Interaction Elements

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Overview

Control-display relationships

- When a user grasps a computer mouse and moves it to the right, the cursor on the system's display moves to the right
- **Control-display relationships** are sometimes called **mappings**, since the relationships attribute how a controller property maps to a display property.
- The mouse/cursor example describes a **spatial** relationship. There are also **dynamic** relationships, describing how a controller affects the speed of the response, and **physical** relationships, describing whether the response is to a movement or a force in the controller

Spatial relationships

- The mapping is **congruent** in left figure, while in right figure, you move the mouse forward which indicates up (fortunately, human can learn this relationship quite naturally)

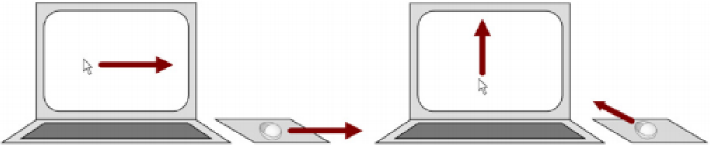


Figure: Source: Figure 3.4 (Mackenzie)

Definitions

- **Control space** (a) depicts the possible movement of the input device
- **Display space** (b) depicts the corresponding display (e.g., cursor) movements
- **Control-display mappings** for a mouse and cursor (c)
- The y-axis cursor motion is an example of a **transformed spatial mapping**. In this case, it is a 90 deg transformation along the y-z plane

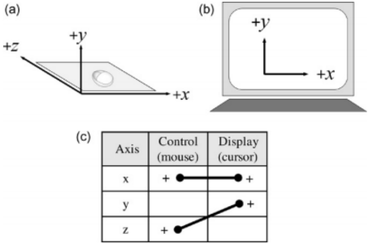


Figure: Source: Figure 3.5 (Mackenzie)

Performance

- Effect of performance in the presence of a spatial transformation is well documented
- **Aiming error** is known to be higher for 90 to 135 deg, and lower for 0 deg or 180 deg (Cunningham, 1989)
- **Adaptations** take as few as 50 trials (Wigdor et al., 2006) - implying that humans are quite good at learning such transformation (in a subconscious manner)

Scrolling

- Consider **scrolling** the view of an image or document. Interaction involves manipulating a physical controller, such as a **mouse** (a hard control), to **move a pointer** to the slider (a soft control), **acquiring** it with a button-down action, then **drag** to change view.
- In this case, the hard control has a **proportional** relationship with the soft control, while having a **reverse** relationship with the display. How?

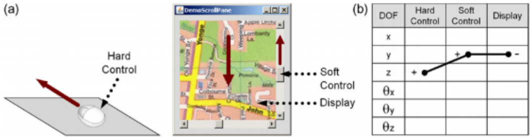


Figure: Source: Figure 3.6 (Mackenzie)

Rotations

- Let's consider another possible transformation: **rotations**
- theta (θ) designate angle, whereas positive direction corresponds to clockwise movement
- **Degree of freedom** refers to the degree in which each parameter may be manipulated independently of the others
- For a 3D object, six parameters are required: three for the object's position in space (x, y, z), and three for object's orientation in space (θ_x, θ_y, θ_z).

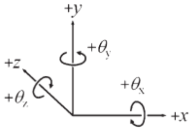


Figure: Source: Figure 3.7 (Mackenzie)

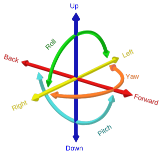


Figure: Source: Wikipedia

Rotations

An example of exact congruence in 3D space

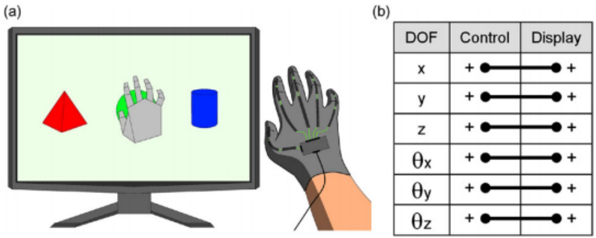


Figure: Source: Figure 3.8 (Mackenzie)

Rotations

An example of map navigation.

