6

3D interaction

Selection, manipulation and application control

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COURSE NOTES

An interaction technique maps a person’s movement or command to an action in the virtual world. Selection, transformation and system control require different mappings. Their design must make the available action, its result and recovery from errors understandable while accounting for precision, reach and fatigue.

Course outline

Interaction design

6.1

Selection

6.2

Manipulation

6.3

Modalities and physical supports

6.4

Control and evaluation

6.5

COURSE NOTES

An interaction technique maps a person’s movement or command to an action in the virtual world. Selection, transformation and system control require different mappings. Their design must make the available action, its result and recovery from errors understandable while accounting for precision, reach and fatigue.

The sequence connects the following topics: Interaction design ; Selection ; Manipulation ; Modalities and physical supports ; Control and evaluation.

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Part 1 of 5

6.1

Interaction design

COURSE NOTES

Selection and manipulation concern objects, navigation concerns movement and orientation, and system control concerns commands, modes and parameters. These families organise the tasks supported by an interface, rather than defining mutually exclusive devices. A miniature world can support both selection and navigation, for example. The useful question is what action the user is trying to perform at each moment.

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6.1 Interaction design

Three families of 3D interaction

Object manipulation

Select and transform

Navigation

Change viewpoint or scale

Application control

Change tools, modes and parameters

COURSE NOTES

Selection and manipulation concern objects, navigation concerns movement and orientation, and system control concerns commands, modes and parameters. These families organise the tasks supported by an interface, rather than defining mutually exclusive devices. A miniature world can support both selection and navigation, for example. The useful question is what action the user is trying to perform at each moment.

6.1 Interaction design

Norman’s action cycle

1. **Goal**
   What do I want?
2. **Execution**
   Plan, specify and perform
3. **Perception**
   Observe the result
4. **Evaluation**
   Interpret and compare

COURSE NOTES

Norman’s cycle links intention, action and interpretation of feedback. The execution gap concerns translating a goal into an available action. The evaluation gap concerns understanding what happened and whether it met the goal. VR does not remove these gaps simply by allowing bodily movement.

6.1 Interaction design

Principles of interaction design

Visibility

Available actions and current state

Affordances and mappings

What appears possible and how it works

Feedback and constraints

Consequences and error prevention

COURSE NOTES

Feedforward communicates what an action would do, while feedback communicates its result. A glowing handle may advertise grasping; a change in sound and appearance may confirm attachment. Constraints can reduce ambiguity and prevent impossible actions. Good mapping depends on the task and user’s expectations, not only on visual familiarity.

6.1 Interaction design

Direct manipulation

Continuous representation

The object remains perceptible

Incremental action

Effects appear during the movement

Reversibility

Actions can be corrected

COURSE NOTES

Direct manipulation is an interface property, not simply the absence of a mouse. A controller-mediated virtual hand can support continuous object control. A bodily gesture can still invoke an indirect symbolic command. Evaluate the relation between the user's action, representation and effect rather than classify devices as inherently direct or indirect.

6.1 Interaction design

Natural interaction and extended ability

Natural mapping

Use familiar bodily skills

Extended mapping

Overcome reach or scale limits

Tradeoff

Learnability, control and task performance



Design fiction and the constraints of tracked interfaces

COURSE NOTES

The World Builder example suggests gestures, speech and contextual controls with few visible constraints. Real systems have finite tracking, field of view and feedback. Naturalism is one design resource, not a guarantee of usability. An intentionally non-physical technique can be more effective for a particular task.

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6.1 Interaction design

World Builder: interaction analysis

World Builder: interaction analysis

Watch the video ↗

COURSE NOTES

The World Builder example suggests gestures, speech and contextual controls with few visible constraints. Real systems have finite tracking, field of view and feedback. Naturalism is one design resource, not a guarantee of usability. An intentionally non-physical technique can be more effective for a particular task.

Why interaction in 3D is difficult

Perception

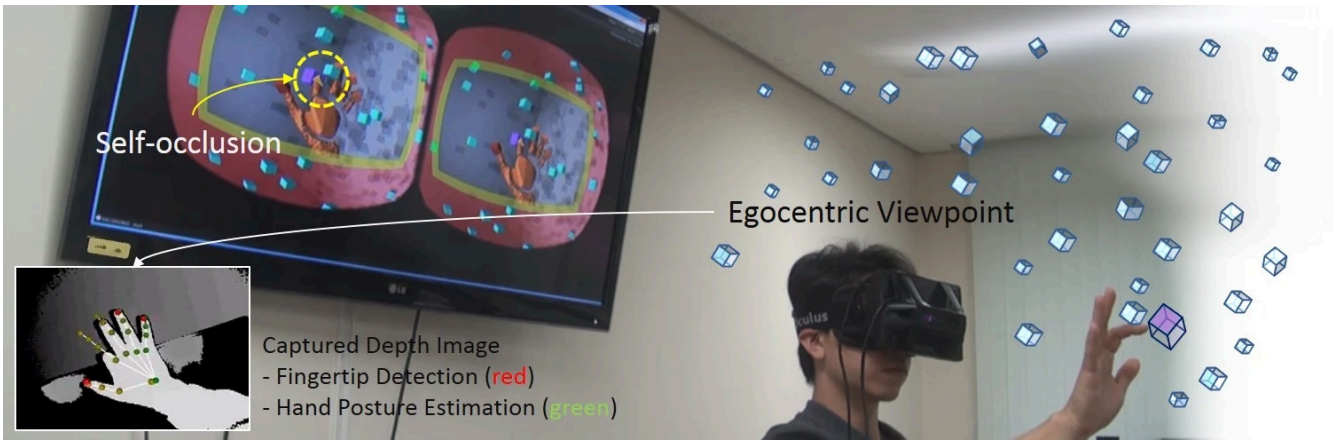
Depth, occlusion and object density

Motor control

Precision, tremor and fatigue

Interface knowledge

Tools, modes and unfamiliar conventions



Spatial complexity in 3D interaction

COURSE NOTES

Compared with many desktop tasks, 3D interaction can have fewer physical constraints, more degrees of freedom and less stable support for the hands. The user may also lack tactile contact with the virtual surface. Improving graphics alone does not resolve these motor and cognitive difficulties.

