7

3D navigation

Locomotion, orientation and changes of scale

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COURSE NOTES

Navigation combines travelling through an environment with understanding where one is and how to reach a destination. Physical walking, steering, teleportation and viewpoint controls distribute effort and information differently. A successful technique must support the intended journey as well as orientation and comfort.

Course outline

Navigation tasks

7.1

Physical locomotion

7.2

Steering and flying

7.3

Destination and world manipulation

7.4

Orientation and scale

7.5

Technique comparison

7.6

COURSE NOTES

Navigation combines travelling through an environment with understanding where one is and how to reach a destination. Physical walking, steering, teleportation and viewpoint controls distribute effort and information differently. A successful technique must support the intended journey as well as orientation and comfort.

The sequence connects the following topics: Navigation tasks ; Physical locomotion ; Steering and flying ; Destination and world manipulation ; Orientation and scale ; Technique comparison.

Slide 3 / 44

Online slide ↗

Part 1 of 6

7.1
Navigation tasks

COURSE NOTES

Navigation combines motor travel with the cognitive activity of finding a route and maintaining orientation. A technique determines how the viewpoint moves, but also which information remains available about the journey. Fast movement can support immediate access while making a route harder to understand or retrace. Destination control and spatial knowledge are therefore different outcomes.

Slide 4 / 44

Online slide ↗

7.1 Navigation tasks

Navigation and wayfinding

Locomotion

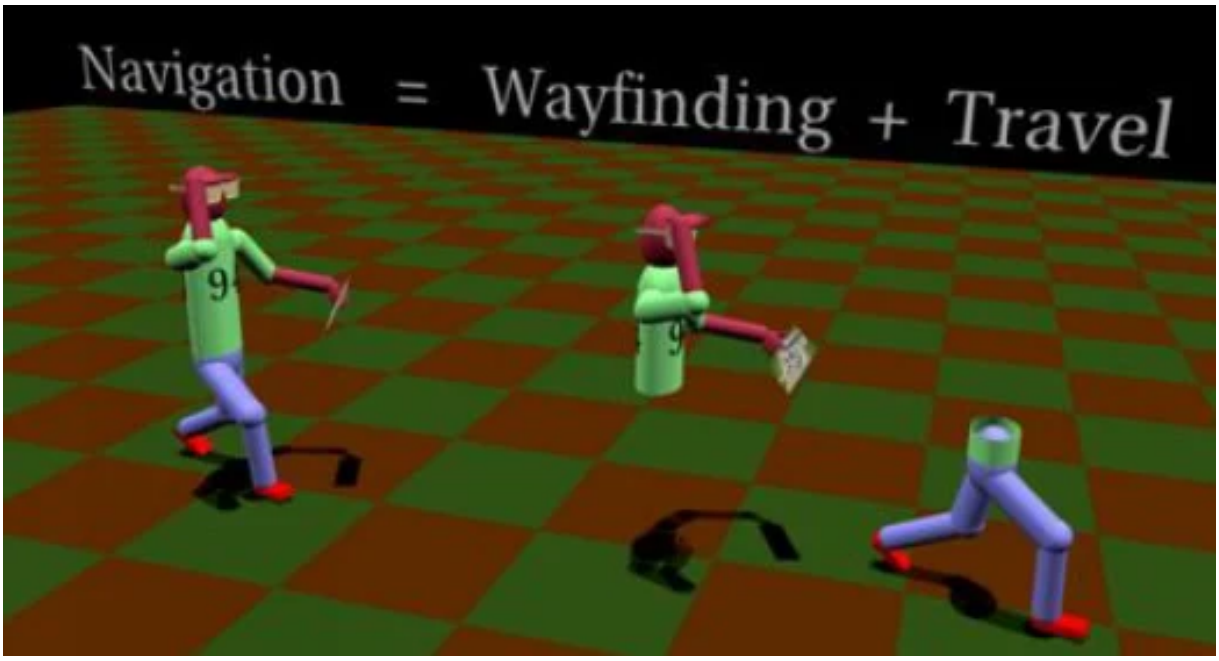
Moving the viewpoint

Wayfinding

Knowing where to go and how

Scale

Changing the spatial relation to the world



Navigation combines travel and wayfinding

COURSE NOTES

Navigation combines motor travel with the cognitive activity of finding a route and maintaining orientation. A technique determines how the viewpoint moves, but also which information remains available about the journey. Fast movement can support immediate access while making a route harder to understand or retrace. Destination control and spatial knowledge are therefore different outcomes.

Exploration, search and known targets

Exploration

Build knowledge of an unfamiliar place

Naive search

Find a target with unknown location

Primed search

Travel toward a known target

COURSE NOTES

The task changes which navigation features are useful. An overview may help known-target travel but reduce local detail during exploration. Search combines perception and navigation, so target visibility and environmental structure influence performance. State whether the participant knows the target’s identity and location.