- **Panning**: drag the mouse where linear movement of the mouse in x-axis (left-right) rotates the display along the y-axis, a linear movement of the z-axis (forward-backward) rotates the scene along the x-axis
- **Zooming**: clicking on + and - soft controls, or use the middle-wheel of a mouse. The middle wheel is a spatially congruent control-display mapping but the problem is its jerkiness (non-continuous). A better way is to use z-axis movement but oops...it is already occupied by panning, if then, how to solve?
- A yet unexplored interaction is to use y-axis rotation of the mouse to perform y-axis rotation of the camera to create left-right panning - but why it is not being explored?

Figure: Source: Figure 3.9 (Mackenzie)

CD gain and transfer function

- **CD gain** refers to the amount of movement in a display object (e.g., cursor), for a given amount of movement in a control.
- For example, if a mouse is moved three cm, and the cursor also moves three cm, then the CD gain is 1
- If the cursor moves six cm, then the CD gain is $6/3 = 2$

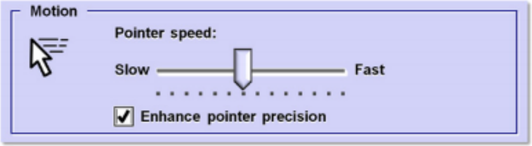


Figure: Source: Figure 3.10 (Mackenzie)

CD gain and transfer function

- Often, the CD gain relationship is non-linear. Why?
- Follows a **power function** - enables by "Enhance pointer precision". If the mouse moves quickly, CD gain increases. Vice versa.
- Lowering the CD gain for slow controller movements is useful to enhance the precision of target selection at the end
- The term **transfer function** is sometimes used. To ensure the cursor is responsive to mouse movement, with no perceivable delay, the software implementation of a non-linear relationship typically uses a **lookup table** to map controller movement to display movement.

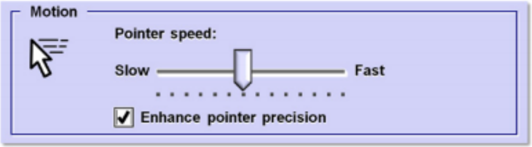


Figure: Source: Figure 3.10 (Mackenzie)

CD gain and transfer function

- Research on CD gain dates back to at least 1940s
- Varying CD gain evokes a tradeoff between **gross positioning time** (getting to the target) and **fine positioning time** (final acquisition).
- Other confounding factors (e.g., display size or scale) adds to the difficulty of optimization

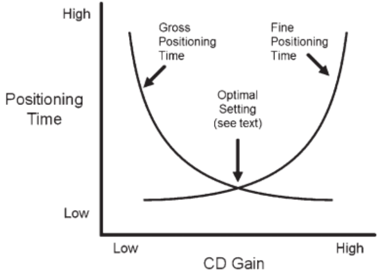


Figure: Source: Figure 3.11 (Mackenzie)

CD gain and transfer function

- In the past 30 years, our understanding of CD gain becomes much better.
- The majority of studies found that significant performance benefits are not achieved by adjusting CD gain
- One challenge in optimizing CD gain is in defining optimal performance. Is the goal to maximize speed (viz. minimize positioning time) or to maximize accuracy? The goal of optimizing both speed and accuracy is problematic, because of the **speed-accuracy trade-off**
- CD gain research is still ongoing, although the focus is often in **different settings** - very large displays, very small displays, remote pointing, accessible computing, 3D interaction

Latency

- Not surprisingly, human performance and the interaction experience are adversely affected when feedback is delayed. The delay between an input action and the corresponding response on a display is called **latency** or **lag**.
- Latency is negligible in many interactive computing tasks, such as typing or cursor positioning but is not true for **remote manipulation** where huge latency can occur due to transmission delays
- In virtual reality environment, as expected, when lag occurs, the loss of fidelity is dramatic and frustration increases.