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Part 2 of 5

6.2
Selection

COURSE NOTES

Selection and subsequent manipulation can use different mappings. A good selection tool may be poor at rotation. Explicitly separate indicating a candidate, confirming selection and attaching control. The interaction needs a clear release or cancellation action, especially when several objects are close together.

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6.2 Selection

Selection and transformation

1. **Indicate**
   Identify a candidate
2. **Confirm**
   Choose the intended object
3. **Attach**
   Establish a control relation
4. **Transform**
   Move, rotate or resize

COURSE NOTES

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6.2 Selection

The virtual hand

Mapping

Tracked hand to virtual hand

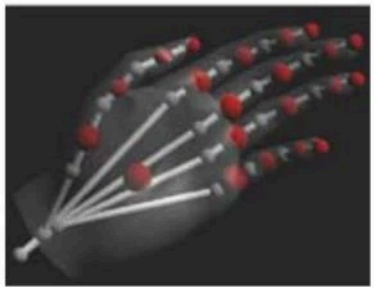
Selection

Contact or overlap near the object

Constraint

Physical reach and missing contact forces





Near-object manipulation

COURSE NOTES

A virtual hand supports familiar near-object actions and can preserve a simple spatial mapping. It is limited by reach, tracking and the absence of physical surfaces. Selection can use colliders, gestures or buttons. The apparent hand shape does not determine how those mechanisms work.

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6.2 Selection

Go-Go interaction

Near the body

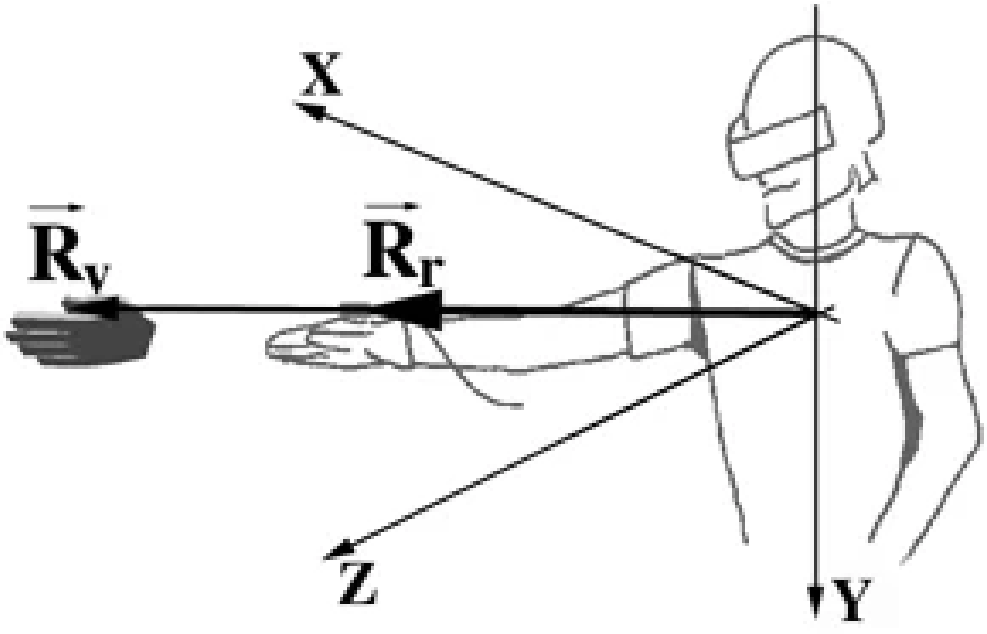
Approximately direct movement

Beyond a threshold

Reach grows nonlinearly

Result

Access to distant objects



Go-Go: the physical and virtual reach relation

COURSE NOTES

Go-Go extends virtual reach by changing the mapping from physical hand position to virtual hand position beyond a distance threshold. Near the body, the relation remains close to direct manipulation. Farther away, a nonlinear extension allows the user to reach distant objects. This extra reach comes with a different relation between movement, precision and the apparent position of the virtual arm.

6.2 Selection

A 3D cursor

Position control

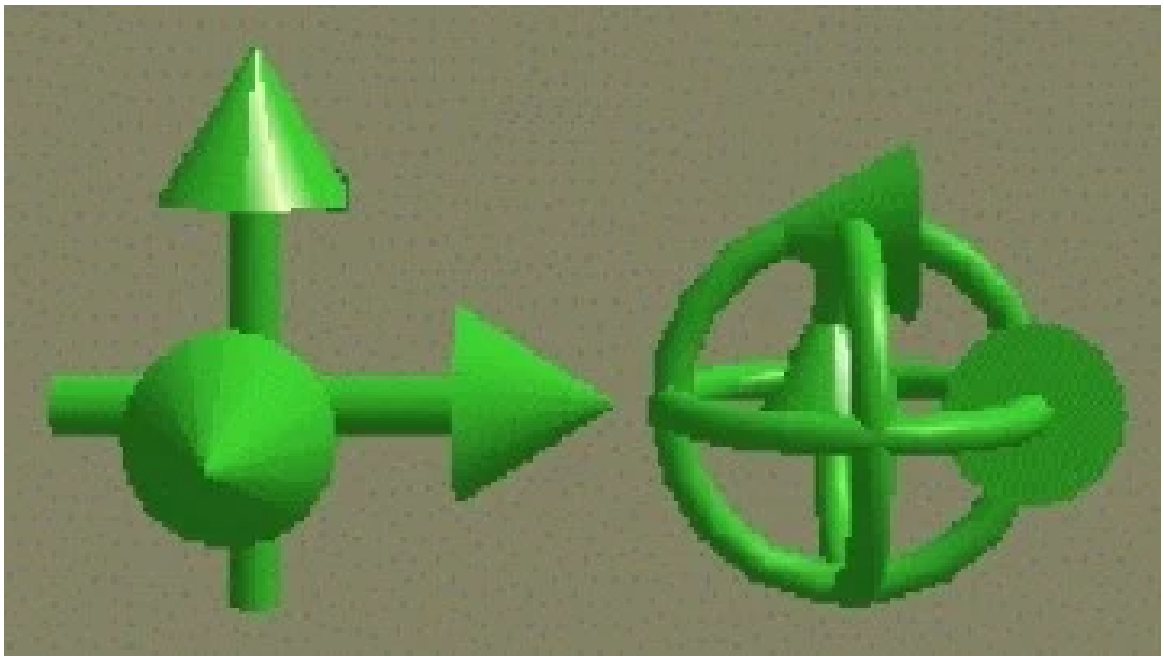
Input specifies location

Rate control

Input specifies velocity

Clutching

Reposition input without moving the cursor



Translation and rotation cursor controls

COURSE NOTES

A cursor can decouple the controlled position from the physical input. Position and rate control have different precision and travel tradeoffs. Clutching lets a participant reset a limited physical input range. A cursor still needs depth cues and a clear confirmation action.