Egocentric and exocentric navigation

Egocentric

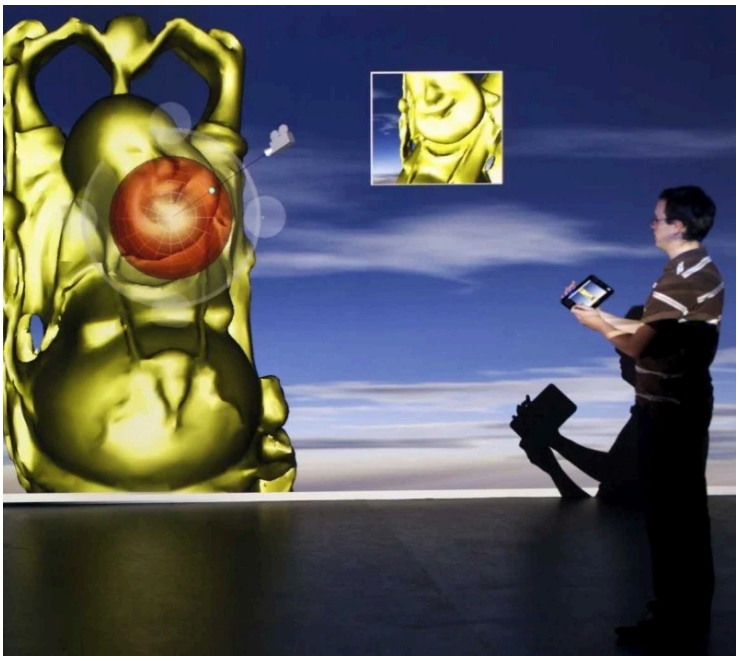
Move as a participant within the scene

Exocentric

Control the scene from an external reference

Transition

Maintain correspondence between views



Alternative navigation metaphors

COURSE NOTES

Walking and flying generally use the participant’s viewpoint. World manipulation and a miniature can give an external reference. These descriptions are useful dimensions rather than strict mutually exclusive categories. A system can switch or combine them during a task.

Slide 7 / 44

Online slide ↗

Part 2 of 6

7.2
Physical locomotion

COURSE NOTES

Real walking preserves many relationships among vision, proprioception and vestibular input. It remains constrained by physical space and tracking coverage. Virtual obstacles do not guarantee physical protection. Room layout, cables or other participants can change what is feasible even when the virtual environment looks open.

Slide 8 / 44

Online slide ↗

7.2 Physical locomotion

Real walking

Input

Physical displacement

Output

Corresponding virtual displacement

Limit

The usable tracked space

COURSE NOTES

Real walking preserves many relationships among vision, proprioception and vestibular input. It remains constrained by physical space and tracking coverage. Virtual obstacles do not guarantee physical protection. Room layout, cables or other participants can change what is feasible even when the virtual environment looks open.

7.2 Physical locomotion

Walking in place

Input

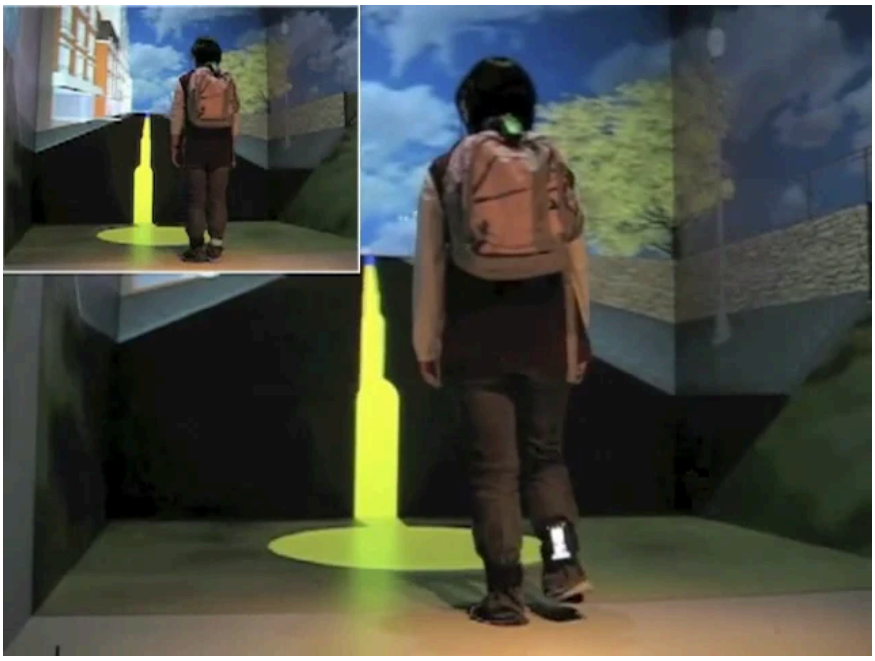
Stepping without travelling far

Mapping

A step estimate drives virtual speed

Tradeoff

Reduced space, altered bodily cues



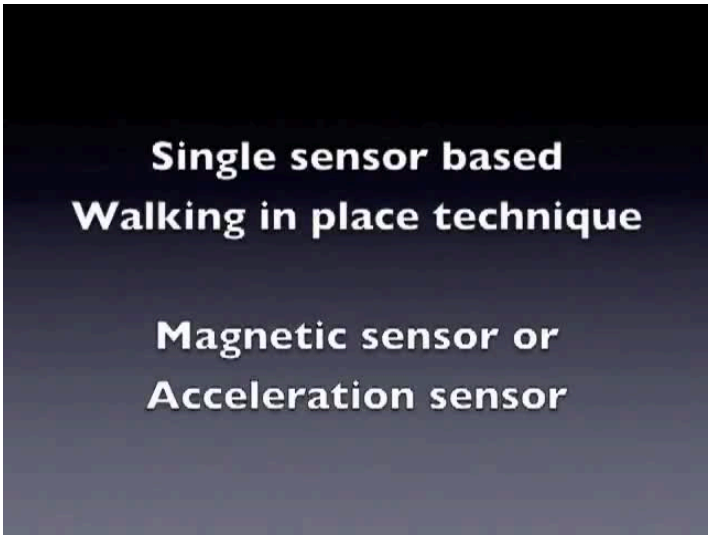
Walking-in-place demonstration

COURSE NOTES

Walking in place uses stepping or related bodily movement to command displacement. It differs from real walking because translation through the room is absent or limited. Step detection, acceleration, stopping and fatigue affect use. It should be evaluated as its own interaction technique rather than assumed to reproduce natural walking.

