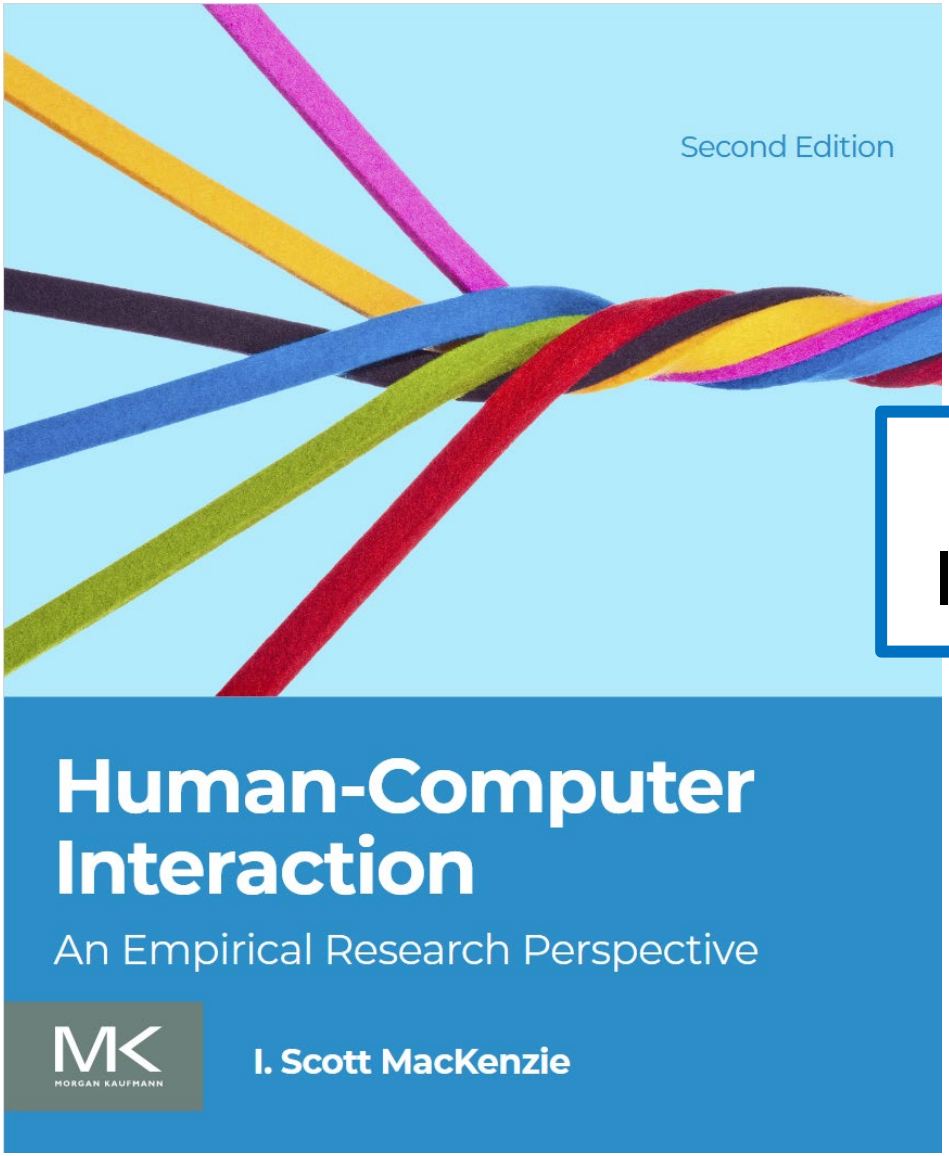


Chapter 3
Interaction Elements

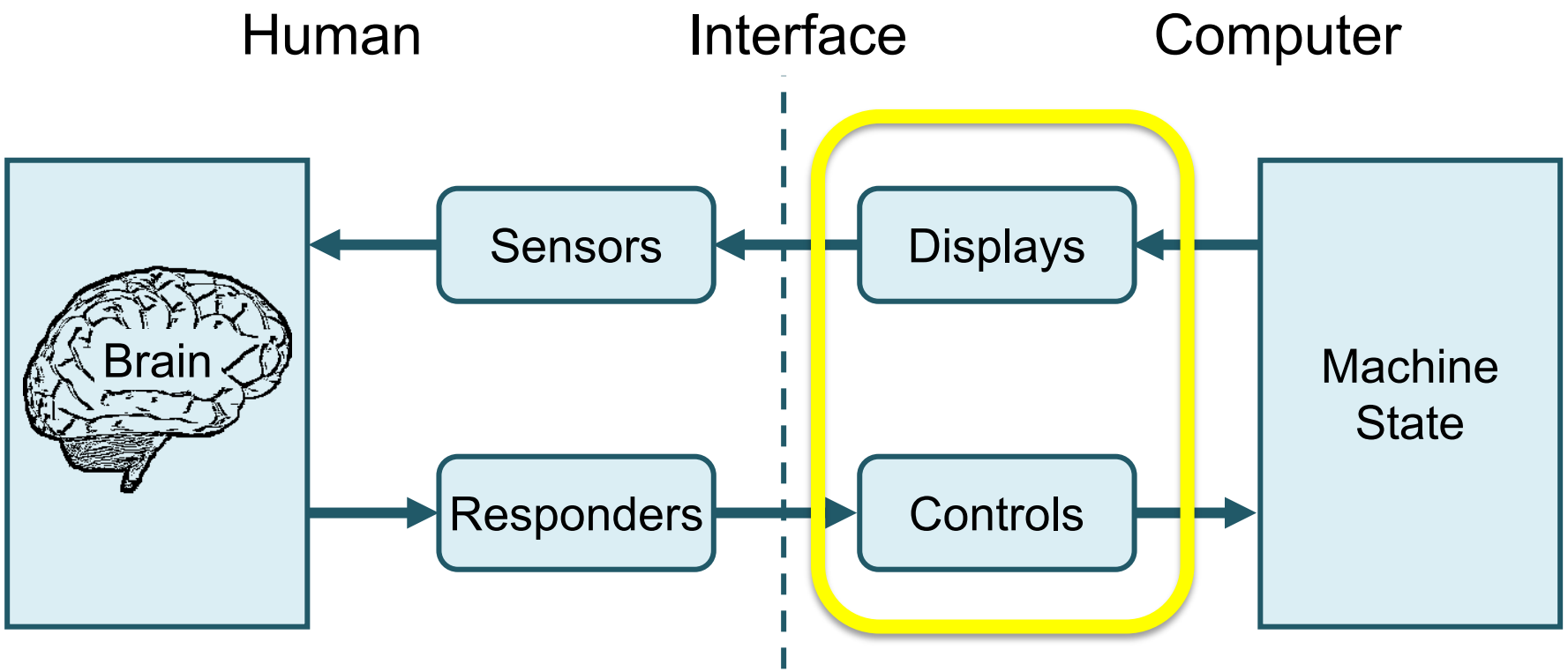
Interaction

- *Interaction* occurs when a human performs a task using computing technology
- Interaction tasks with a goal:
  - Send an e-mail
  - Move files to memory stick
  - Program a thermostat
  - Enter a destination in a GPS device
- Interaction tasks without a goal:
  - Browse the web
  - Chat with friends on a social networking site

Interaction Elements

- Can be studied at many levels and in different contexts
- As presented here, the tasks are in the cognitive band of Newell's time scale of human action (see Chapter 2)
  - Deliberate acts (≈100 ms)
  - Operations (≈1 s)
  - Unit tasks (≈10 s)
- Tasks in this range are well suited to empirical research
- Experimental methodology preferred (extraneous behaviours easy to control)
- Early human factors research on "knobs and dials" is relevant today
- Knobs → "controls"; dials → "displays" (next slide)

Human Factors Model (revisited)



Interaction Techniques (1)

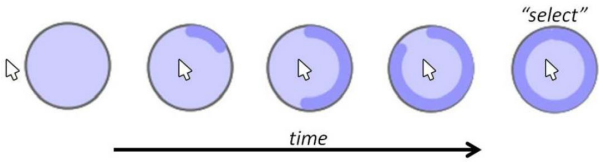
- Many interactions can be described as "forming an intent" followed by "confirming an intent"
- Often, this involves "pointing" and "selecting"