Ray casting

Origin and direction

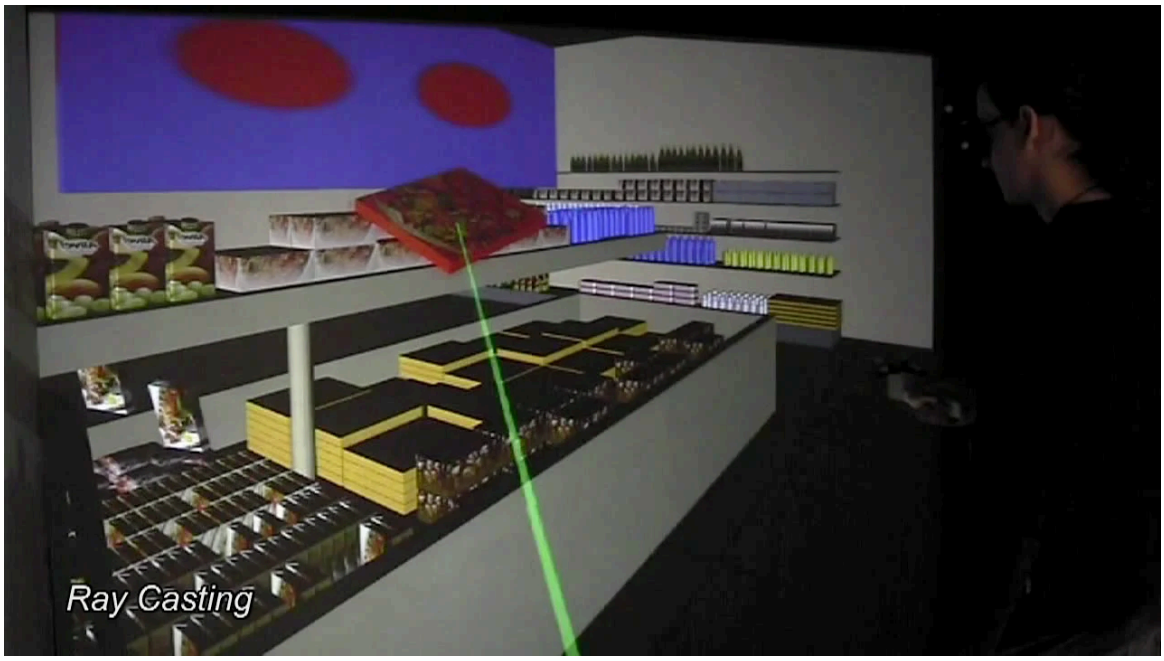
A pointing device defines a ray

Candidate

The ray intersects a target

Confirmation

A button, gesture or other action



A virtual ray for distant selection

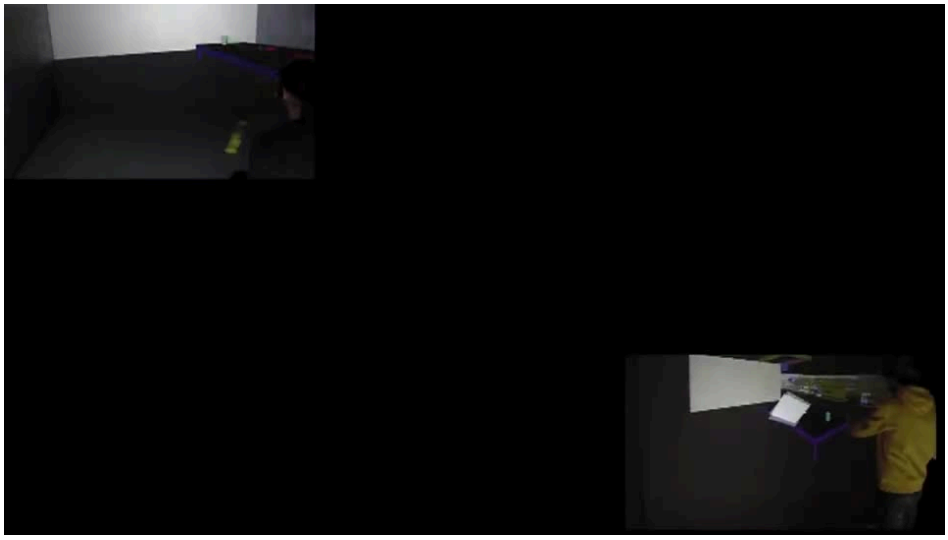
COURSE NOTES

Mine’s virtual ray uses a laser-pointer metaphor. It reaches distant objects without requiring the hand to travel to them. Angular instability becomes more consequential with distance. Occlusion and which intersection counts as the candidate need explicit rules. The ray may be visible continuously or appear only when useful.