Latency

- Latency is attributable to properties of I/O or software.
- Input devices are typically sampled at fixed rates in the range of 10 to 60 samples per second. At 60Hz sampling, for example, an input movement may not be sensed for $1/60$ s $=$ 0.01667s $=$ 16.67ms. Note that latency may increase due to software overhead as well
- MacKenzie and Ware (1993) systematically introduced latency in a system and measured the effect on human performance in simple point-select tasks. With 75ms latency, movement time increased by 16 percent and error rate by 36 percent. At 225ms the effect was dramatic, with movement time increasing by 64 percent and error rate by 214 percent.

Property sensed and order of control

- The input controller senses the interaction and coverts a **property sensed** into data that are transmitted to the host computer for processing. For pointing devices, the most common properties sensed are **position**, **displacement**, and **force**.
- Another interesting point is to ask whether the property sensed control the position or the velocity of the object or view? This question speaks to the **order of control**

Property sensed and order of control

- With a tablet or touchscreen, the property sensed is the **position** of a stylus or finger, in **absolute coordinate** at the point of contact along the x and z axis
- Mouse is different and uses **displacement** instead which is **relative** to previous movement.
- The most common orders of control are **position-control** (aka zero-order control) and **velocity-control** (aka first-order control) (Zhai, 1995, p. 4). With position control, the sensed property of the input device controls the position of the object or view on a display. With velocity-control, the sense property controls the velocity of the object or view. A mouse is a position-control input device, since mouse displacement controls the position of the cursor.

Isotonic

- Order of control is often associated with joysticks. Joysticks are either **isotonic** or **isometric**.
- With an isotonic joystick, the user manipulates the stick handle, which, in turn, swivels about a pivot-point. The property sensed is the movement of the stick.
- Isotonic joysticks are also called **displacement** joysticks. The output signal represents the position of the stick as the amount of displacement (i.e., rotation) from the neutral or home position, about the x- and z-axes

(a)

Isometric

- With an isometric joystick, the stick does not move. The property sensed is the **force** applied to the stick. The output signal represents the amount of force along the x-axis and z-axis. An example is trackpoint build in many Thinkpad laptops

(b)

Figure: Source: Figure 3.13b (Mackenzie)

Isotonic vs. Isometric

- Which mappings are best in terms of speed and accuracy for common point-select tasks?
- Kantowitz and Elvers (1988) evaluated an isometric joystick in both position-control and velocity-control modes. Velocity-control performed best
- Zhai (1995) observed that position control is best for a position-sensing device and that velocity control is best for a force-sensing device.

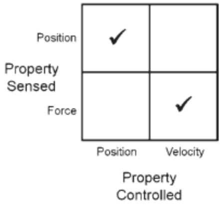


Figure: Source: Figure 3.14 (Mackenzie)

Activities

Classwork

Download GoFitts.jar from
`http://www.yorku.ca/mack/FittsLawSoftware/`
Perform a 1D fitts tasks with default settings ($A = 100, 200, 400$; $W = 20, 40, 80$). Other factors include **pointing speed** - *slow, medium, fast*, and **precision mode** - *on & off*.
Set the Number of Trials to 5
Set Condition Code according to the point speed and precision mode, e.g., C00 - Slow—On, C01 - Medium—On, C02 - Fast—On, C03 - Slow —Off, etc.
Leave Session Code and Group Code default for now as we are not using them
The total number of measurements is 90 (five repetitions * three pointer speed settings * two precision mode * three As * three Ws). Perform three-way ANOVA with pointing speed, precision mode, A, and W as IV and performance (speed, accuracy) as DV. Write a brief report on your observations and measurements. (Note that I haven't teach about ID so it's ok to use A and W for now)

