Fall 2019

CS6501: Topics in Human-Computer Interaction

http://seongkookheo.com/cs6501_fall2019

Lecture 4: Interaction Elements

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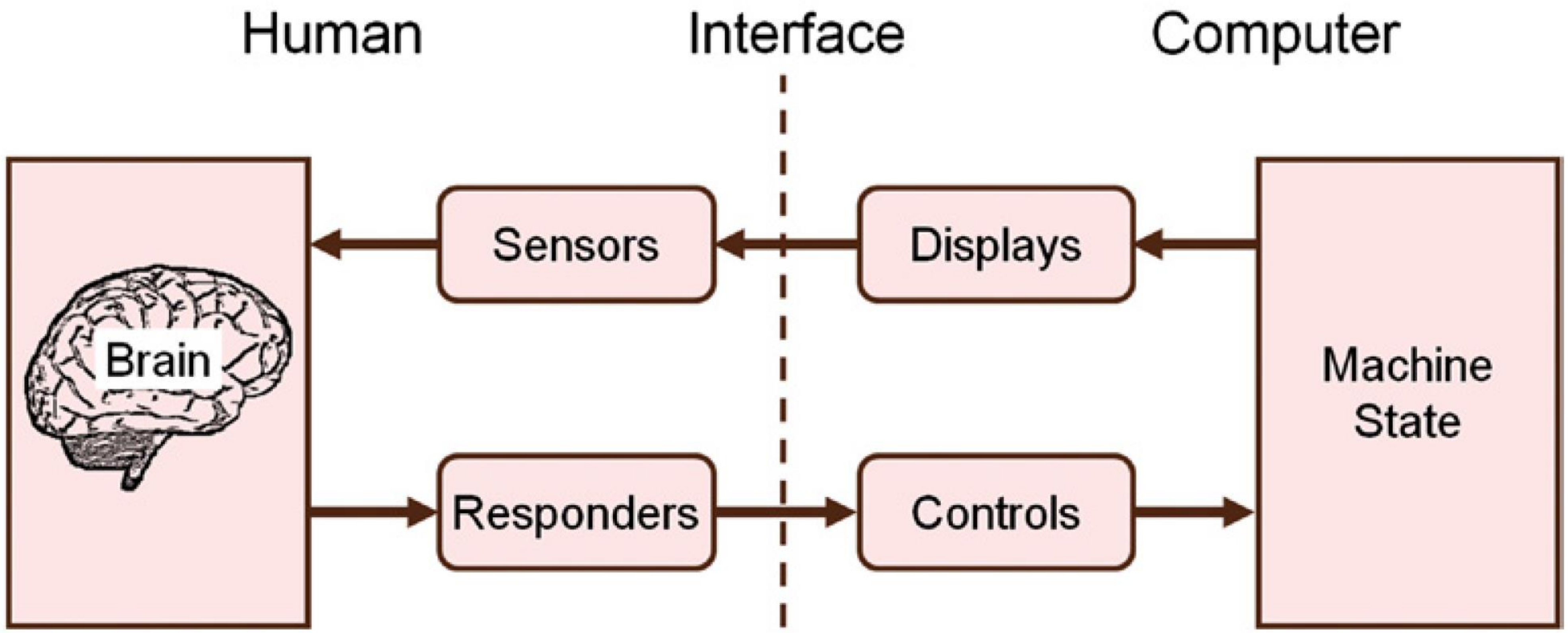
UNIVERSITY of VIRGINIA | SCHOOL of ENGINEERING & APPLIED SCIENCE

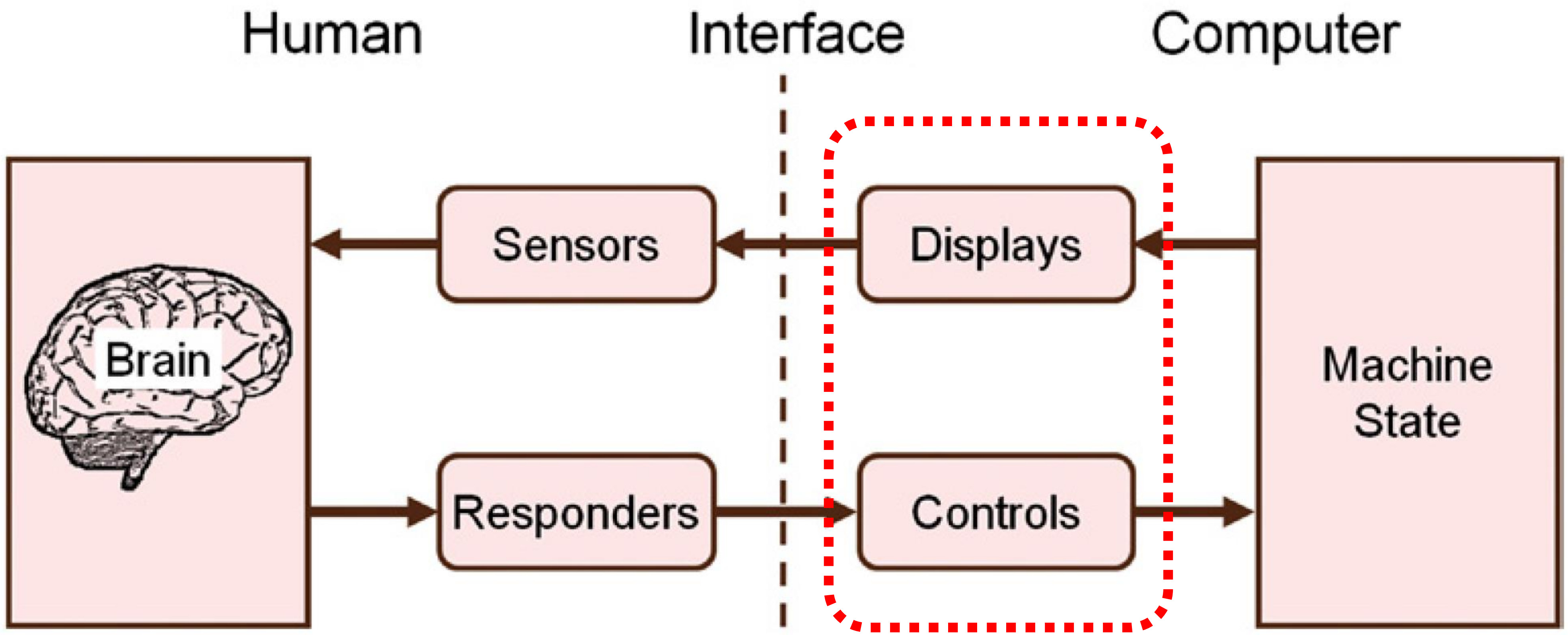
Human Factors Model



Interaction

- *Interaction* occurs when a human performs a task using computing technology
- Interaction tasks with a goal:
  - Send an e-mail
  - Program a thermostat
  - Enter a destination in a GPS device
- Interaction tasks without a goal:
  - Browse the web
  - Chat with friends on Facebook