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6.2 Selection

Ray casting and image-plane interaction



Ray casting and image-plane interaction

Watch the video ↗

COURSE NOTES

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6.2 Selection

Selection in the image plane

Projection

Objects as seen from the user

Alignment

A finger or hand indicates an image location

Depth ambiguity

Several objects may share the direction

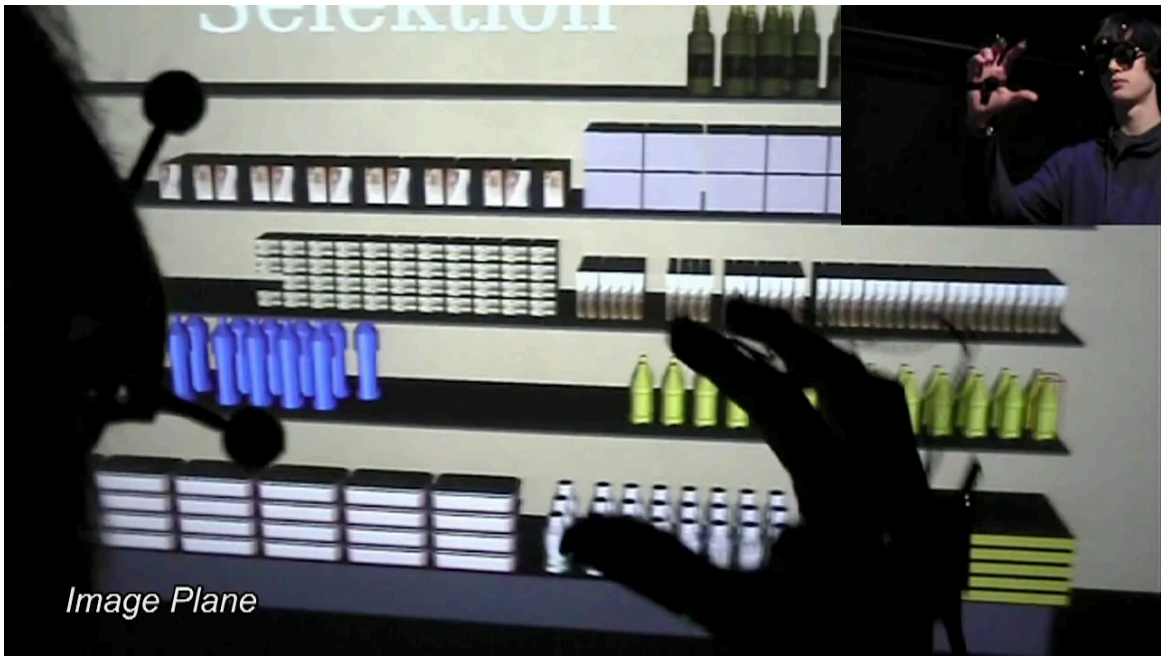


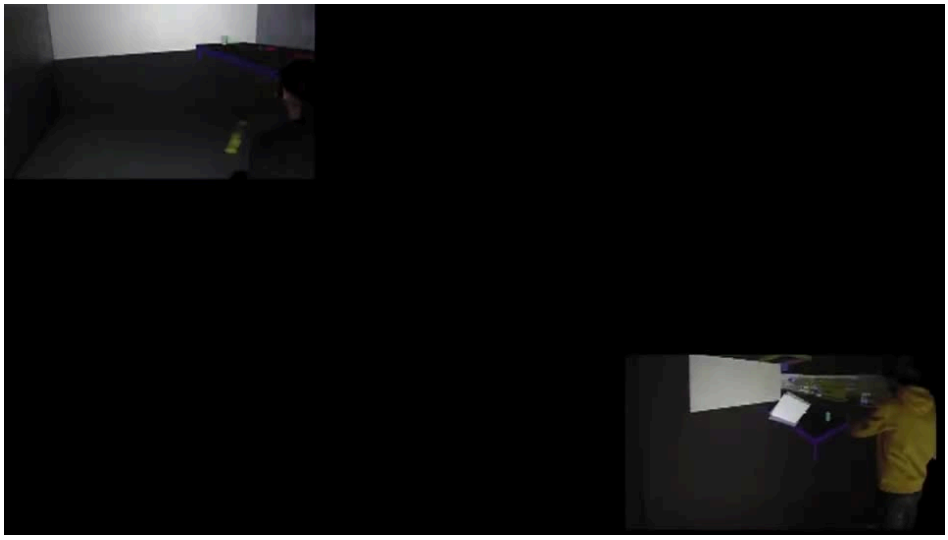
Image-plane interaction

COURSE NOTES

Pierce and colleagues use the projected scene as an interaction surface. The technique relates a body part to what the user sees, rather than simply using the controller’s orientation. It inherits ambiguities when projected targets overlap. Explain how the candidate is chosen and how the system handles depth.

6.2 Selection

Ray casting and image-plane interaction



Ray casting and image-plane interaction

Watch the video ↗

COURSE NOTES

Pierce and colleagues use the projected scene as an interaction surface. The technique relates a body part to what the user sees, rather than simply using the controller’s orientation. It inherits ambiguities when projected targets overlap. Explain how the candidate is chosen and how the system handles depth.

6.2 Selection

Fitts’ law and pointing

$$MT = a + b \log_2(1 + D / W)$$

Distance D

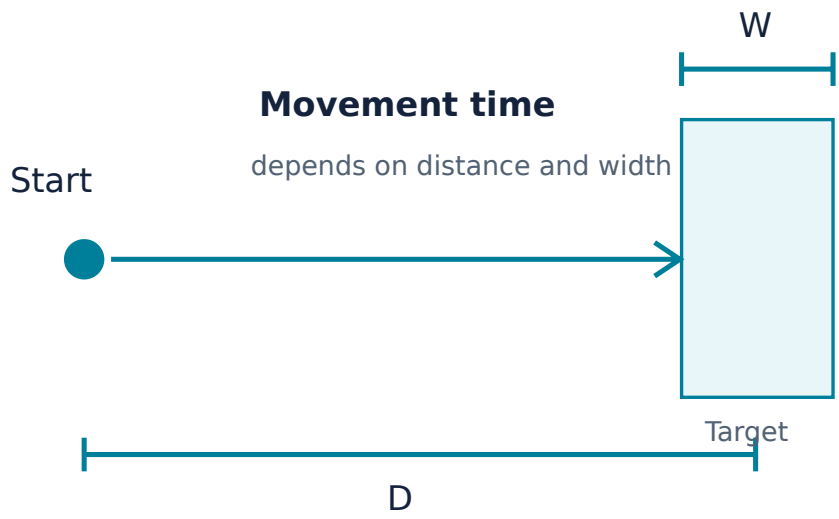
Travel to the target

Width W

Tolerance for error

Index of difficulty

A model of the speed–accuracy relation



COURSE NOTES

Fitts’ law relates movement time to distance and effective target width in a defined pointing task. Parameters a and b require empirical fitting. Extending the model to 3D needs careful definitions of distance, width and movement constraints. Fatigue, tremor, device behaviour and depth can add effects beyond the simple expression.