Input Method	Pointing (Forming an Intent)	Selecting (Confirming an Intent)
Mouse (indirect)	Position a tracking symbol inside SOI	Press and release a button on the device
Touchpad (indirect)	Position a tracking symbol inside SOI	Finger tap on touchpad or press down
Finger on display (direct)	Move finger to SOI	Brief touch followed by lift on SOI
Eye gaze	Look at SOI	Gaze dwell on SOI for a pre-defined period
Keyboard	Use TAB or SHIFT-TAB to move "focus" to SOI	Press and release ENTER
Single-switch scanning	Wait for scanning highlight to reach SOI	Activate switch when highlight is on SOI

SOI = selectable object of interest

Interaction Techniques (2)

- Indirect pointing
  - Archetype device is the mouse
  - A cursor, or tracking symbol, is needed
  - CD relationship → between the input device (the control) and movement of the on-screen tracking symbol (the display)
- Direct pointing
  - Archetype device is a stylus (or finger on a touchscreen)
  - A cursor is *not* needed
- Selecting
  - Typically, a switch or button (indirect) or a tap (direct)
  - For eye input using an eye tracker, dwell-time selection

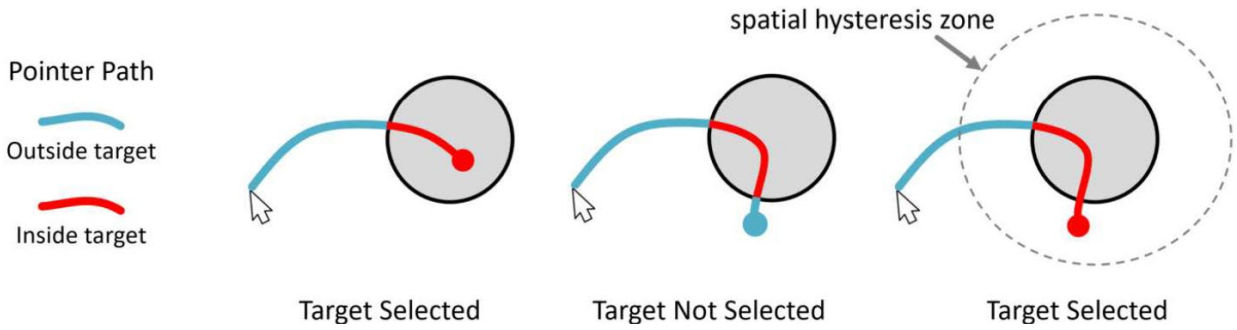


Point-select Improvement

- Lots of HCI research on improving interaction for point-select operations
- A few examples follow

Spatial Hysteresis

- On the right, spatial hysteresis is used:



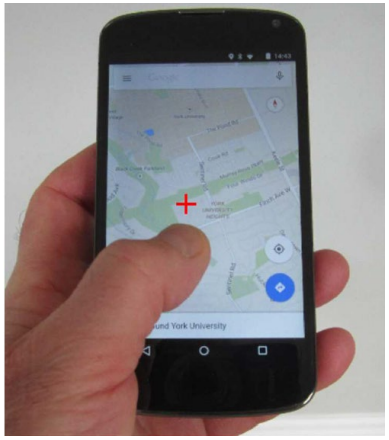
- The target is selected since the pointer enters the target, then leaves the target but remains in the spatial hysteresis zone
- Note: The dashed line showing the spatial hysteresis zone does not appear on the display

J.P. Hansen, V. Rajanna, I.S. MacKenzie, P. Bækgaard, A Fitts' law study of click and dwell interaction by gaze, head and mouse with a head-mounted display, in: Proc COGAIN '18, ACM, New York, 2018, pp. 7.1–7.5.