7.2 Physical locomotion

Walking in place: source recording



Walking in place: source recording

Watch the video ↗

COURSE NOTES

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7.2 Physical locomotion

Walking in place

Walking in place

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Dedicated walking devices

Active surfaces

Move beneath the user

Passive low-friction systems

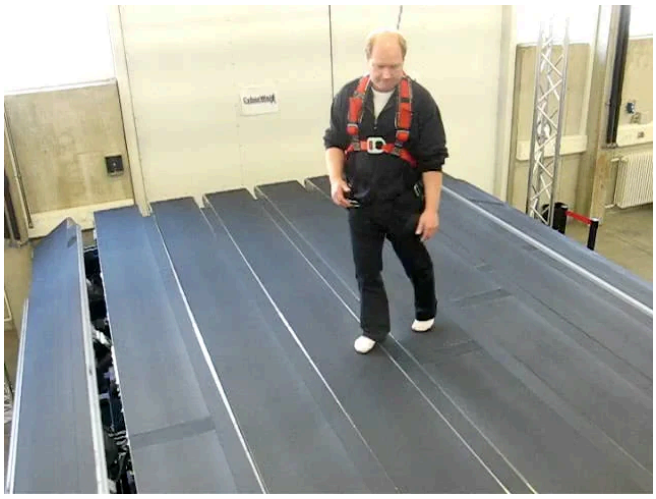
Constrain and support sliding

Spherical or specialised mechanisms

Alternative physical arrangements



Dedicated locomotion devices



A moving-surface walking interface

COURSE NOTES

The examples include active treadmills, passive systems, a locomotion sphere and moving supports. Their mechanics and sensory consequences differ. Compare support, gait, turning, setup cost and safety procedures, rather than classify all devices as equivalent walking simulators. Images are historical research and product examples.

Redirected walking

Virtual path

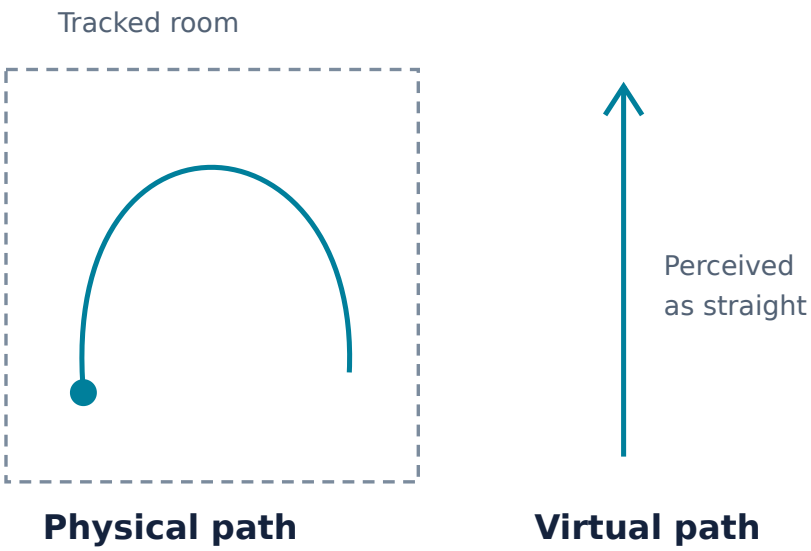
The intended trajectory

Physical path

A different trajectory in the room

Mapping

Subtle changes to visual motion



COURSE NOTES

Redirected walking changes the relation between physical and virtual movement to use a limited space. Rotation, translation or curvature gains can redirect a trajectory under particular conditions. Detection thresholds vary with task and participant. The simplified sketch explains the principle without claiming an arbitrary path can fit in any room.