Ambiguity in distant selection

Occlusion

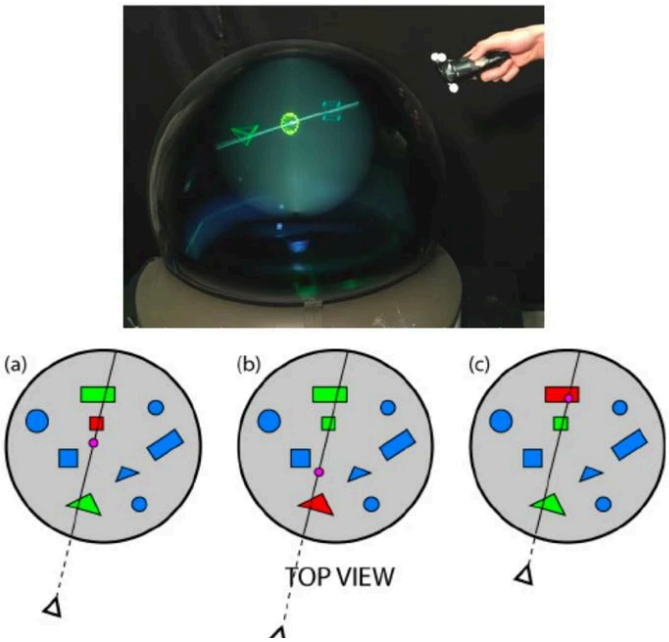
A visible ray meets the wrong surface

Dense scenes

Several plausible targets

Depth

Targets overlap along a direction



Selection disambiguation examples

COURSE NOTES

Broad selection volumes make acquisition easier but may include multiple objects. The application needs a disambiguation strategy such as a secondary choice, a depth control or spatial separation of candidates. Increasing a target’s effective area should not silently select an object the user did not intend.

Adaptive and staged selection

Bubble selection

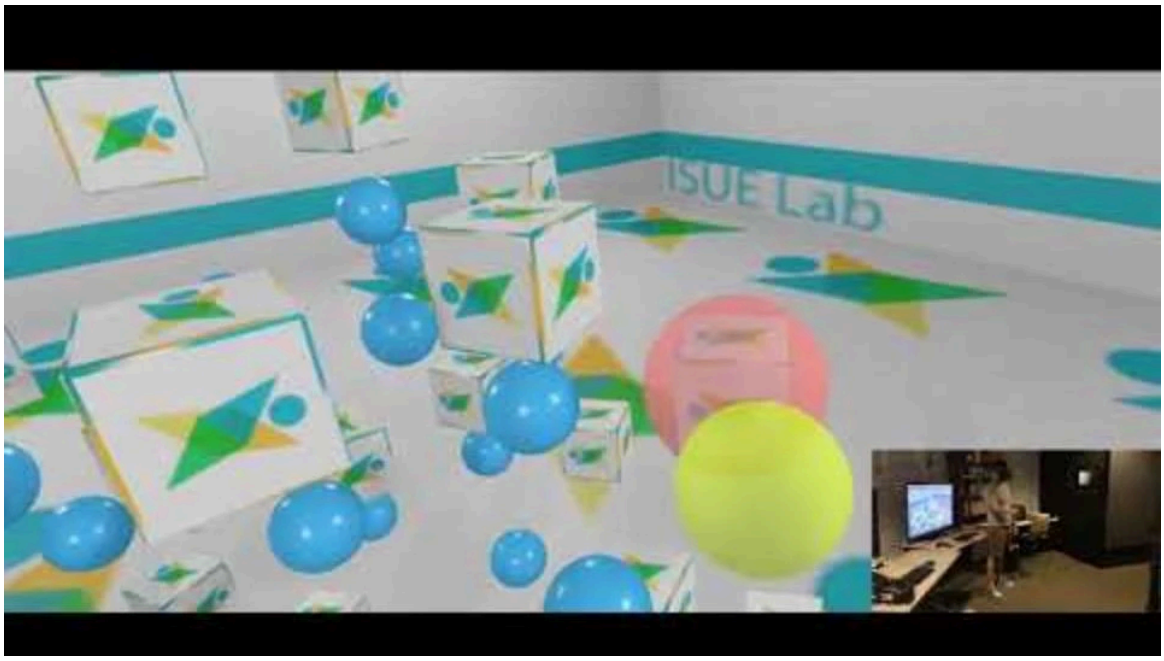
A region adapts around a candidate

Two-stage selection

Coarse acquisition, then precise choice

Semantic selection

Use task-relevant knowledge



A bubble-based 3D selection demonstration

COURSE NOTES

The diagram presents bubble, semantic and two-stage approaches as ways to improve pointing. Their benefit depends on target layout and task assumptions. Compare acquisition time, errors and the cost of disambiguation. A technique tuned for isolated targets may behave differently in dense or changing scenes.

6.2 Selection

Bubble selection in 3D

Bubble selection in 3D

Watch the video ↗

COURSE NOTES

The diagram presents bubble, semantic and two-stage approaches as ways to improve pointing. Their benefit depends on target layout and task assumptions. Compare acquisition time, errors and the cost of disambiguation. A technique tuned for isolated targets may behave differently in dense or changing scenes.

Other ways to select

A menu

Choose an explicit named target

Voice and pointing

Combine identity and direction

World in miniature

Select through a spatial proxy



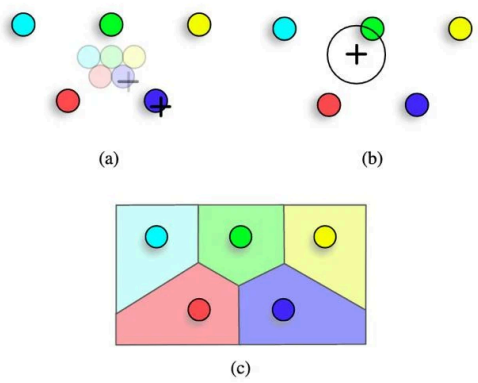
Selection through an alternative representation

COURSE NOTES

Selection need not always operate on the full-size scene. A menu can expose semantic identities, voice can distinguish candidates, and a miniature can make distant content accessible. These techniques add correspondence and memory demands. The best option depends on what information the user has and how frequently selection occurs.