Human Factors Model



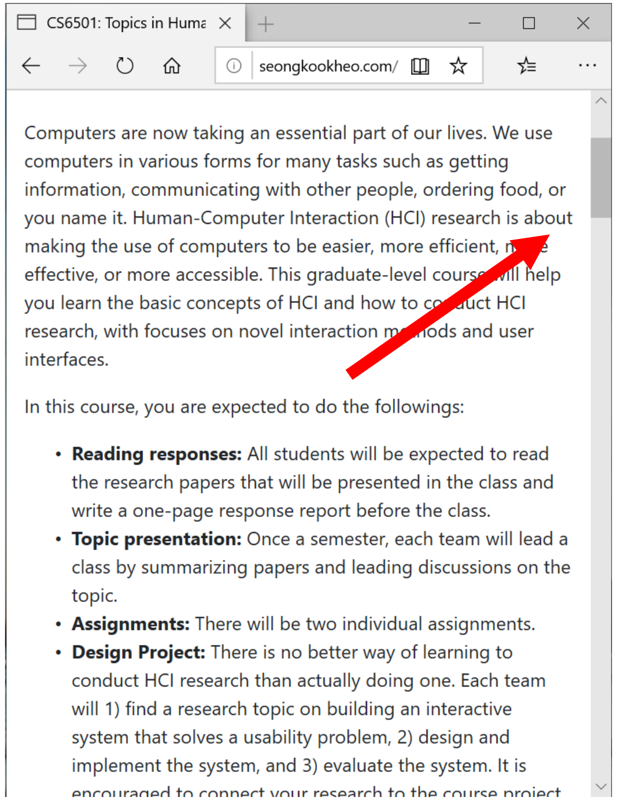
Hard Controls, Soft Controls

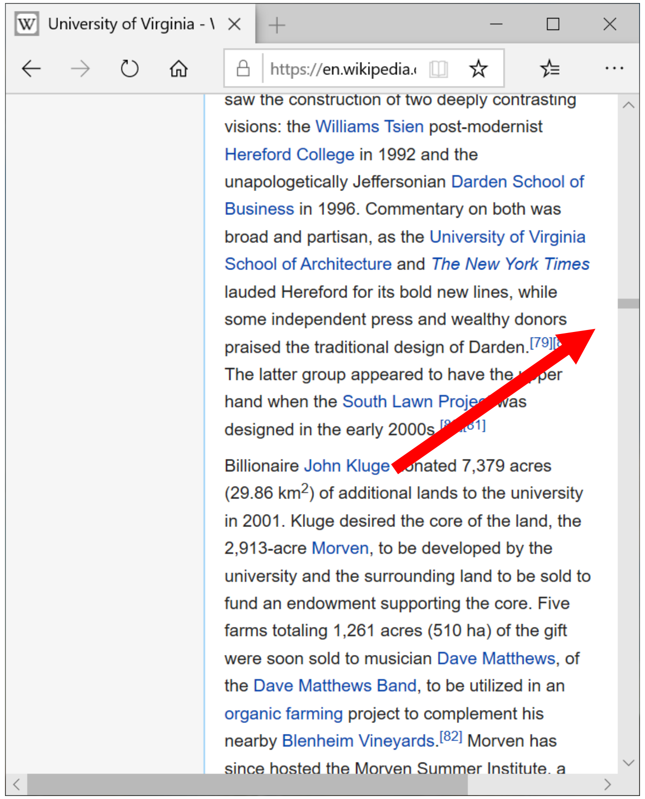
- Controls were physical, single-purpose devices → *hard controls*
- Today's graphical displays are malleable
- Interfaces created in software → *soft controls*
- Soft controls rendered on a display
- Distinction blurred between soft controls and displays

Soft controls are also displays!

Scrollbar Slider

- Example of a soft control (control + display)
- As a control
  - Moved to change view in document
- As a display
  - Size reveals view size relative to entire document
  - Position reveals view location in document

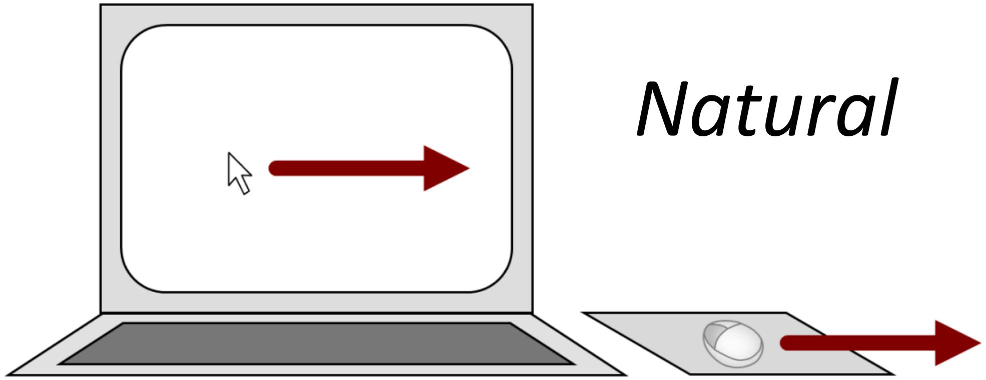




Control-Display Relationships

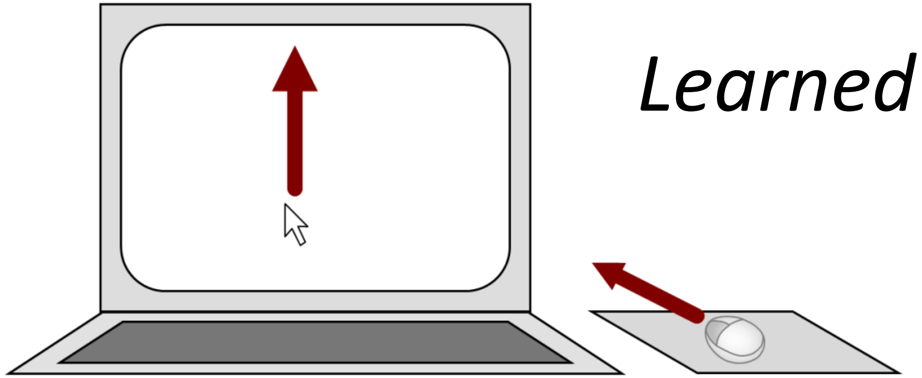
- Also called *mappings*
- Relationship between operation of a control and the effect created on a display
- At least three types:
  - Spatial relationships
  - Dynamic relationships
  - Physical relationships

Spatial Relationships



Natural

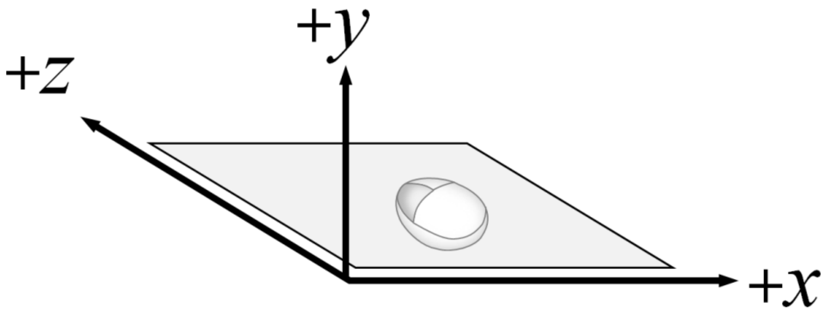
Spatial congruence
Control: right
Display: right



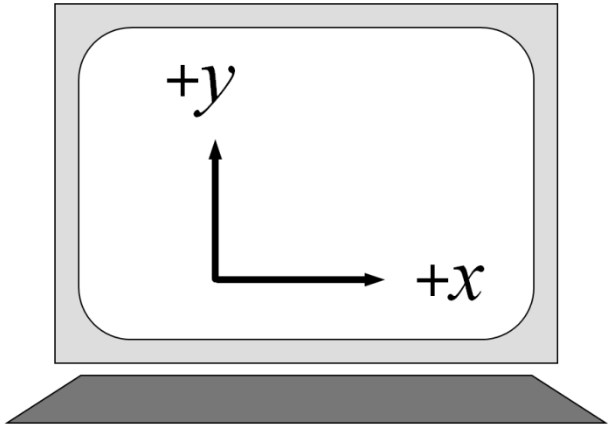
Learned

Spatial transformation
Control: forward
Display: up

Axis Labeling



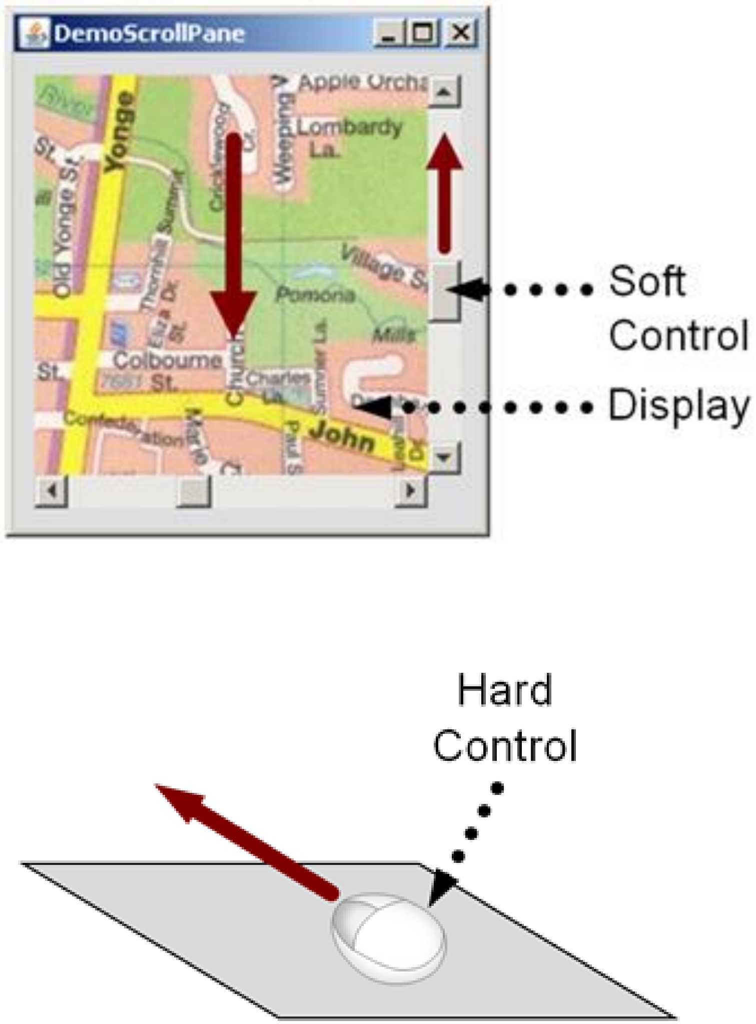
Control



Display

Axis	Control (mouse)	Display (cursor)
x	+	+
y		+
z	+	

Third Tier



DOF	Hard Control	Soft Control	Display
x			
y		+	-
z	+		

How to map?