7.2 Physical locomotion

Redirection demonstrations

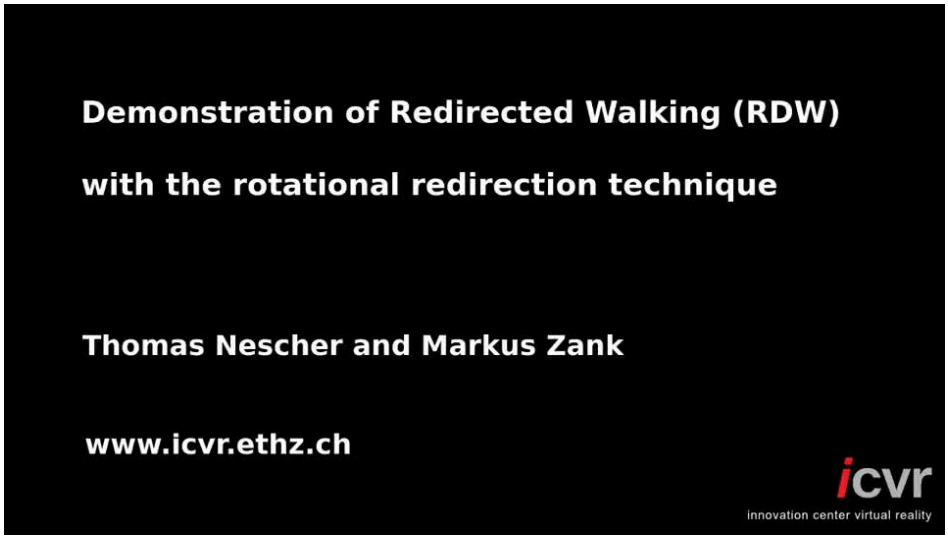


A redirected walking demonstration

COURSE NOTES

Redirected walking changes the relationship between physical movement and the virtual trajectory. A person can follow an apparently straight or curved virtual path while taking a different path in the room. Resets and distractors can help manage the physical boundary. The perceptibility of the manipulation depends on its magnitude, the available cues and the activity; there is no universal amount of unnoticed redirection.

Rotational redirection



Rotational redirection

Watch the video ↗

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An extended virtual corridor: source recording



An extended virtual corridor: source recording

Watch the video ↗

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Redirection explanation

Redirection explanation

Watch the video ↗

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An extended virtual corridor

An extended virtual corridor

Watch the video ↗

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Slide 19 / 44

Online slide ↗

Part 3 of 6

7.3
Steering and flying

COURSE NOTES

Steering converts an input into a direction and speed of virtual movement. Direction may be defined by the head, a hand, the torso or another reference frame. Decoupling viewing direction from movement allows inspection while travelling, but adds a control relationship to learn. Speed, acceleration and stopping behaviour determine both precision and the motion presented to the senses.

Slide 20 / 44

Online slide ↗

7.3 Steering and flying

Steering and virtual flight

Direction

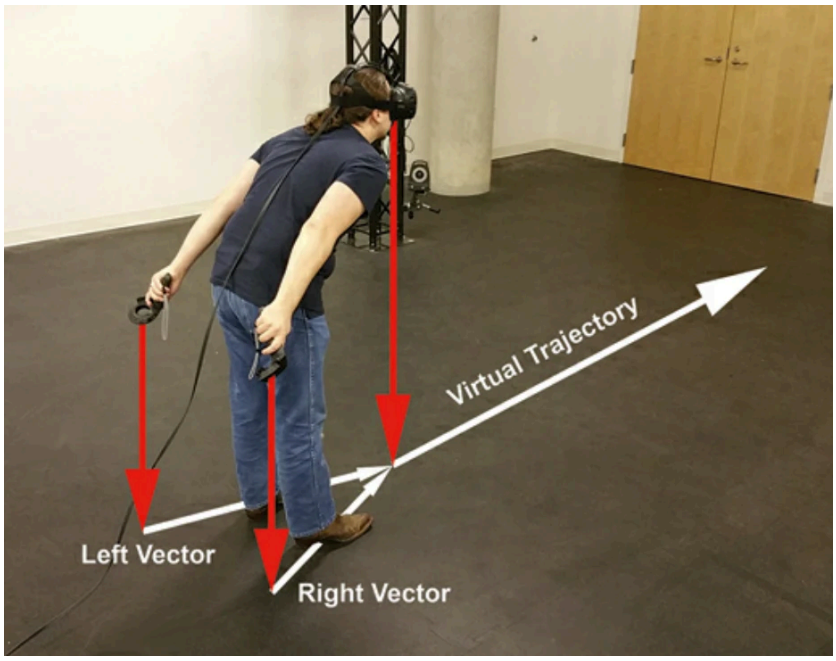
Where movement should go

Speed

How fast to move

Activation

When movement begins and ends



Body-related directions for virtual movement

COURSE NOTES

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Choosing a steering reference

Reference	Opportunity	Constraint
Head direction	Simple to discover	Looking also changes travel direction
Hand direction	Viewing and travel can differ	Arm pose and fatigue matter
Body direction	A bodily reference	Needs a reliable orientation estimate
Device axes	Familiar control mapping	Requires learned coordination

COURSE NOTES

No steering reference is universally best. Compare the task’s need to look around, control orientation and keep the arms free. An external controller can express direction without aligning to the body. The navigation study must specify the reference frame to make its results interpretable.

Vehicle metaphors

A cockpit

A stable reference and control context

Dedicated controls

Steering wheel, pedals or handles

Virtual dynamics

A chosen model of motion



Examples of vehicle-style navigation

COURSE NOTES

Vehicle metaphors can exploit familiar control skills and make constraints understandable. A virtual cockpit does not by itself reproduce physical accelerations. Simulated vehicles can also be fictional. Explain which control relations imitate an existing vehicle and which are simply a convenient interface.

7.4

Destination and world manipulation

COURSE NOTES

Teleportation separates destination specification from the transition. Candidates may be predefined or freely indicated on permitted surfaces. The interface needs clear validity and orientation feedback. Teleportation often reduces continuous visual motion, but can disrupt spatial updating or introduce arrival ambiguity.