6.2 Selection

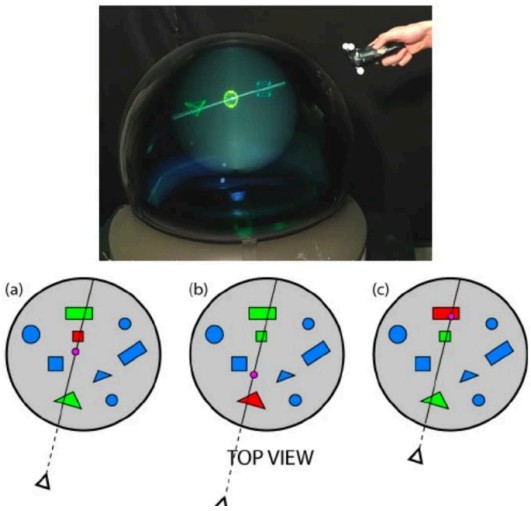
Pointing and target acquisition



Adaptive selection regions



Changing effective target size



Disambiguating candidates

> Larger effective targets can introduce selection ambiguity

COURSE NOTES

Target acquisition depends on target size, distance and the presence of competing candidates. A selection technique defines how an input becomes a target and how ambiguity is resolved. Larger effective targets can make acquisition easier, but may also change which neighbouring object is selected. A Fitts-type model is meaningful only when the movement, target geometry and fitted parameters are clearly specified.

6.3
Manipulation

COURSE NOTES

Moving an object and placing it accurately are different tasks. A technique can support all degrees of freedom at once or separate them through modes and constraints. Full freedom can create unwanted motion. A placement task may benefit from surface alignment, axis constraints or snapping when these match the intended activity.

Manipulation degrees of freedom

Translation

Three positional dimensions

Rotation

Three orientation dimensions

Scale

An additional application parameter

COURSE NOTES

Moving an object and placing it accurately are different tasks. A technique can support all degrees of freedom at once or separate them through modes and constraints. Full freedom can create unwanted motion. A placement task may benefit from surface alignment, axis constraints or snapping when these match the intended activity.

Selection versus manipulation

Distant acquisition

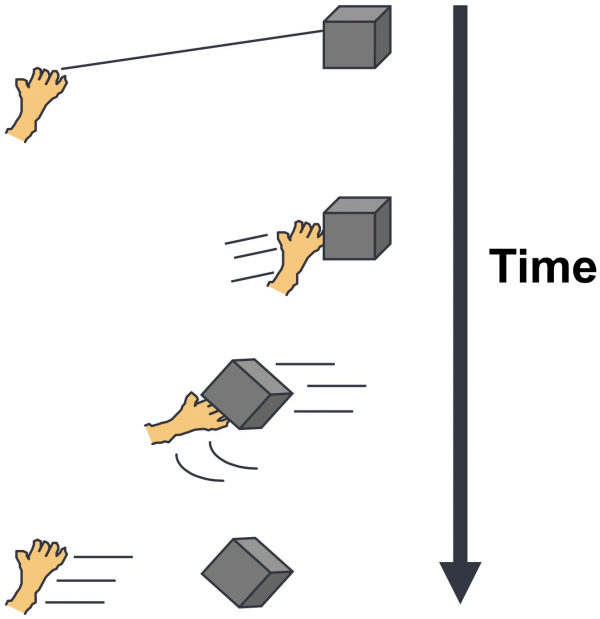
A ray can find an object

Precise transformation

A near-hand mapping can help

Transition

Control must change predictably



HOMER: a sequence linking distant selection and hand control

COURSE NOTES

Selecting an object and transforming it impose different control requirements. A ray may efficiently identify a distant target while making precise rotation awkward. Hybrid techniques change the control relation after selection, for example by bringing manipulation closer to the hand. Attachment, transition and release must remain understandable so that the object does not jump or move unexpectedly.

HOMER

Select with a ray

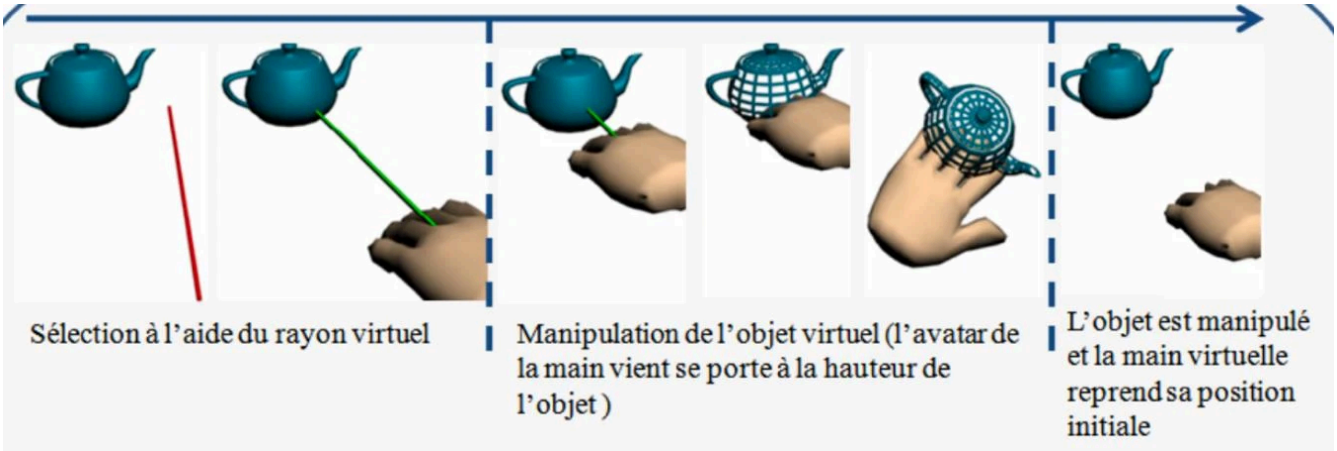
Reach a distant target

Manipulate with the hand

A scaled hand-centred mapping

Release

End the control relation



Hand-Centered Object Manipulation Extending Ray-Casting

COURSE NOTES

Bowman and Hodges combine ray selection with hand-centred manipulation. After distant selection, a scaled mapping relates hand displacement to object movement. Explain the attachment, movement gain and release, including whether the virtual hand changes position. Bringing an object physically closer to the user is another design option with different consequences.

Egocentric and exocentric control

Egocentric

Act from the participant's viewpoint

Exocentric

Act through an external representation

Change of scale

Make an object or world accessible



Interaction through different spatial viewpoints

COURSE NOTES

An exocentric representation can expose an entire world or object for manipulation. A world-in-miniature provides an accessible proxy whose changes map to the larger scene. The control relation must preserve the intended reference frame and make scale changes legible. The same representation can support navigation in the next course.