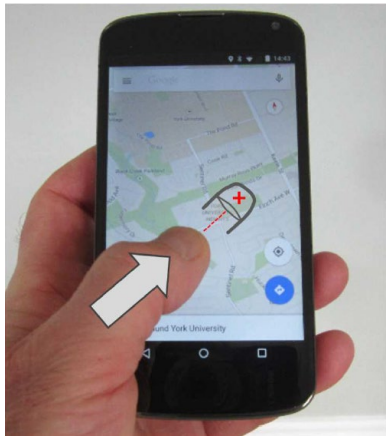
Offset Cursor (1)

- Important on touchscreens due to occlusion
- Offset Cursor:[1] appears above the point of contact
- ExtendedThumb:[2] cursor position is offset in direction of movement

Offset cursor [1]



Extended Thumb [2]



[1] R.L. Potter, L.J. Weldon, B. Shneiderman, Improving the accuracy of touch screens: an experimental evaluation of three strategies, in: Proc CHI '88, ACM, New York, 1988, pp. 27–32.

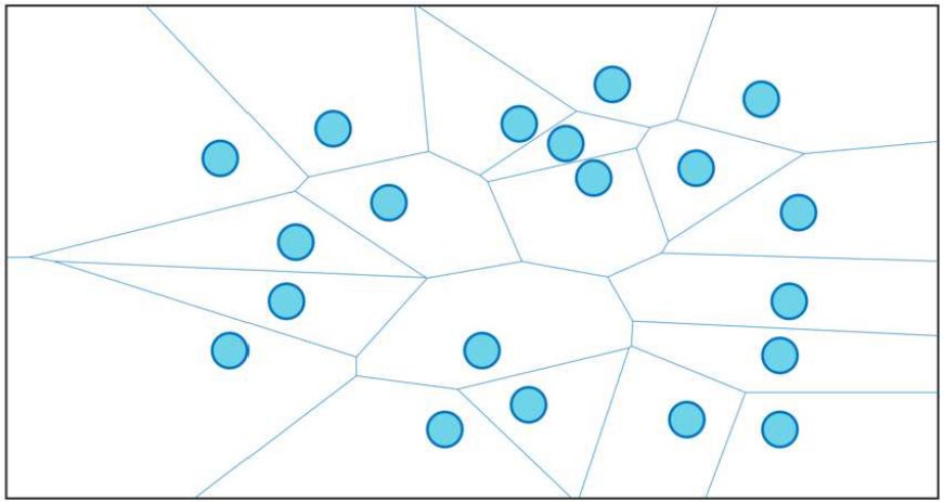
[2] J. Lai, D. Zhang, ExtendedThumb: a target acquisition approach for one-handed interaction with touch-screen mobile phones, IEEE Trans Human-Machine Systems 45 (3) (2015) 362–370.

Offset Cursor (2)

- Typical example with smartphone

Bubble Cursor

- Target size expands to an effective size determined by Voronoi regions



- Each target gets maximum space without encroaching on the space of neighboring targets
- Can also be applied in 3D (e.g., virtual reality)

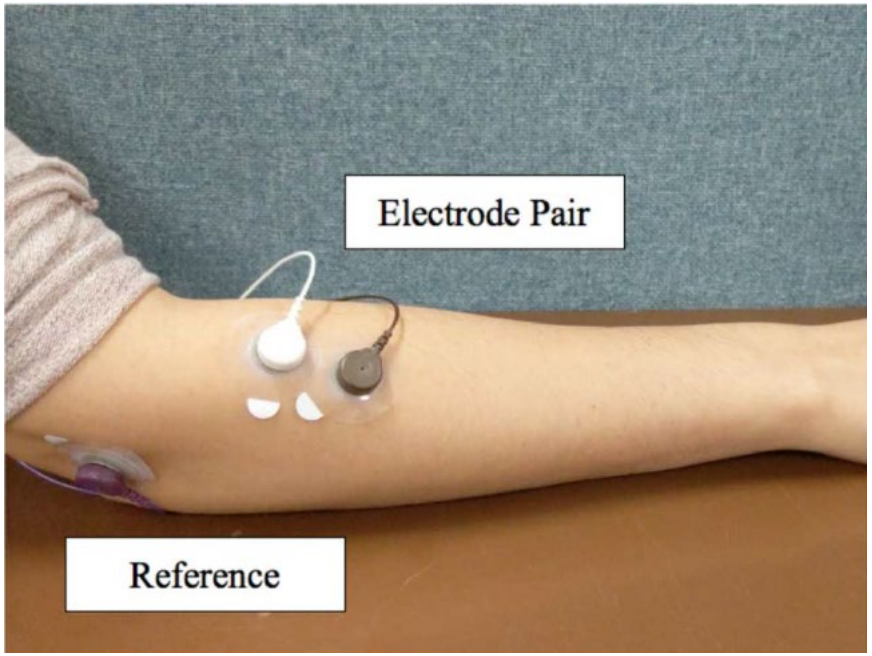
T. Grossman, R. Balakrishnan, The Bubble Cursor: enhancing target acquisition by dynamic resizing of the cursor's activation area, in: Proc CHI '05, ACM, New York, 2005, pp. 281–290.