Teleportation

Specify

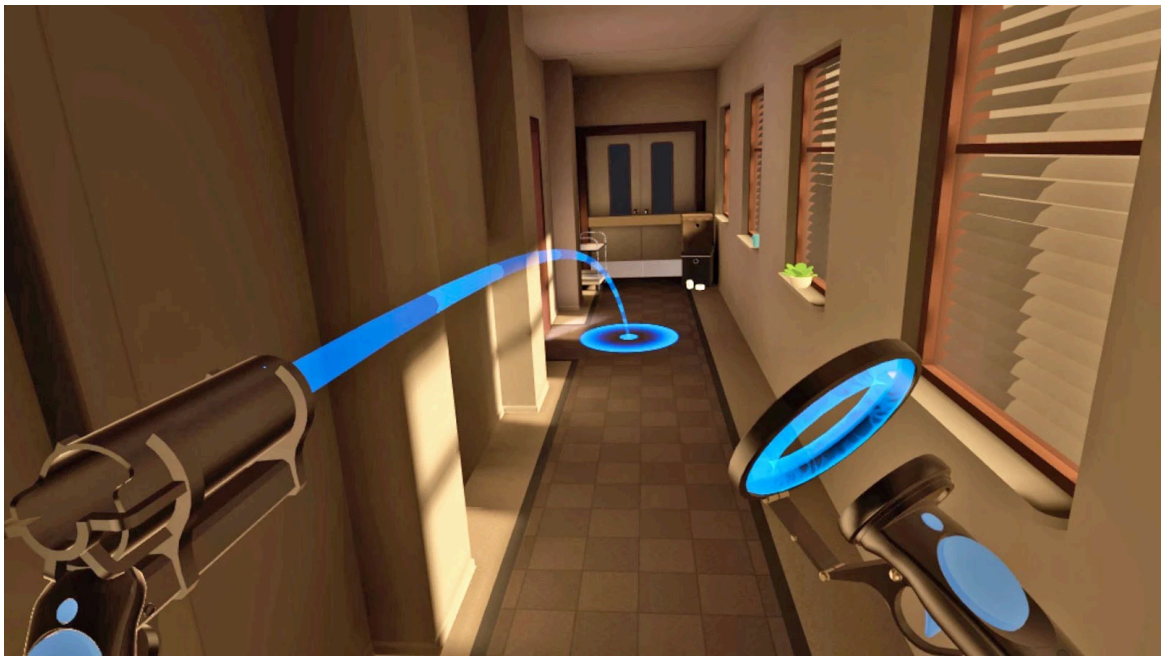
A destination and possibly orientation

Preview

The proposed arrival location

Commit

An immediate change of viewpoint



Destination preview for teleportation

COURSE NOTES

Teleportation separates destination specification from the transition. Candidates may be predefined or freely indicated on permitted surfaces. The interface needs clear validity and orientation feedback. Teleportation often reduces continuous visual motion, but can disrupt spatial updating or introduce arrival ambiguity.

Immediate and interpolated transitions

Transition	Property	Tradeoff
Immediate	Little visual travel	A discontinuity in spatial context
Interpolated	A visible route or movement	Additional visual motion
Guided path	A constrained journey	Reduced freedom of travel

COURSE NOTES

Destination selection and transition style are independent choices. A user may point to a location and then jump or travel through an interpolated path. Compare orientation, travel time and comfort. A smooth path is not automatically comfortable, especially if the movement is unexpected or bodily cues disagree.

Guided navigation

A predefined route

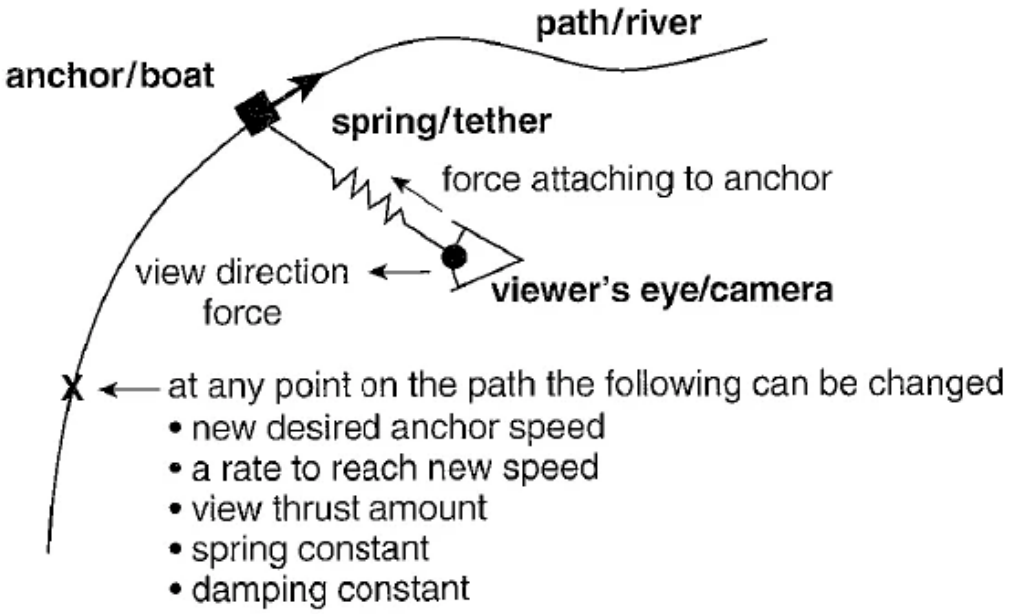
The system constrains the journey

Local freedom

The user can look or move within an envelope

Control

Start, stop and limited steering



The water-skiing metaphor for guided navigation

COURSE NOTES

Guided navigation constrains travel to a route or region while retaining some local control. The river or water-skiing metaphor allows movement around a predefined path, directing attention without fixing every detail of the journey. The design must specify how the user can pause, deviate or regain control. Camera movement generated by the system also changes the relationship between bodily motion and visual travel.