Natural versus learned relationships

- It is worth examining which kind of mapping is more natural than others
- For the figure below of turning the knob, is it intuitive?
- On might argue that clockwise is the same as moving up, thus it is natural. Nevertheless, this relationship remains a **"learned"** relationship

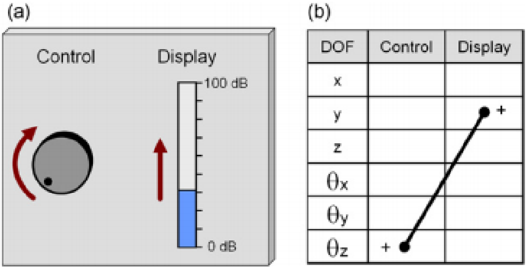


Figure: Source: Figure 3.15 (Mackenzie)

Natural versus learned relationships

- Best scenario is spatial congruence, where there is a clear 1-1 mapping.

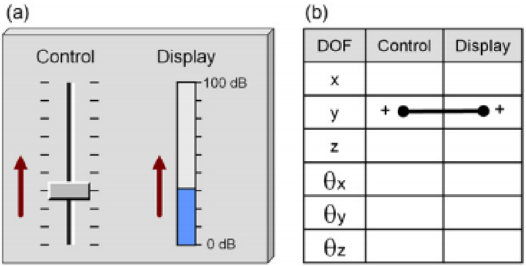


Figure: Source: Figure 3.16 (Mackenzie)

Natural versus learned relationships

- Is the switch having a spatial congruence?
- Since on/off is not something that has spatial properties, it is difficult to design a spatial congruence
- In such case, culture plays a big role. In UK, a up is off, while in US, the light is on (see how problematic it can be!)

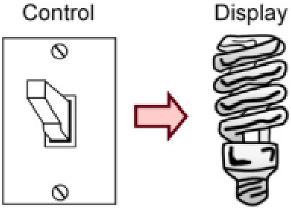


Figure: Source: Figure 3.17 (Mackenzie)

Natural versus learned relationships

- Which one is spatially congruent?

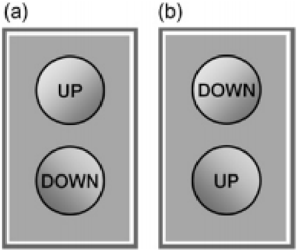


Figure: Source: Figure 3.18 (Mackenzie)

Mental models and metaphor

- Familiarity, convention, consistency all shares the similar design principle - connect existing knowledge
- Here we introduce the notion of **metaphor** or physical analogy that can help users better learn
- Simple example of metaphor is icons of "files" or "floppy disk"

Figure: Source: Figure 3.19 (Mackenzie)

Clock as metaphor

- Most users have a ingrained understanding of a clock
- Numerous HCI research use clock as a metaphor to help users do text-entry or to navigate

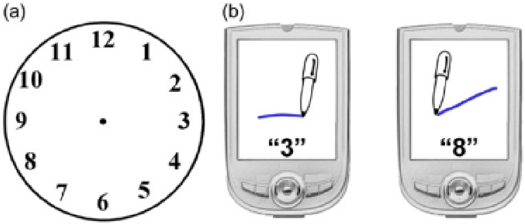


Figure: Source: Figure 3.20 (Mackenzie)

Clock as metaphor

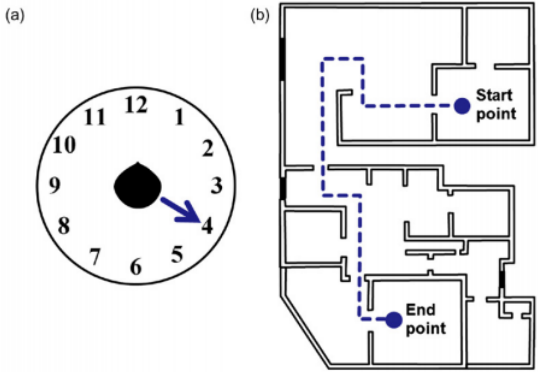


Figure: Source: Figure 3.21a (Mackenzie)