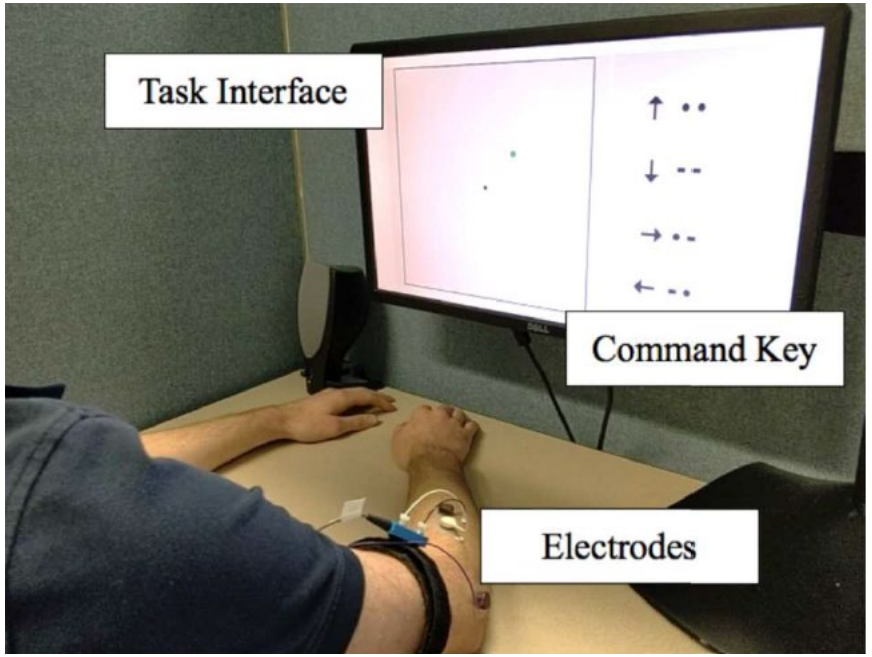
Alternate Inputs

- Many possibilities
- Context is often accessible computing
- A few examples follow

Skin Surface Electrical Signals

- Surface electromyography (sEMG) uses electrical signals produced by muscles measured at the surface of the skin.