7.4 Destination and world manipulation

World in miniature

A spatial proxy

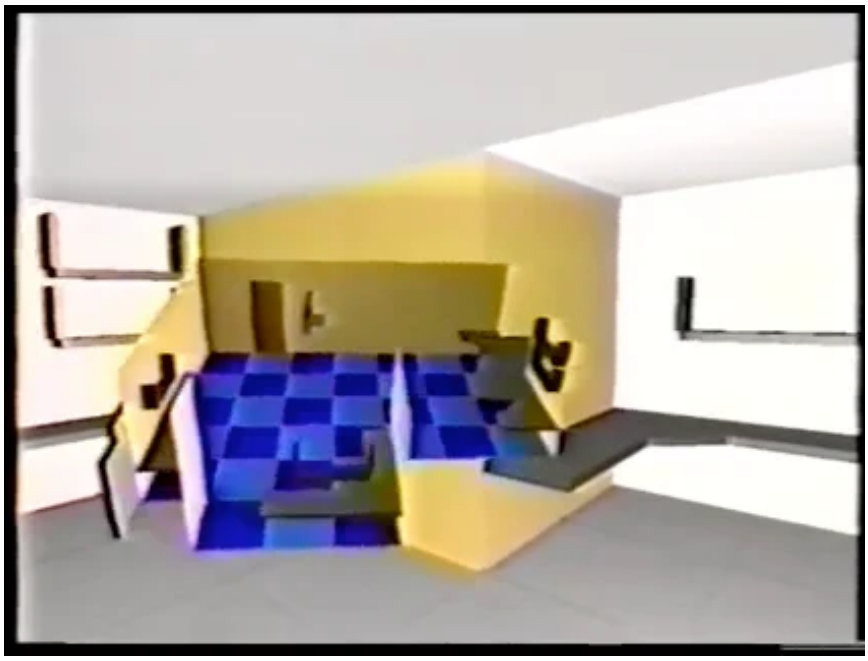
The environment within reach

Selection

Indicate a location on the model

Correspondence

Map model coordinates to the world



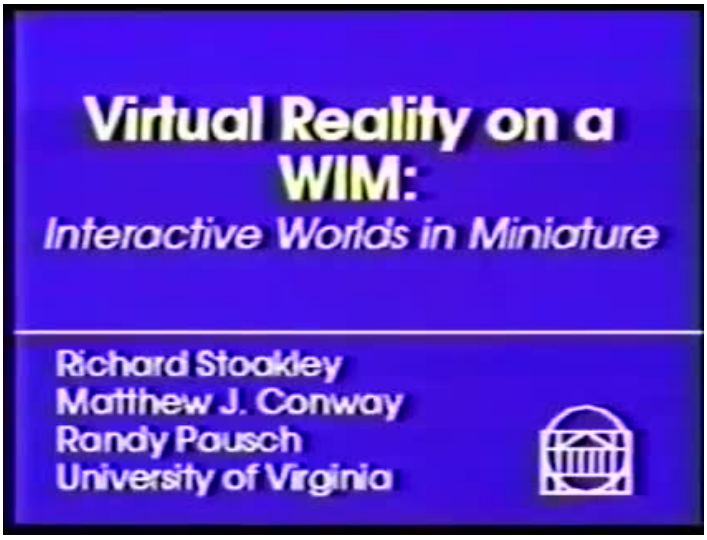
A world-in-miniature representation

COURSE NOTES

Stoakley and colleagues use a miniature to access a larger environment. The representation can support selection, navigation or object manipulation. It offers an overview but may make small targets hard to distinguish. The participant needs a clear relation between current location, model and arrival viewpoint.

7.4 Destination and world manipulation

WIM: source recording



WIM: source recording

Watch the video ↗

COURSE NOTES

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7.4 Destination and world manipulation

World in miniature

World in miniature

Watch the video ↗

COURSE NOTES

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7.4 Destination and world manipulation