How to map?

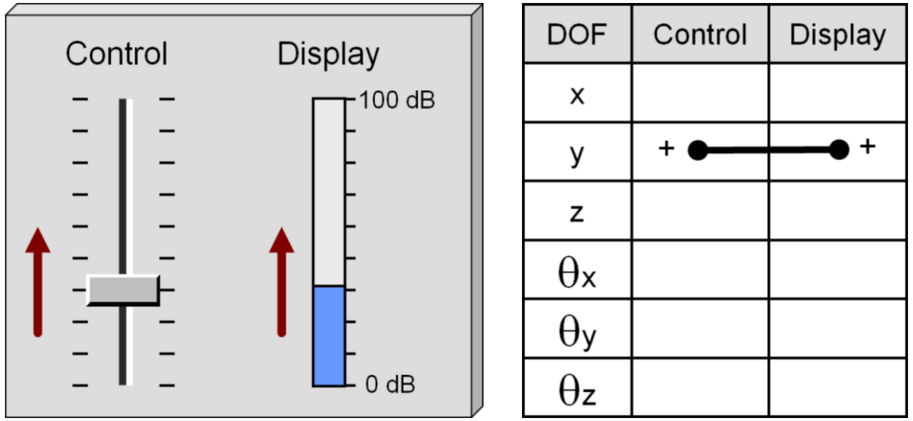

command


Picture viewer
STOCKHOLM

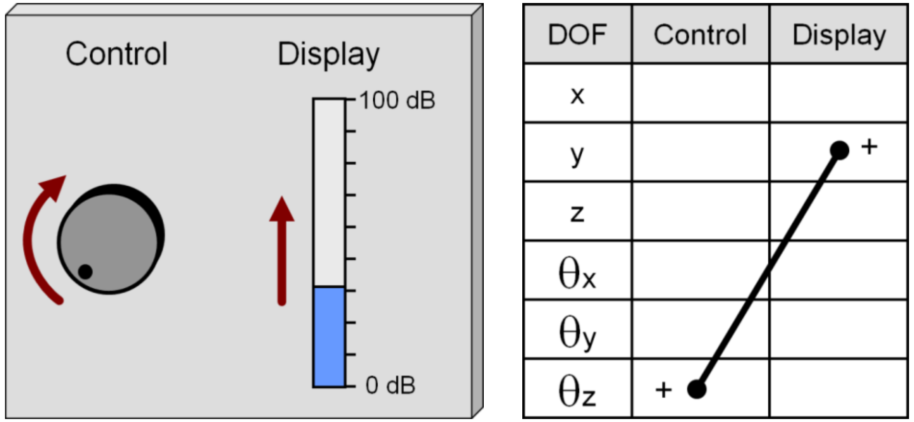

Picture viewer
STOCKHOLM

Natural vs. Learned Relationships

- Natural relationships
  → spatially congruent

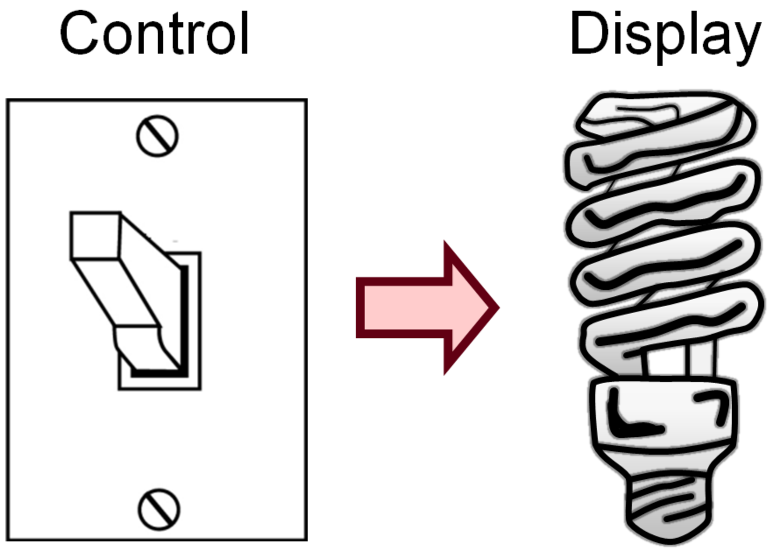


- Learned relationships
  → spatial transformation



Learned Relationships

- Learned relationships seem natural if they lead to a *population stereotype* or *cultural standard*
- A control-display relationship needn't be a spatial relationship…

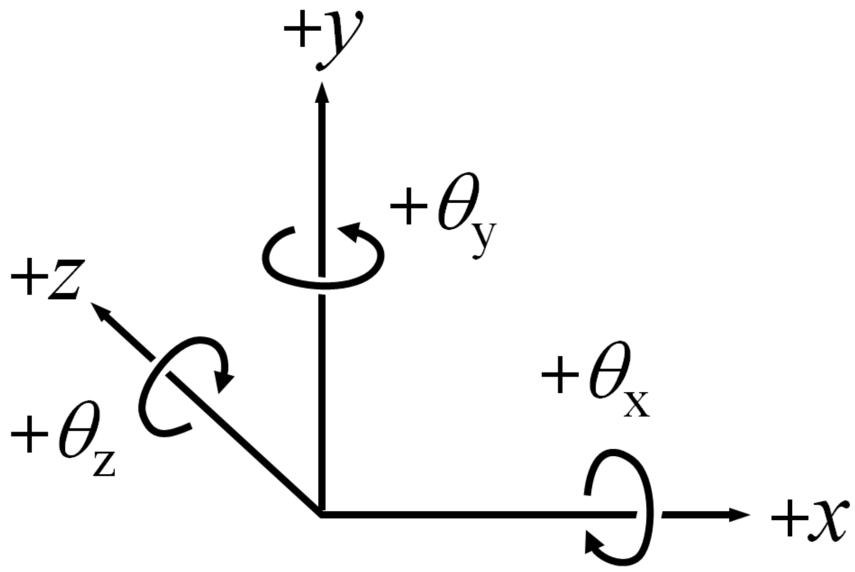


Is the display on or off?

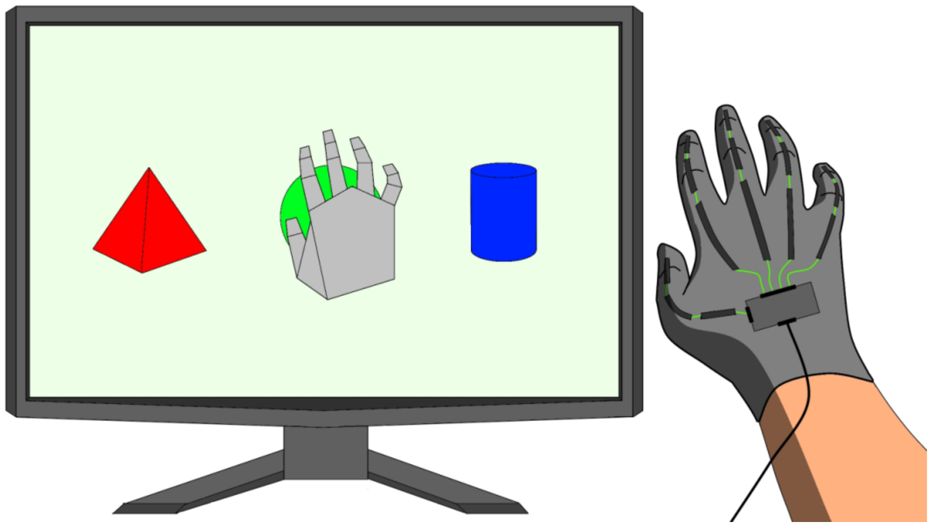
Answer: On (in U.S., Canada)
Off (in U.K.)