Clock as metaphor

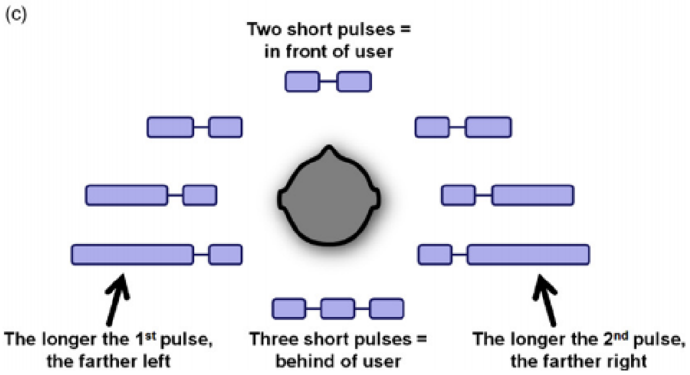


Figure: Source: Figure 3.21b (Mackenzie)

Modes

- A common and sometimes frustrating property of user interfaces is **modes**.
- A mode is the possibilities of a function
- Challenges with modes occur because there are fewer controls than tasks - a standard desktop keyboard has about 100 keys, yet can produce more than 800 key variations, using the modes afforded by modifier keys such as shift, ctrl, alt, function keys.

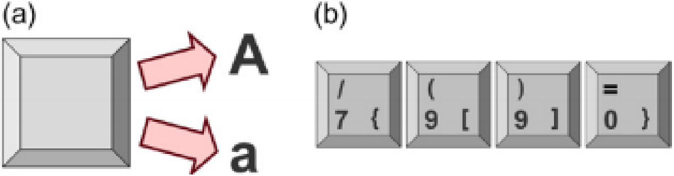


Figure: Source: Figure 3.22 (Mackenzie)

Modes

Modes exist in most interactive systems and are usually difficult to learn

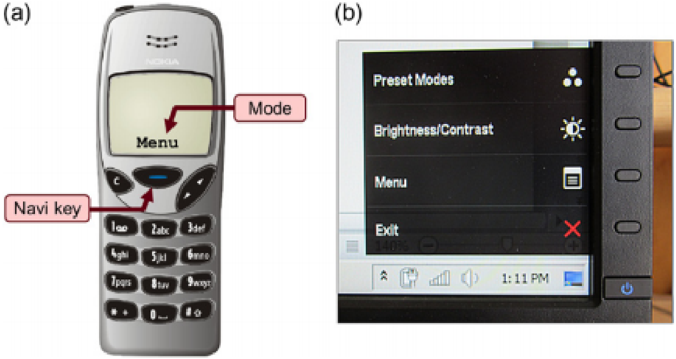


Figure: Source: Figure 3.23 (Mackenzie)

Modes

Changing mode can be easy or difficult!

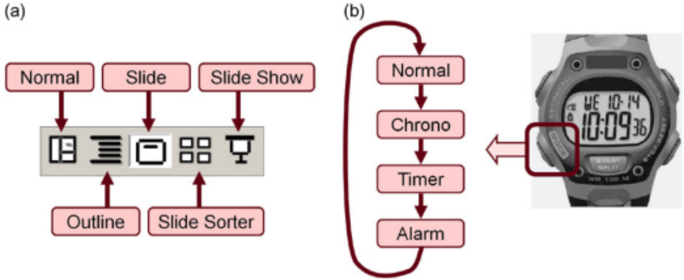


Figure: Source: Figure 3.24 (Mackenzie)