Grabbing the air

Grip

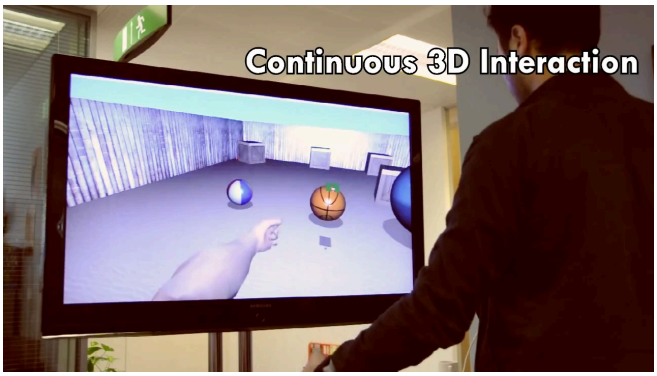
Establish a spatial anchor

Pull

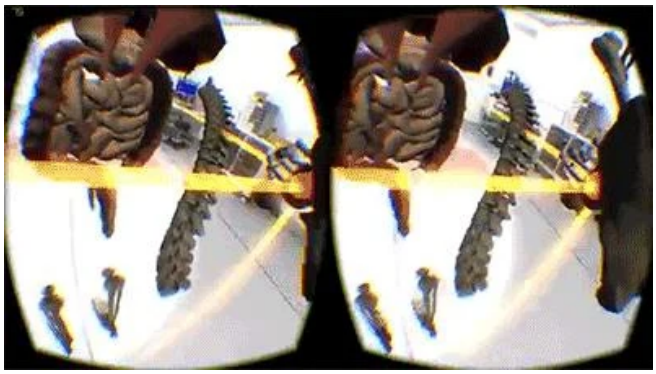
Move the world relative to the body

Release

End or reset the mapping



Grabbing-the-Air world manipulation



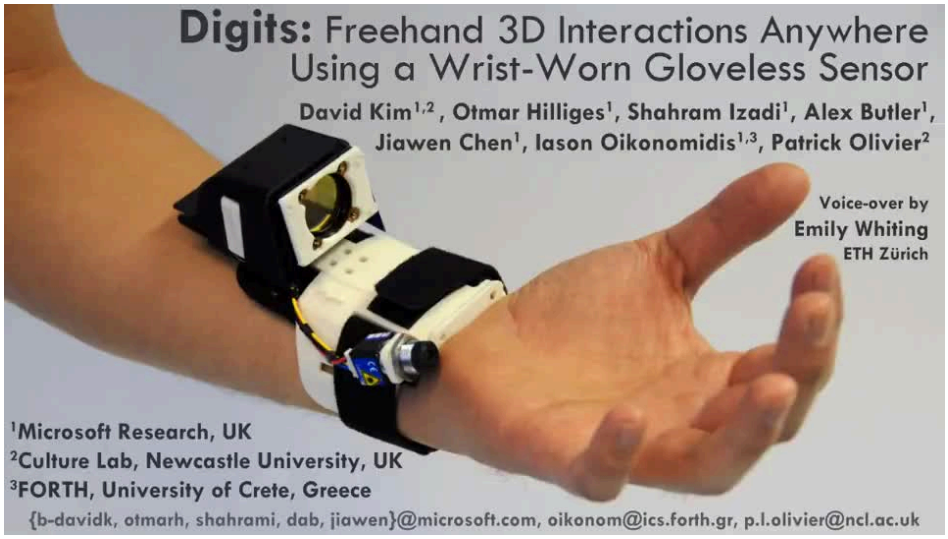
Grab-and-pull movement

COURSE NOTES

Grabbing the air makes the world respond to hand displacement, often as though the participant pulls through it. Climbing is a related metaphor with explicit virtual anchors. The reference frame and gain determine the result. Repeated strokes, two-hand combinations and release behaviour need to be specified and evaluated.

7.4 Destination and world manipulation

Grabbing the air: source recording



Grabbing the air: source recording

Watch the video ↗

COURSE NOTES

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7.4 Destination and world manipulation

Navidget

Designate

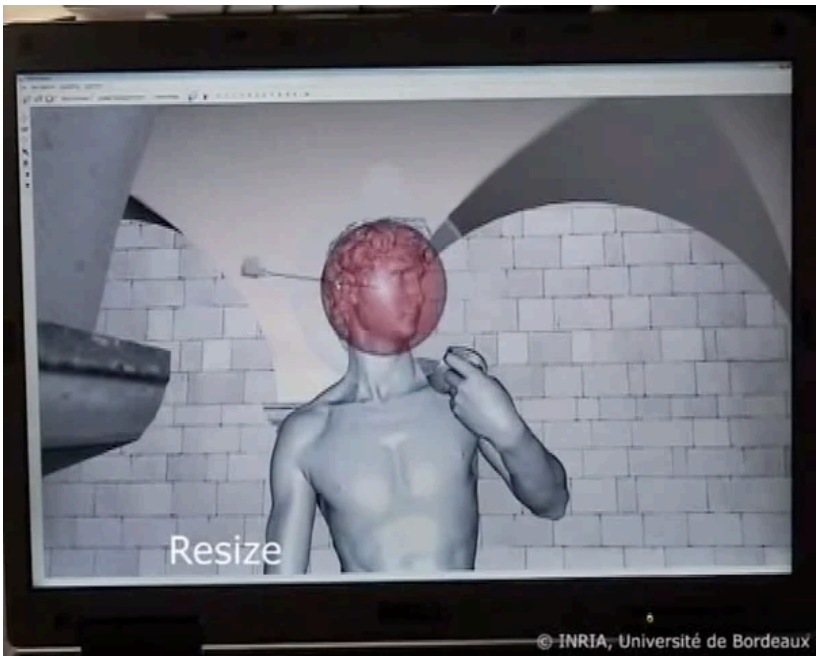
A region of interest

Adjust

A target viewpoint around that region

Navigate

Move to the chosen view



Navidget viewpoint specification

COURSE NOTES

Navidget separates choosing a region of interest from specifying the viewpoint used to inspect it. The user controls where to look from, rather than only selecting a destination on the ground. This is useful for examining an object or a local part of a larger scene. The interface must communicate the intended camera position and orientation, as well as the resulting transition.