Bimanual manipulation

Non-dominant hand

An anchor or reference frame

Dominant hand

A more precise action within that frame

Two-hand relation

Distance and orientation can control scale

COURSE NOTES

The two hands often play complementary roles: one supports or positions an object while the other adjusts a detail. Their separation can also control scale or define an axis. Bimanual interaction therefore concerns the organisation of roles, not merely using two identical pointers. Physical support, reach, fatigue and the stability of the reference frame affect the result.

Constraints and assistance

Axes and planes

Reduce unwanted motion

Snapping

Align to meaningful targets

Precision modes

Change gain or separate adjustments

COURSE NOTES

Constraints can improve precision when they match the task. Snapping that helps assembly may interfere with freeform exploration. Assistance needs visible feedback and a way to recover from an unwanted result. Compare assisted and unassisted conditions using the same target, starting state and success criterion.

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Part 4 of 5

6.4

Modalities and physical supports

COURSE NOTES

The example describes voice commands for selection, movement and mode activation. Voice can leave the hands available, but introduces recognition, memory, noise and social constraints. Collaboration can make spoken commands ambiguous or disruptive. Multimodal design needs clear timing and rules for combining signals.

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6.4 Modalities and physical supports

Multimodal interaction

Pointing

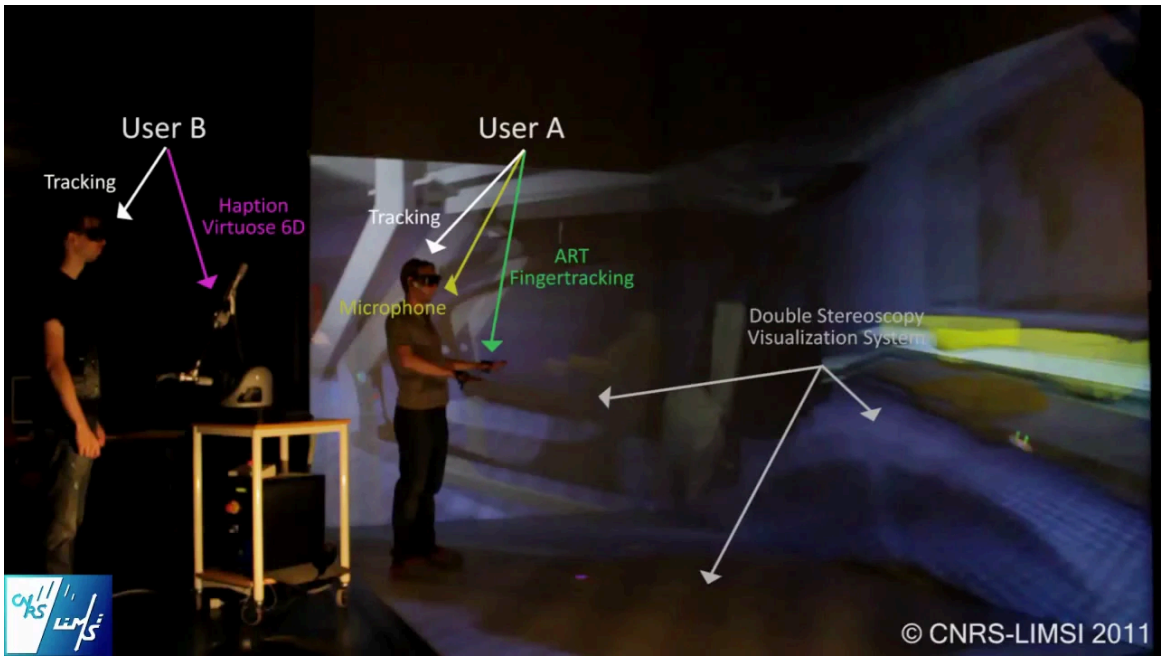
Indicates a spatial candidate

Speech

Expresses an action or parameter

Combination

Resolve what and where together



Multimodal interaction in a shared virtual environment

COURSE NOTES

Voice can select objects, command movement or activate a mode while leaving the hands available. It also introduces recognition errors, remembered commands and constraints from noise or social interaction. In collaboration, a spoken instruction must be distinguishable from conversation. Combining voice and gesture requires a clear temporal relationship and a rule for resolving ambiguous or conflicting inputs.

6.4 Modalities and physical supports

Multimodal interaction: source recording



Multimodal interaction: source recording

Watch the video ↗

COURSE NOTES

The example describes voice commands for selection, movement and mode activation. Voice can leave the hands available, but introduces recognition, memory, noise and social constraints. Collaboration can make spoken commands ambiguous or disruptive. Multimodal design needs clear timing and rules for combining signals.

6.4 Modalities and physical supports

Tangible interfaces

Physical form

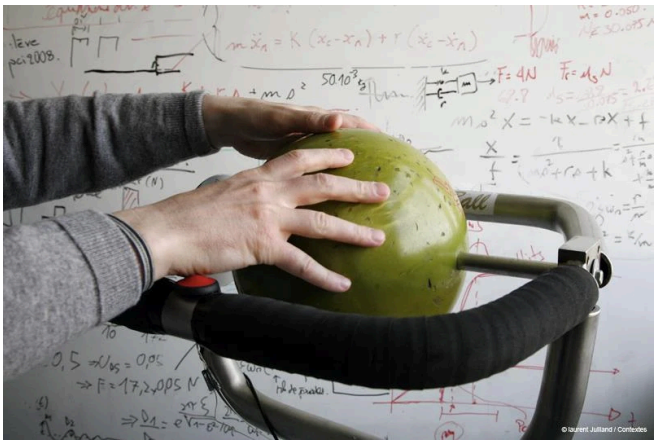
Suggests use and constrains movement

Passive feedback

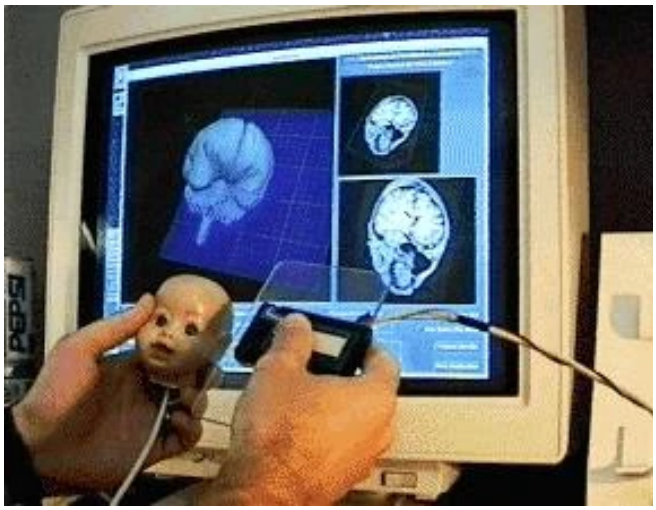
A surface can support the hands

Registration

Physical and virtual objects must align



A dedicated tangible controller



Physical props for 3D manipulation

COURSE NOTES

Hinckley’s head props and the Cubic Mouse illustrate physical supports for particular spatial tasks. Familiar shape can communicate use and provide stable feedback. The prop’s size, mass and manipulation affordances matter. A physical object that is poorly registered to its virtual counterpart can undermine the intended benefit.