3D

- In 3D there are 6 degrees of freedom (DOF)
  - 3 DOF for position (x, y, z)
  - 3 DOF for orientation (θ_x, θ_y, θ_z)



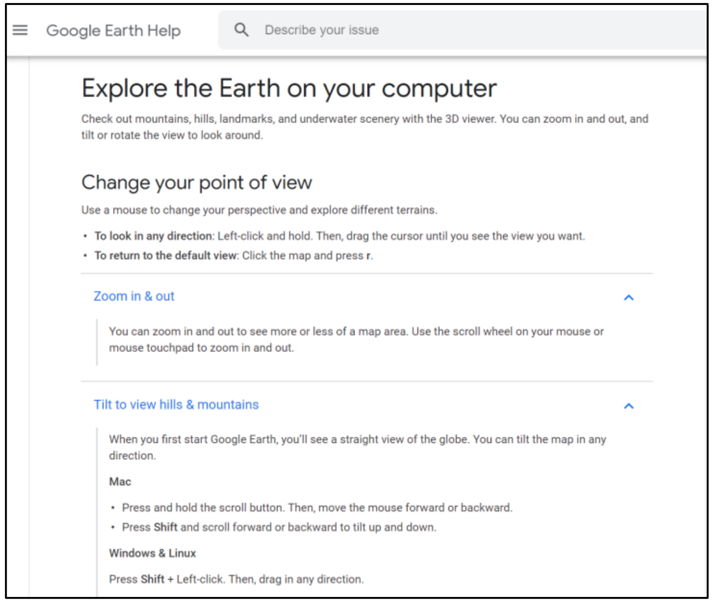
Spatial Congruence in 3D



DOF	Control	Display
x	+	+
y	+	+
z	+	+
θx	+	+
θy	+	+
θz	+	+

3D in Interactive Systems

- Usually a subset of the 6 DOF are supported
- Spatial transformations are present and must be learned
- E.g., Google Earth



Google Earth Help

Describe your issue

Explore the Earth on your computer

Check out mountains, hills, landmarks, and underwater scenery with the 3D viewer. You can zoom in and out, and tilt or rotate the view to look around.

Change your point of view

Use a mouse to change your perspective and explore different terrains.

- **To look in any direction**: Left-click and hold. Then, drag the cursor until you see the view you want.
- **To return to the default view**: Click the map and press **r**.

Zoom in & out

You can zoom in and out to see more or less of a map area. Use the scroll wheel on your mouse or mouse touchpad to zoom in and out.

Tilt to view hills & mountains

When you first start Google Earth, you'll see a straight view of the globe. You can tilt the map in any direction.

Mac

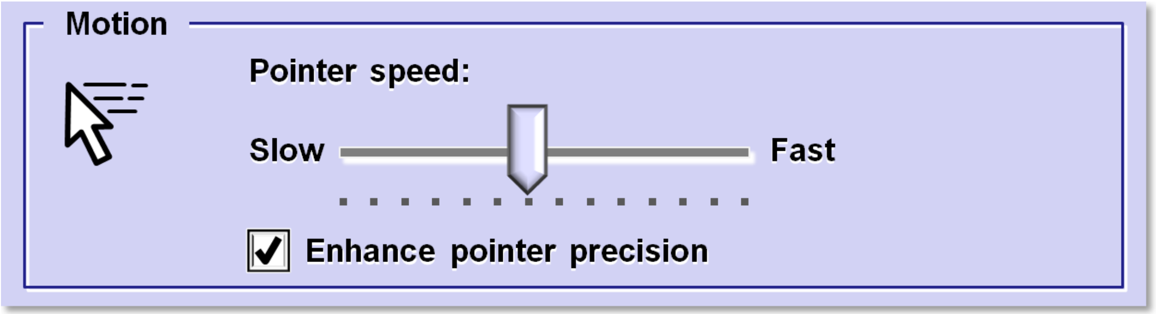
- Press and hold the scroll button. Then, move the mouse forward or backward.
- Press **Shift** and scroll forward or backward to tilt up and down.

Windows & Linux

Press **Shift** + Left-click. Then, drag in any direction.

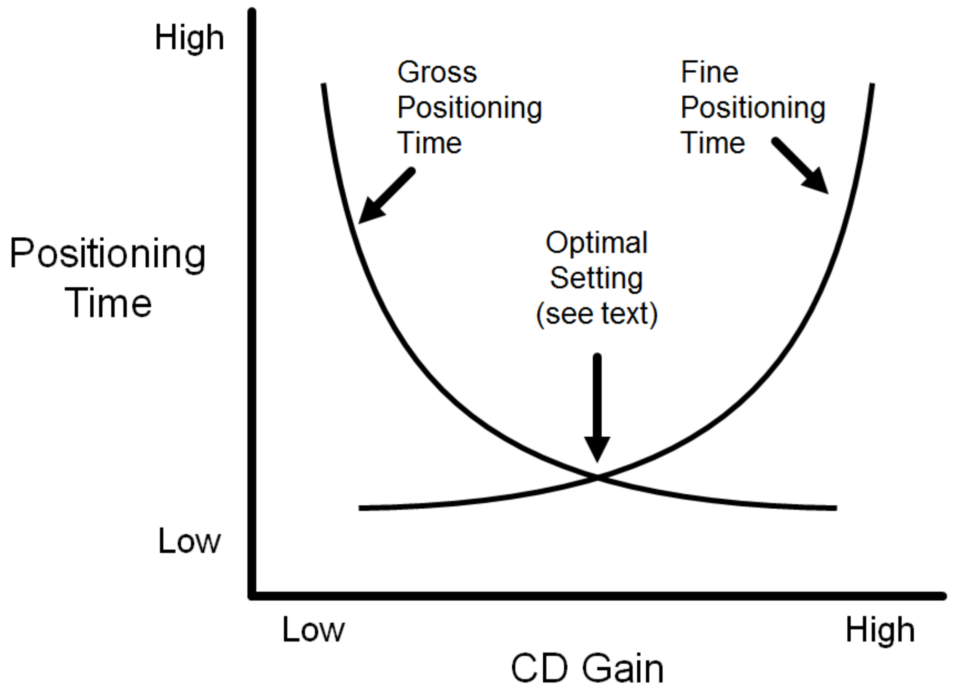
CD Gain

- Quantifies the amount of display movement for a given amount of controller movement
- E.g., CD gain = "2" implies 2 cm of controller movement yields 4 cm of display movement
- Sometimes specified as a ratio (C:D ratio)
- For non-linear gains, the term *transfer function* is used



CD Gain and User Performance

- Tricky to adjust CD gain to optimize user performance
- Issues:
  - Speed accuracy trade-off (what reduces positioning time tends to increase errors)
  - Opposing relationship between gross and fine positioning times:



Latency

- *Latency* is the delay between an input action and the corresponding response on a display

- Maybe negligible on interactive systems (e.g., cursor positioning, editing)

- More noticeable in some settings; e.g.,
  - Touchscreens
  - Remote manipulation
  - Virtual reality (VR)

Albert Ng, Julian Lepinski, Daniel Wigdor, Steven Sanders, and Paul Dietz.
Designing for low-latency direct-touch input. UIST '12

Property Sensed, Order of Control

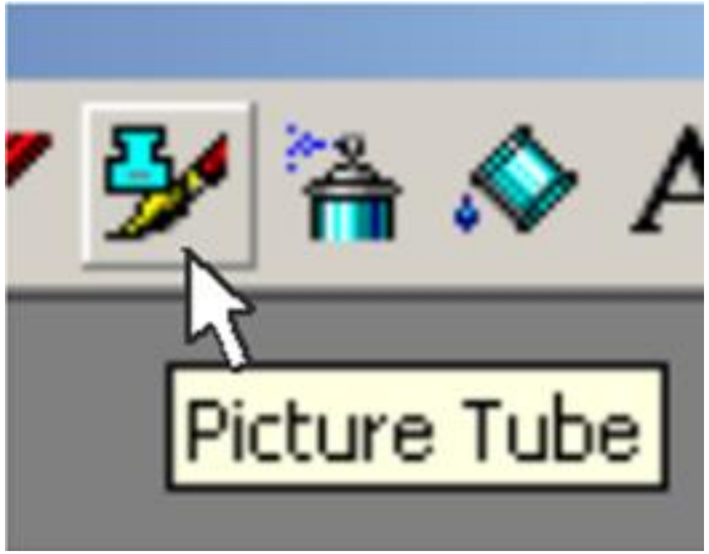
- Property sensed
  - Position (graphics tablet, touchpad, touchscreen)
  - Displacement (mouse, joystick)
  - Force (joystick)
- Order of control (property of display controlled)
  - Position (of cursor/object)
  - Velocity (of cursor/object)

Mental Models

- A physical understanding of an interface or interaction technique based on real-world experience
- Scroll pane: slider up, view up (“up-up” is a conceptual model that helps our understanding)
- *Desktop metaphor* is most common metaphor in computing
- Other commonly exploited real-world experiences:
  - Shopping, driving a car, calendars, painting
- Icon design, in general, strives to foster mental models