Modes

Feedback is crucial in a mode design system

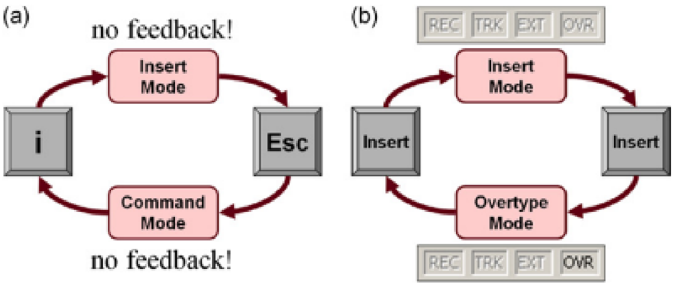


Figure: Source: Figure 3.25 (Mackenzie)

Modes

Modes are common in graphic design software

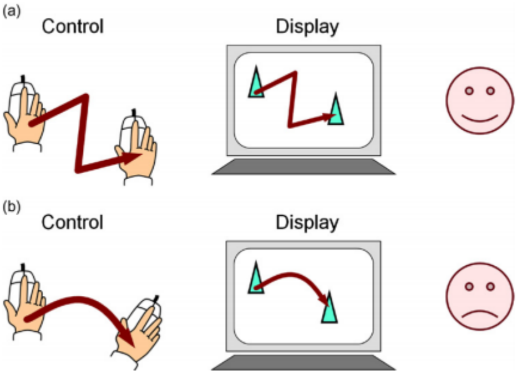


Figure: Source: Figure 3.26 (Mackenzie)

Modes

- I have published a recent paper looking at gesture modes
- Intuitive gestures are limited thus we propose augmenting modifiers

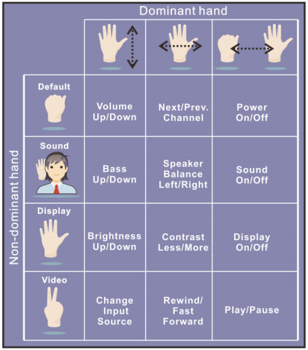
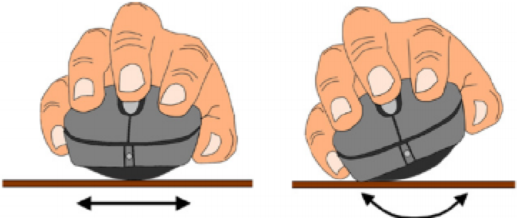


Figure: Delamare, Silpasuwanchai, Sarcar, Shiraki, Ren (2019)

Degrees of freedom

- DOF refers to the interaction bandwidth
- Large amount of HCI research focuses on increasing interaction bandwidth, thus addressing the problem of "hidden" modes
- By increasing dof, we can also increase the modality thus enrich the possible interaction, e.g., doctors performing surgery with two hands busy while using eye gestures to perform additional actions
- Current research explores possibilities of new input device as well as augmenting bio-signals



Degrees of freedom

- **Phantom Premium** offers six degrees of freedom (3 translational, 3 torque) in output capabilities. This device includes a passive stylus and thimble gimbal and provides 3 degrees of freedom positional sensing and 3 degrees of freedom force-feedback. This device can provide force feedback include virtual assembly, virtual prototyping, maintenance path planning, teleoperation, and molecular modeling.

Figure: Phantom Premium 1.4

Degrees of freedom

- Click anywhere you want

Figure: EasySMX Ring: provides convenience but loses full-featured mouse when it comes to productivity

Degrees of freedom

- Chair gestures

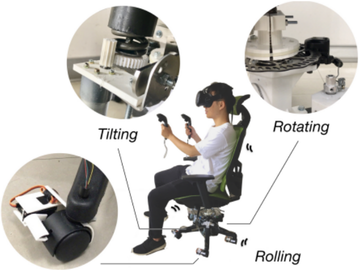


Figure 1: Aarnio modulates the resistive force of rotating, tilting and rolling an office chair for new applications.

Figure: Teng et al., **Aarnio: Passive Kinesthetic Force Output for Foreground Interactions on an Interactive Chair**, CHI 2019

Activities

Classwork

Perform the classwork on Menu Design. This task requires you to investigate why designing menu is such a difficult task for designers.

The End