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Part 5 of 5

6.5
Control and evaluation

COURSE NOTES

Users need system control in addition to object interaction. Mode changes are especially important because the same movement may then do something different. An exit or pause action should remain available even when the user cannot complete the main task. Menu placement should account for reach, legibility and distraction.

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6.5 Control and evaluation

Application control

Application state

Pause, restart and exit

Tools and modes

Change what input means

Parameters

Adjust rendering or task settings



Menus and widgets for application control

COURSE NOTES

Users need system control in addition to object interaction. Mode changes are especially important because the same movement may then do something different. An exit or pause action should remain available even when the user cannot complete the main task. Menu placement should account for reach, legibility and distraction.

Interface placement

World-fixed

Part of the environment

Body-relative

Follows the hand, wrist or participant

View-relative

Remains in the field of view



Spatial and contextual interface placement

COURSE NOTES

A control can be fixed to the screen, the body, an object or the world. Each reference frame changes when and where the control is visible. A wrist menu follows the user, whereas a wall panel remains at a place in the environment. Whether the control belongs to the fictional world is a separate question. Visibility, access and posture determine which arrangement suits the activity.

Usability and user experience

Effectiveness

Can the goal be achieved?

Efficiency

At what time and effort cost?

Satisfaction

How does use feel?

Broader experience

Emotion, aesthetics and presence

COURSE NOTES

Utility concerns whether the application supports a relevant need. Usability concerns how effectively and efficiently people can operate it in a given context. User experience also includes expectations, feelings and the meaning of the activity. An application can be useful but difficult to use, or enjoyable without supporting the intended task. These dimensions need distinct questions and measures.

Comparing interaction techniques

Dimension	Possible observations
Performance	Completion time, errors, placement precision
Effort	Reach, sustained arm elevation, fatigue
Learning	Discoverability and improvement with practice
Experience	Perceived control and satisfaction

3D interaction lab ↗

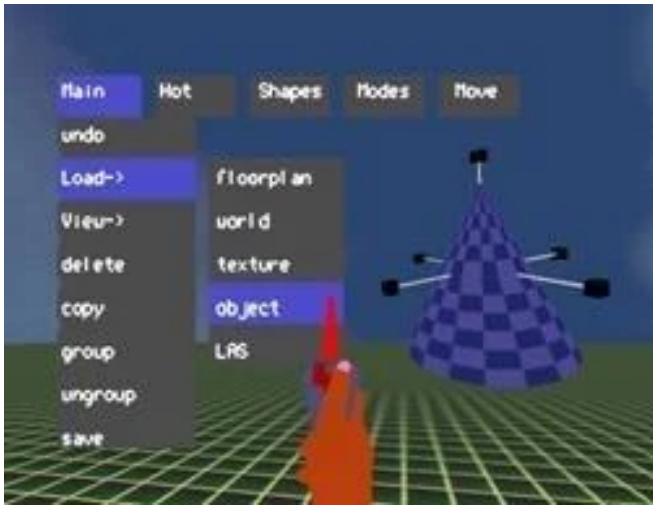
COURSE NOTES

A meaningful comparison uses the same task, starting conditions and success criteria for each technique. Order can influence performance through practice or fatigue. Completion time therefore needs to be interpreted with errors, abandoned attempts, precision and physical effort. A faster technique is not necessarily better when it achieves speed by sacrificing accuracy or increasing fatigue.

Menus, widgets and physical supports



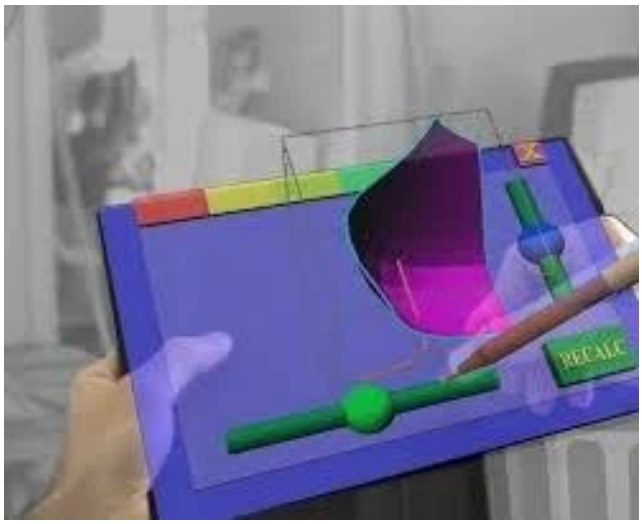
A tangible control surface



A spatial menu



An object-related menu



A spatial widget

> Where is the control, and how does the user know its state?

COURSE NOTES

A system-control interface makes modes, parameters and commands accessible during an activity. Positioning a control changes how easily it can be found, reached and used without sustained arm effort. Physical support can stabilise the hand, while visible state helps the user understand the current mode. The same command can therefore be implemented through several physical and virtual arrangements with different costs.

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6.5 Control and evaluation

Interaction design review

A distant small target

A precise object rotation

A repeated action at shoulder height

A shared object controlled by two people

COURSE NOTES

Choose techniques for these situations and justify the tradeoffs. State how the user discovers the action, confirms it, detects an error and recovers. Include the physical workspace and what happens if tracking becomes unreliable.

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6.5 Control and evaluation

Sources and further reading

C. Fleury, 3D interaction (2025–26)

FILA3, 3D interaction

C. Fleury, 3D navigation (2025–26)

Bowman et al., 3D User Interfaces: Theory and Practice ↗ 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.