Graphics and Paint Applications

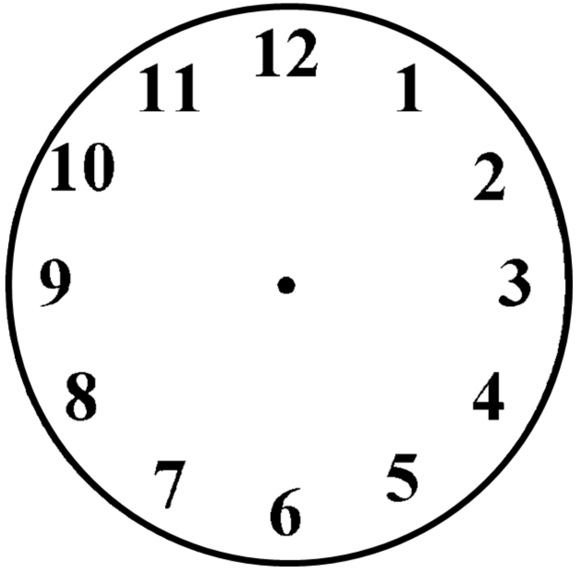
- Icons attempt to leverage real-world experiences with painting, drawing, sketching, etc.



tooltips help for obscure features

Clock Metaphor

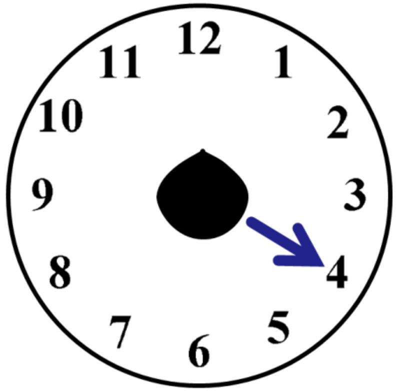
- Numeric entry on PDA[1]
- Users make straight-line strokes in direction of digit on clock face

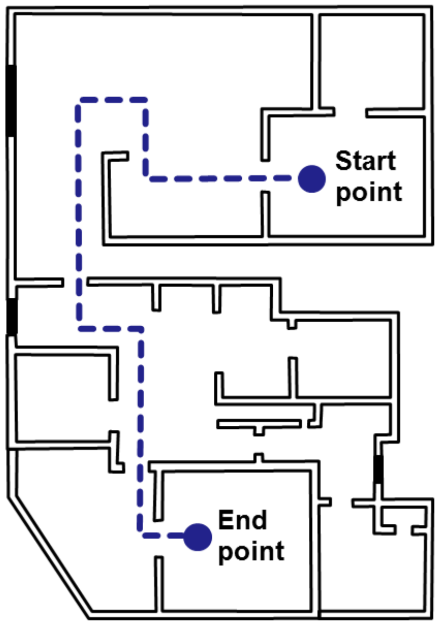


[1] McQueen, C., MacKenzie, I. S., & Zhang, S. X. (1995). An extended study of numeric entry on pen-based computers. *Proceedings of Graphics Interface '95*, 215-222, Toronto: Canadian Information Processing Society.

Clock Metaphor (2)

- Blind users carry a mobile locating device[1]
- Device provides spoken audio information about nearby objects (e.g. “door at 3 o’clock”)

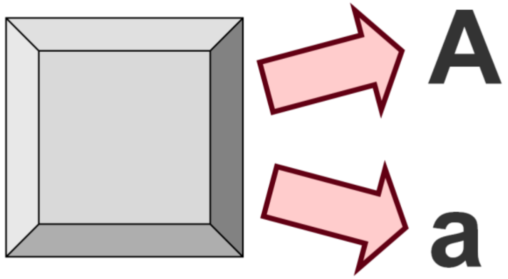




[1] Sáenz, M., & Sánchez, J. (2009). Indoor position and orientation for the blind. *Proceedings of HCI International 2007*, 236-245, Berlin: Springer.

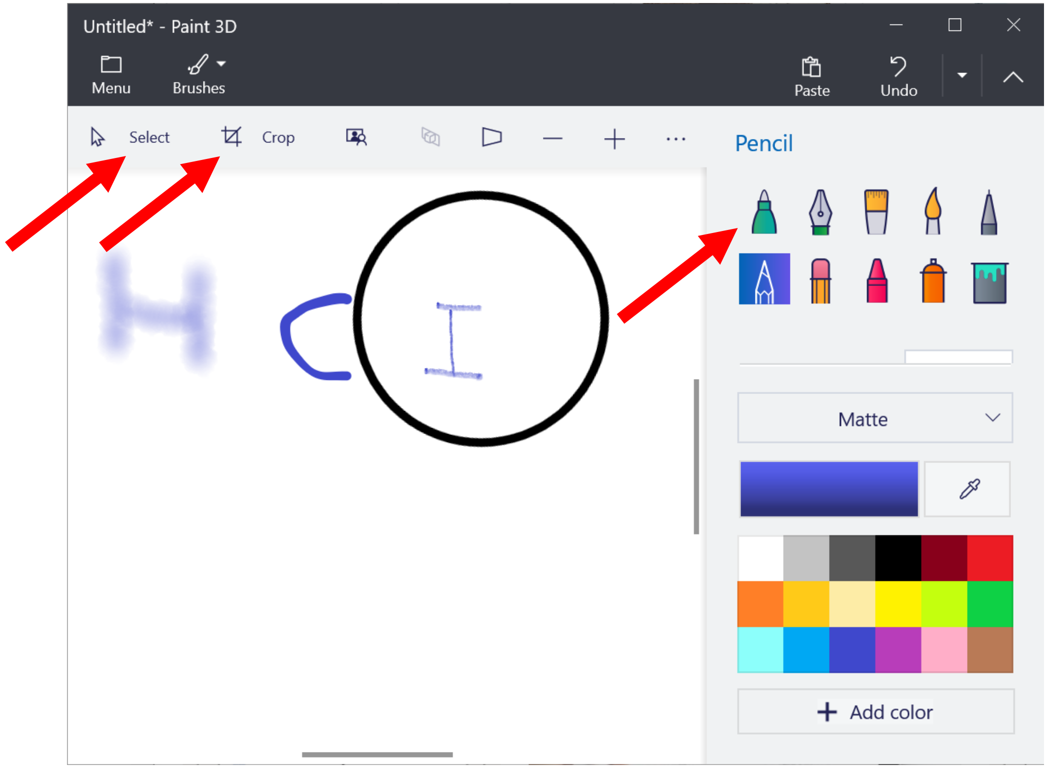
Modes

- If control DOF < display DOF, modes are necessary to fully access the display DOF
- Modes are everywhere (and in most cases are unavoidable)
  - Gas pedal in a car: Move forward (D), move backward (R)
- Computer keyboards have modes
  - ≈100 keys + SHIFT, CTRL, ALT ➔ ≈800 key variations



Modes

Ctrl
Alt
Shift



Untitled* - Paint 3D
Menu
Brushes
Paste
Undo
Select
Crop
Pencil
Matte
Add color

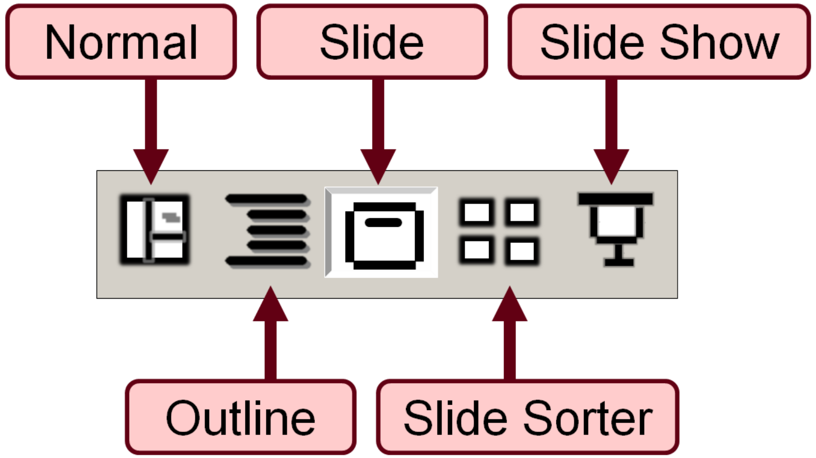
Preset Modes
Brightness/Contrast
Menu
Exit
1:11 PM

Modes

- Modes are necessary, but cause many problems
- Two key challenges with modes
  - Efficient mode switching
  - Mode visibility

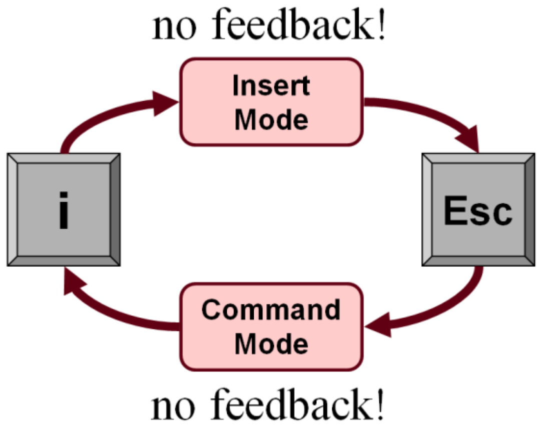
Mode Switching

- PowerPoint: Five view modes
- Switch modes by clicking soft button
- Current mode apparent by background shading
- How to exit Slide Show mode?
  - PowerPoint → Esc
  - Firefox → ?