7.4 Destination and world manipulation

Navidget: source recording



Navidget: source recording

Watch the video ↗

COURSE NOTES

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7.4 Destination and world manipulation

Navidget

Navidget

Watch the video ↗

COURSE NOTES

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Slide 35 / 44

Online slide ↗

Part 5 of 6

7.5
Orientation and scale

COURSE NOTES

Wayfinding uses several forms of spatial knowledge. A participant may remember landmarks without understanding the whole layout. Repeated use can build route knowledge, while an overview may support relations among places. A task should specify which of these abilities it aims to support or measure.

Slide 36 / 44

Online slide ↗

7.5 Orientation and scale

Spatial knowledge

Landmarks

Recognisable locations and objects

Routes

Ordered sequences of actions

Survey knowledge

Relations between places

COURSE NOTES

Wayfinding uses several forms of spatial knowledge. A participant may remember landmarks without understanding the whole layout. Repeated use can build route knowledge, while an overview may support relations among places. A task should specify which of these abilities it aims to support or measure.

Orientation aids

Environmental landmarks

Distinctive places and local context

Maps and miniatures

An external spatial representation

Guidance cues

Visual or auditory direction

COURSE NOTES

Orientation aids include maps, landmarks, sound and attentional cues. A guide can help immediate travel while reducing opportunities to learn the environment. Repeated or visually similar scenes can create ambiguity. Test orientation after removing assistance if spatial learning is an intended outcome.

Multi-scale navigation

Manual scale

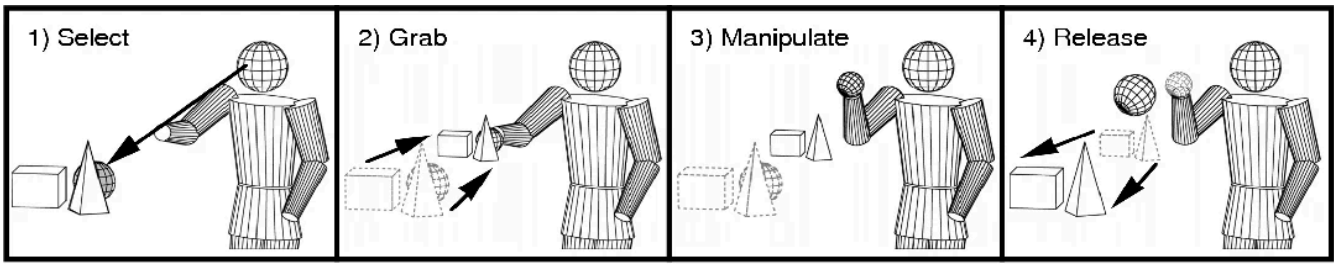
The participant changes the scale

Automatic scale

The system adapts to a target or context

Additional control

Scale changes reach and travel



Multi-scale navigation examples

COURSE NOTES

The examples include Head-butt Zoom, scaled-world grab and automatic bounding-box approaches. Changing scale affects the relation among physical movement, virtual displacement and object size. This can make large environments accessible, but it may also change spatial understanding and apparent body size. Clarify whether the world, viewpoint or representation is being scaled.

Scale and movement gain

Smaller world

A physical step covers more of the model

Larger world

Fine spatial inspection

Transition

A new relation between body and environment

COURSE NOTES

Scale is not merely a visual zoom. If the world is resized around the participant, physical displacement and reach change relative to its objects. A camera field-of-view change produces a different effect. Identify the actual transformation before explaining a technique or measuring its performance.

Slide 40 / 44

Online slide ↗

Part 6 of 6

7.6
Technique comparison

COURSE NOTES

The comparison summarises tradeoffs rather than ranks techniques. Comfort, spatial learning and task performance may favour different choices. The user’s mobility, available physical space and familiarity also matter. Provide alternatives where possible and test with the intended participants.

Slide 41 / 44

Online slide ↗

7.6 Technique comparison

Choosing a navigation technique

Technique	Opportunity	Constraint
Real walking	Strong bodily correspondence	Physical room limits
Steering	Continuous access to large spaces	Visual–bodily mismatch
Teleportation	Rapid destination changes	Spatial discontinuities
World manipulation	Reach and scale flexibility	Mapping and orientation demands

COURSE NOTES

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7.6 Technique comparison

A navigation evaluation

Performance

Search time and targets reached

Orientation

Pointing, route recall and location estimates

Experience

Control, effort and discomfort

3D navigation lab ↗

COURSE NOTES

Finding a target and learning an environment are different outcomes. A technique can shorten search time while leaving the user with a poor understanding of the route. Comparing navigation methods therefore requires measures of performance, spatial knowledge and comfort. Exposure duration, order of conditions and prior practice influence the comparison and need to be controlled or recorded.

7.6 Technique comparison

Navigation design review

A small tracked room and a large virtual city

A guided cultural visit

A precision inspection task

An application used seated or standing

COURSE NOTES

Choose locomotion, orientation aids and transition behaviour for each setting. Explain the expected physical cues and any mismatch. Identify what can be tested technically and what requires evaluation with participants.

Sources and further reading

C. Fleury, 3D interaction (2025–26)

FILA3, 3D interaction

Introduction to VR and AR

C. Fleury, 3D navigation (2025–26)

All course materials ↗

COURSE NOTES

Scientific work connects a result to a question, a method and conditions of observation. A demonstration shows a possibility; a study compares conditions and measures their effects. The scope of a conclusion depends on that distinction and on the limits of the evaluation.