testbed evaluation” of travel techniques:

Bowman, Johnson, & Hodges, Testbed Evaluation of VE Interaction Techniques, ACM VRST ’99

We tested manipulation-based techniques (use hand motion to travel) – in particular, an “air grabbing” technique. This was efficient for search tasks. A technique in which you move around an object was efficient for a relative motion task, because you can grab the object of interest and move around it to the correct location. Both of these types of techniques are tiring for the user, however, due to excessive arm motion used.

We also tested a route-planning technique using a map and an icon representing the user (bottom image). This has intuitive appeal because it gives the user an overview of the space and doesn’t require the user to do the traversal of intervening space between current location and target directly. However, our experiment showed this technique to produce by far the longest times both for cognitive processing and actual time spent moving. We believe this is because the environment was unfamiliar and the user spent time trying to match the map to the world, and because our tasks required greater precision of motion (the ring around the flag in the top image) than could be achieved with a small map.

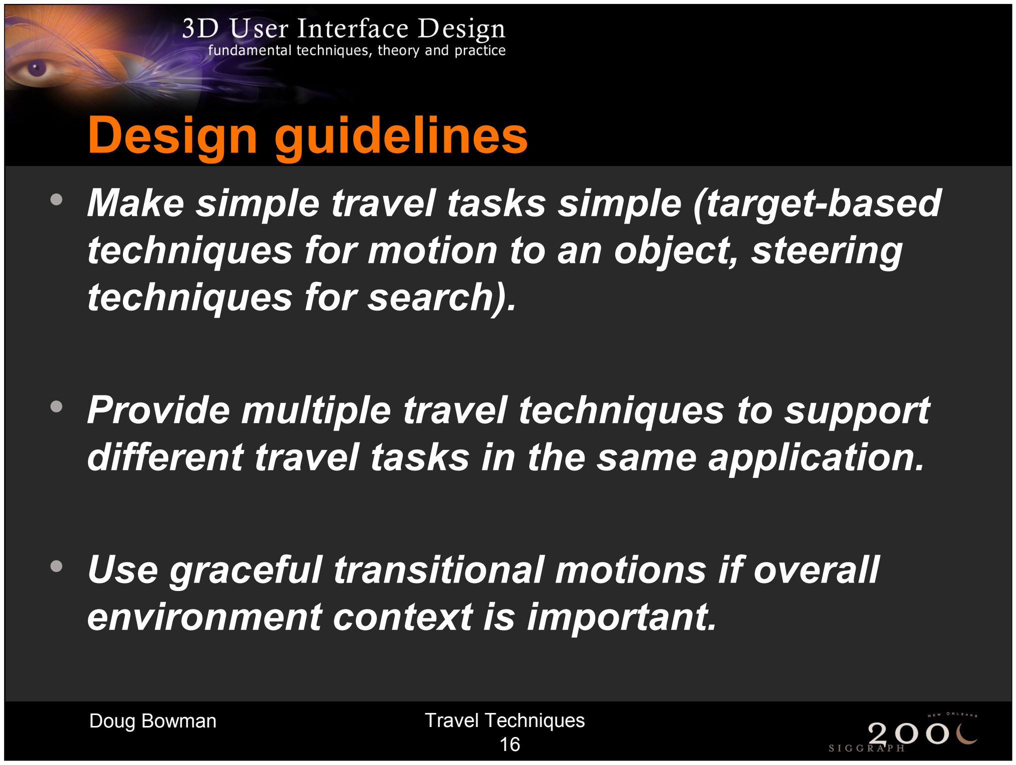


Debunking the myths:

-There is no such thing as the “optimal” travel technique – the best travel IT depends on the task, environment, and user.

-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 (Mel Slater’s work at University College London).

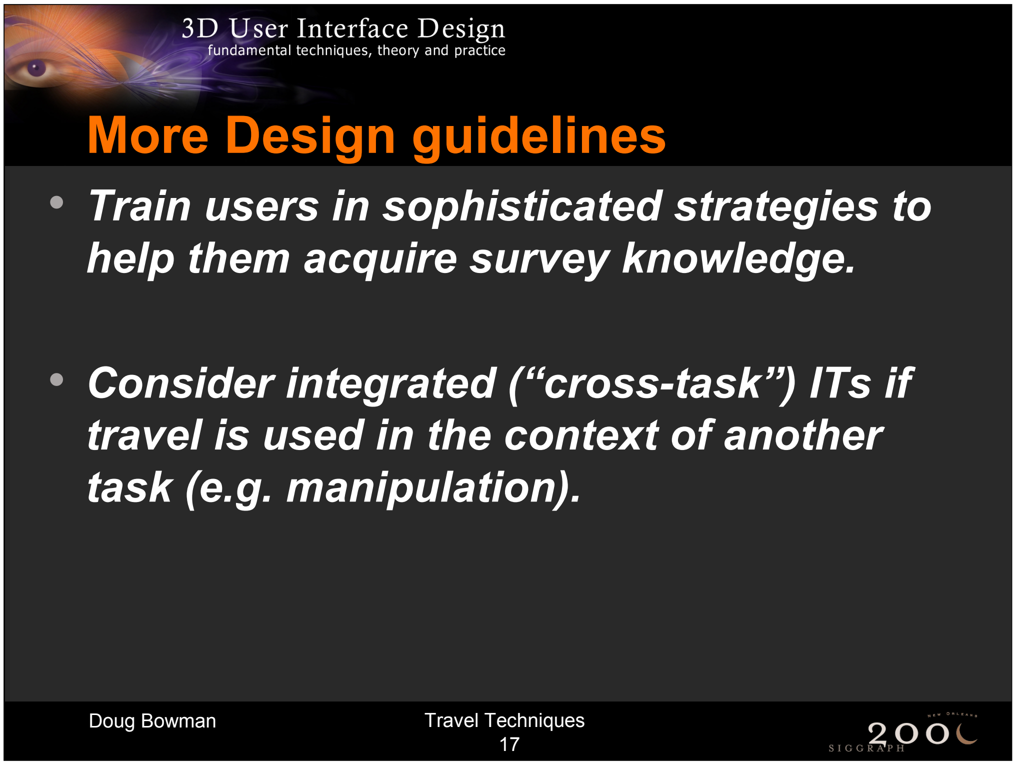
-The display modality must be considered when designing travel ITs (e.g. workbench exocentric vs. HMD egocentric view).



Most travel tasks are simple in the mind of the user – they just want to change their location while focusing on something else. Thus, you should use a technique that meets the requirements of the task: e.g. use a target-based technique if the only goal is to move between known objects - don't put unnecessary cognitive load on the user.

Remember the differences between tasks such as exploration and primed search – you may need more than one technique. There is a tradeoff between the specificity of the technique and the amount of learning load you want to put on the user. In many cases, multiple techniques requiring a bit more learning time may be much more efficient in the long run.

Many applications require the user to be aware of their location within the space, have an overall survey knowledge of the space, etc. (see the lecture on wayfinding). In these cases it is important to use transitional motion between locations, even if it is fast, in order to maintain awareness of the space. (A good use of this concept in a desktop system is Mackinlay, Card, and Robertson, Rapid controlled movement through a virtual 3D workspace, SIGGRAPH '90, 171-176.)



Strategies (how the user uses the technique) are as important as the technique itself, especially in tasks requiring spatial knowledge. Therefore, you should provide training, instructions, and guidance to help the user take advantage of the technique.

Cross-task ITs can be useful if travel is not the main interaction, but is only used, for example, to gain a better viewpoint on a manipulation task. Remember that such motion can be tiring, however, and should not be used for very long exposure period applications.