Mode Visibility

- Shneiderman: “offer information feedback”[1]
- Norman: “make things visible”[2]
- unix *vi* editor: Classic example of no mode visibility:

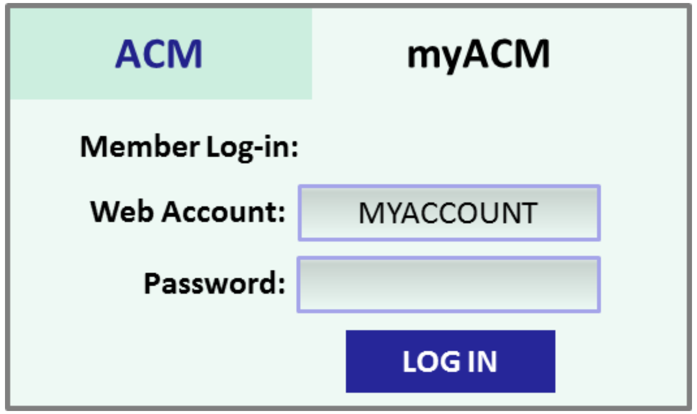


[1] Shneiderman, B., & Plaisant, C. (2005). *Designing the user interface: Strategies for effective human-computer interaction.* (4th ed.). New York: Pearson.
[2] Norman, D. A. (1988). *The design of everyday things*. New York: Basic Books.

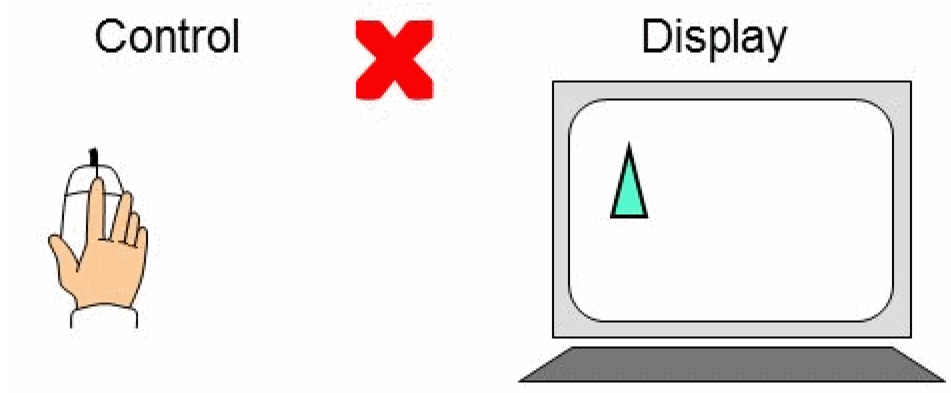
CAPS_LOCK

- Some log-in dialogs alert the user if CAPS_LOCK is on…

- while others do not…

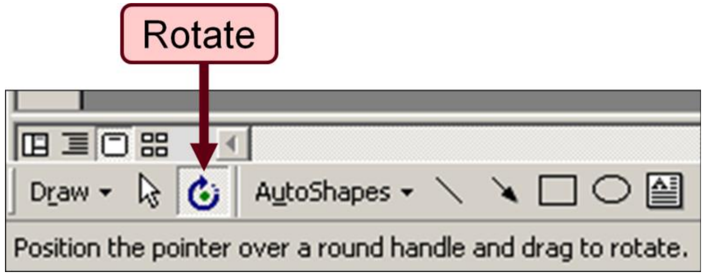


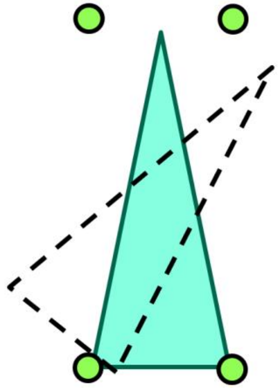
- Rotation is a problem:



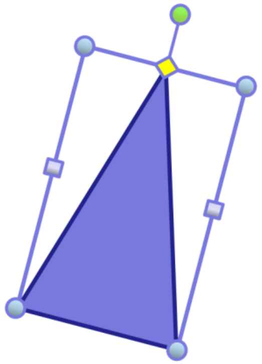
Rotate Mode

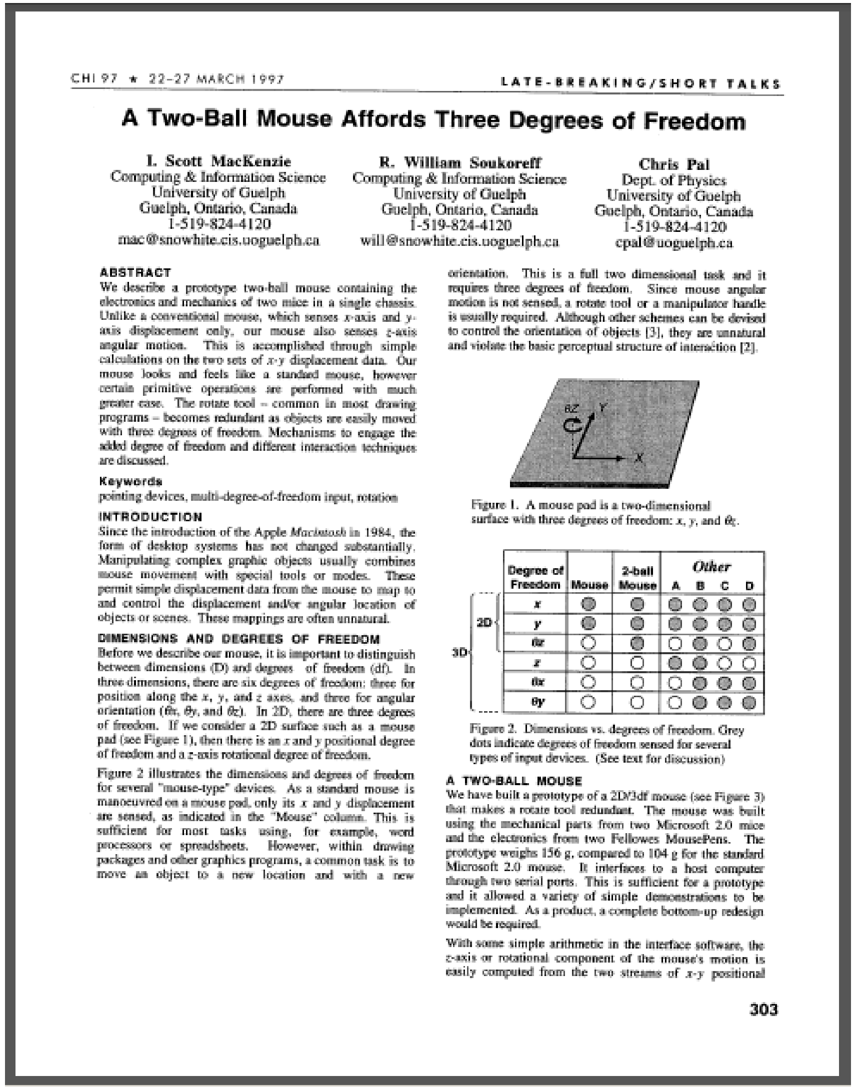
- The solution: Rotate mode
- Two approaches
  - Separate rotate mode:





  - Embedded rotate mode:





A Two-Ball Mouse Affords Three Degrees of Freedom

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ABSTRACT

We describe a prototype two-ball mouse containing the electronics and mechanics of two mice in a single chassis. Unlike a conventional mouse, which senses *x*-axis and *y*-axis displacement only, our mouse also senses *z*-axis angular motion. This is accomplished through simple calculations on the two sets of *x-y* displacement data. Our mouse looks and feels like a standard mouse, however certain primitive operations are performed with much greater ease. The rotate tool – common in most drawing programs – becomes redundant as objects are easily moved with three degrees of freedom. Mechanisms to engage the added degree of freedom and different interaction techniques are discussed.

Keywords

pointing devices, multi-degree-of-freedom input, rotation

INTRODUCTION

Since the introduction of the Apple *Macintosh* in 1984, the form of desktop systems has not changed substantially. Manipulating complex graphic objects usually combines mouse movement with special tools or modes. These permit simple displacement data from the mouse to map to and control the displacement and/or angular location of objects or scenes. These mappings are often unnatural.

DIMENSIONS AND DEGREES OF FREEDOM

Before we describe our mouse, it is important to distinguish between dimensions (D) and degrees of freedom (df). In three dimensions, there are six degrees of freedom: three for position along the *x*, *y*, and *z* axes, and three for angular orientation (θx, θy, and θz). In 2D, there are three degrees of freedom. If we consider a 2D surface such as a mouse pad (see Figure 1), then there is an *x* and *y* positional degree of freedom and a *z*-axis rotational degree of freedom.

Figure 2 illustrates the dimensions and degrees of freedom for several "mouse-type" devices. As a standard mouse is manoeuvred on a mouse pad, only its *x* and *y* displacement are sensed, as indicated in the "Mouse" column. This is sufficient for most tasks using, for example, word processors or spreadsheets. However, within drawing packages and other graphics programs, a common task is to move an object to a new location and with a new orientation. This is a full two dimensional task and it requires three degrees of freedom. Since mouse angular motion is not sensed, a rotate tool or a manipulator handle is usually required. Although other schemes can be devised to control the orientation of objects [3], they are unnatural and violate the basic perceptual structure of interaction [2].

Figure 1. A mouse pad is a two-dimensional surface with three degrees of freedom: *x*, *y*, and θz.

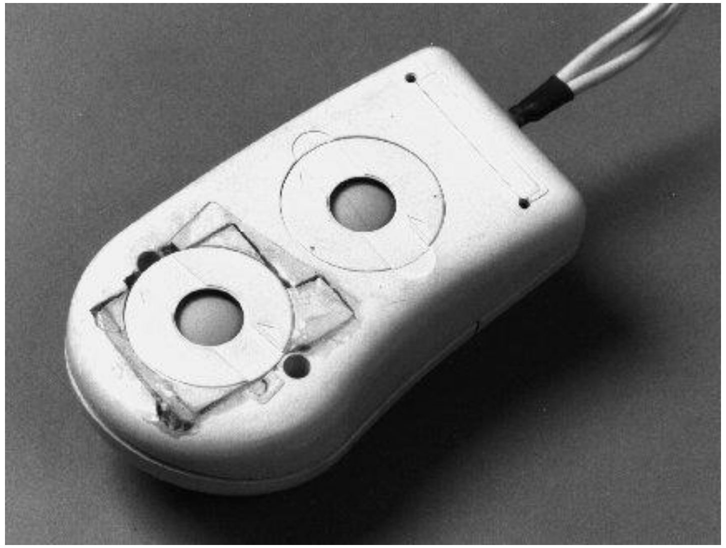
	Degree of Freedom	Mouse	2-ball Mouse	Other A	Other B	Other C	Other D
3D / 2D	*x*	●	●	●	●	●	●
3D / 2D	*y*	●	●	●	●	●	●
3D / 2D	θz	○	●	○	●	○	●
3D	*z*	○	○	●	●	○	○
3D	θx	○	○	○	●	●	●
3D	θy	○	○	○	●	●	●

Figure 2. Dimensions vs. degrees of freedom. Grey dots indicate degrees of freedom sensed for several types of input devices. (See text for discussion)

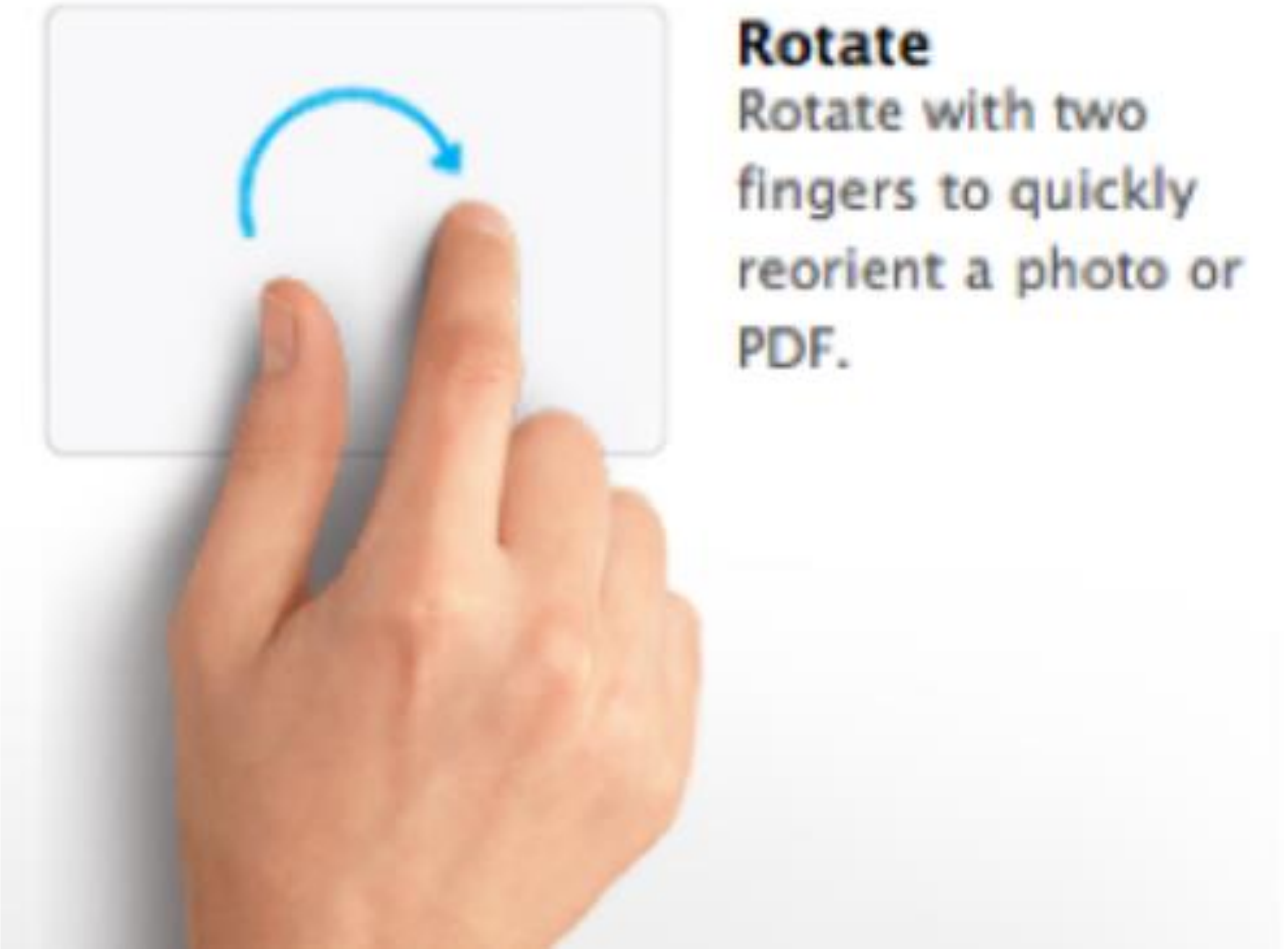
A TWO-BALL MOUSE

We have built a prototype of a 2D/3df mouse (see Figure 3) that makes a rotate tool redundant. The mouse was built using the mechanical parts from two Microsoft 2.0 mice and the electronics from two Fellowes MousePens. The prototype weighs 156 g, compared to 104 g for the standard Microsoft 2.0 mouse. It interfaces to a host computer through two serial ports. This is sufficient for a prototype and it allowed a variety of simple demonstrations to be implemented. As a product, a complete bottom-up redesign would be required.

With some simple arithmetic in the interface software, the *z*-axis or rotational component of the mouse's motion is easily computed from the two streams of *x-y* positional



MacKenzie, I. S., Soukoreff, R. W., & Pal, C. (1997). A two-ball mouse affords three degrees of freedom. *Proc CHI '97*, 303-304, New York: ACM.



Apple Trackpad Gesture

Hinckley, K., Pahud, M., Benko, H., Irani, P., Guimbretiere, F., Gavriliu, M., Chen, X., Matulic, F., Buxton, B., Wilson, A., Sensing Techniques for Tablet+Stylus Interaction. UIST 2014

Devamardeep Hayatpur, **Seongkook Heo**, Haijun Xia, Wolfgang Stuerzlinger, Daniel Wigdor,
Plane, Ray, and Point: Enabling Precise Spatial Manipulations with Shape Constraints, UIST 2019

Touch Interfaces

- Direct mapping, 1:1 CD Gain
- Occlusion and accuracy (“fat finger problem”)
- Contemporary systems use variations; e.g., offset animation:

Understanding Touch

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ABSTRACT

Current touch devices, such as capacitive touchscreens are based on the implicit assumption that users acquire targets with the center of the contact area between finger and device. Findings from our previous work indicate, however, that such devices are subject to systematic error offsets. This suggests that the underlying assumption is most likely wrong. In this paper, we therefore revisit this assumption.

In a series of three user studies, we find evidence that the features that users align with the target are *visual* features. These features are located *on the top* of the user's fingers, not at the bottom, as assumed by traditional devices. We present the *projected center model*, under which error offsets drop to 1.6mm, compared to 4mm for the traditional model. This suggests that the new model is indeed a good approximation of how users conceptualize touch input.

The primary contribution of this paper is to help understand touch—one of the key input technologies in human-computer interaction. At the same time, our findings inform the design of future touch input technology. They explain the inaccuracy of traditional touch devices as a "parallax" artifact between user control based on the top of the finger and sensing based on the bottom side of the finger. We conclude that certain camera-based sensing technologies can inherently be more accurate than contact area-based sensing.

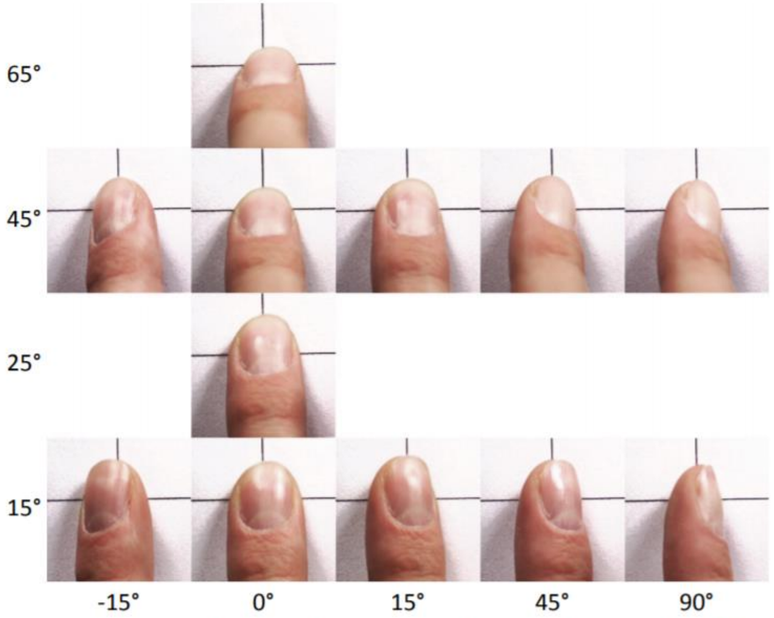


Figure 1: A study participant targeting crosshairs using different finger angles. Can you guess how this user is conceptualizing touch, i.e., what geometric relationship between finger and crosshairs the user is trying to maintain independent of how the finger is held? Our findings suggest that users indeed target as suggested by this illustration, i.e., by aligning finger features and outlines in a hypothesized top-down perspective.

encode which target they are trying to refer to, e.g., by touching the target with the center of the finger contact area.

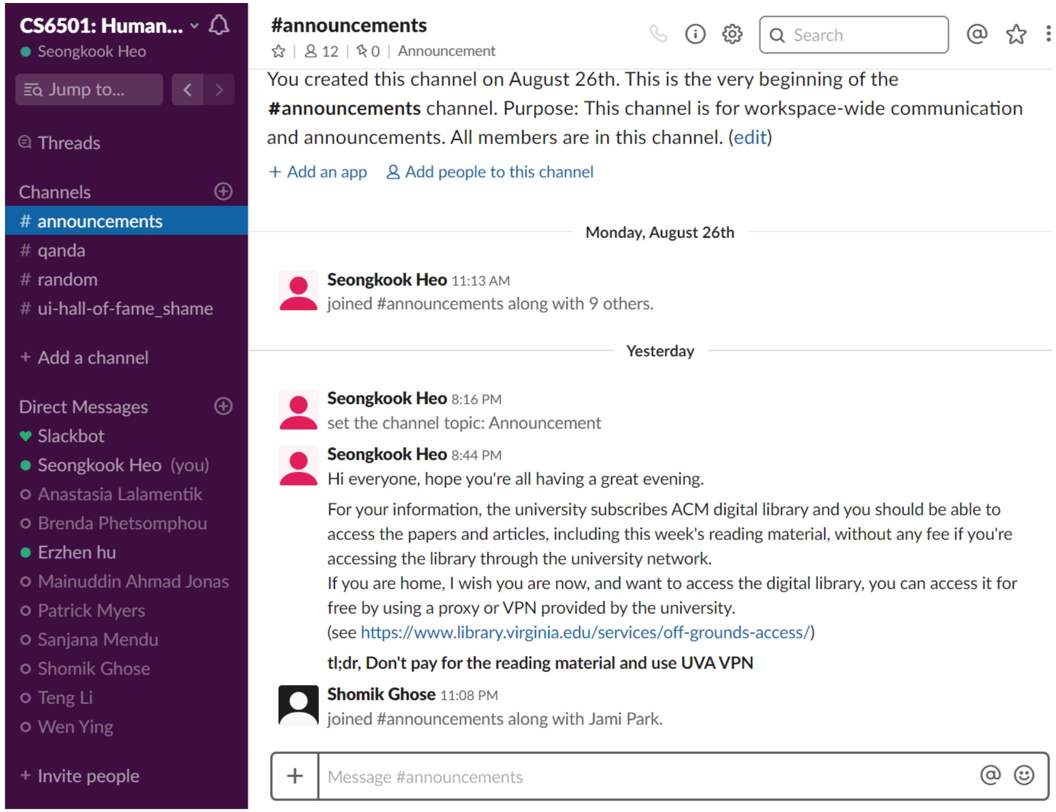
Holz, C. and Baudisch, P. Understanding Touch. CHI 2011

Reading Response

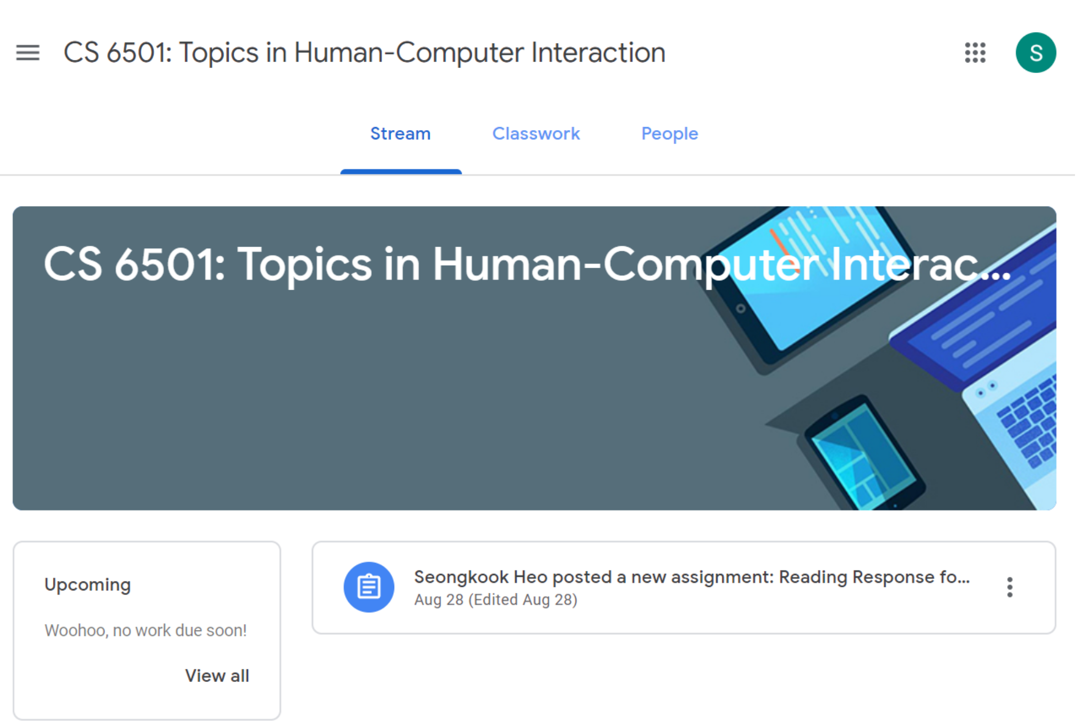
- One-page report that you write about the reading material or one of the papers to be discussed in the class.
- One response/week.
- Should include
  - A summary of the paper in your words.
  - Your reaction to the paper, such as your thoughts and critiques about it.
  - Three paragraphs should be enough.
- Deadline: Every Monday night (23:59 pm).

Slack and Google Classroom

http://topicshci.slack.com
Use your virginia.edu email



http://classroom.google.com
Class code: hemfvt9



Please enroll!

TODO items for you

- **Read reading material for week 3** (**Due Monday Night**)
- Upload at least **Three** Usability Problems on Slack by **Friday Night**

  "I can't see my phone when it vibrates in my pocket without disturbing the conversation with my friend"

  "I keep typing in the wrong window after switching applications using hotkeys"
- We will **vote until Tuesday** and **team up in the Tuesday Class**
- Topic Presentation papers will be uploaded on **Friday Noon on a Google Sheet.** First come first serve.

Acknowledgements

- Some of the materials are based on materials by
  - Tovi Grossman, Univ. of Toronto
  - Juho Kim, KAIST
  - Scott MacKenzie, Human-Computer Interaction: An Empirical Research Perspective

Thank you!