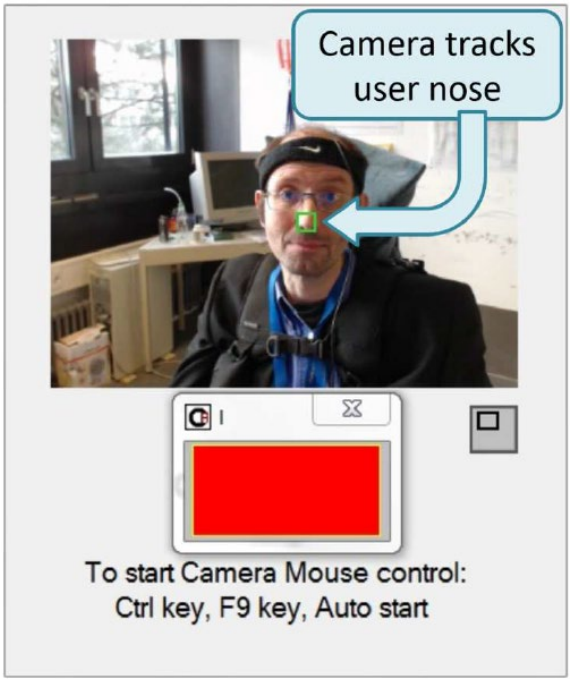


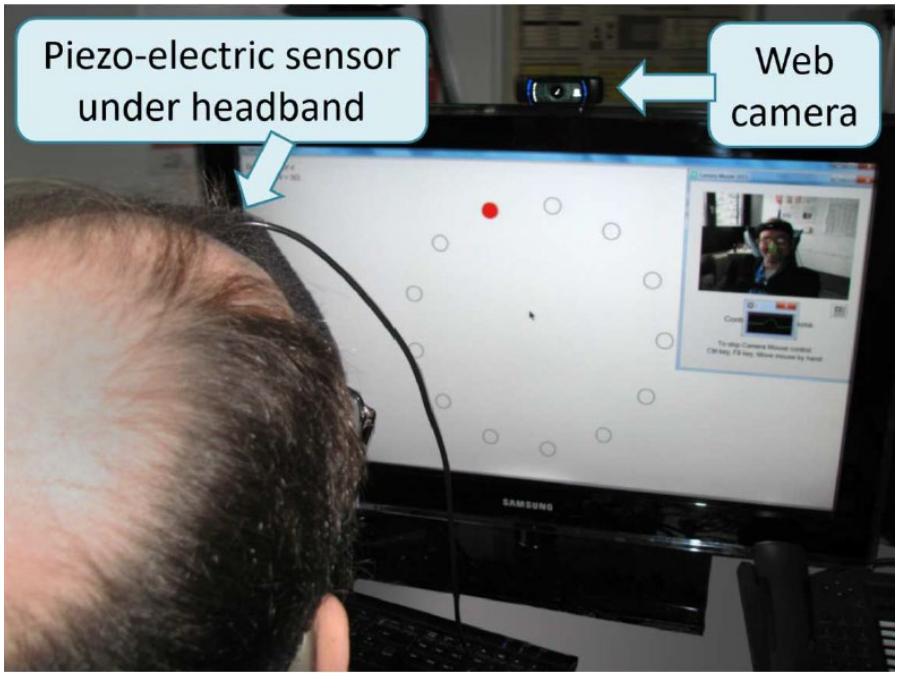


S. O'Meara, Single-site surface electromyography for human-machine interfaces, Doctoral Dissertation, University of California, Davis, 2021.

Piezo-electric Sensor

- ClickerAid: A piezo-electric sensor is positioned on the user's forehead under a headband
- Activated by raising the eyebrow

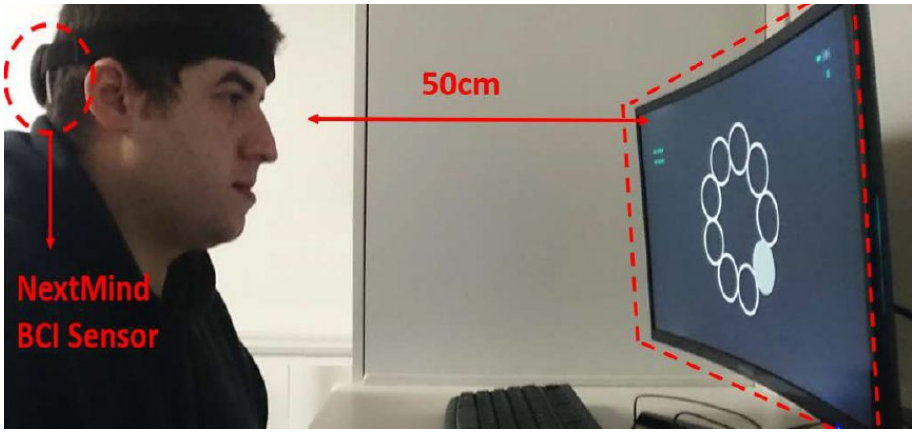


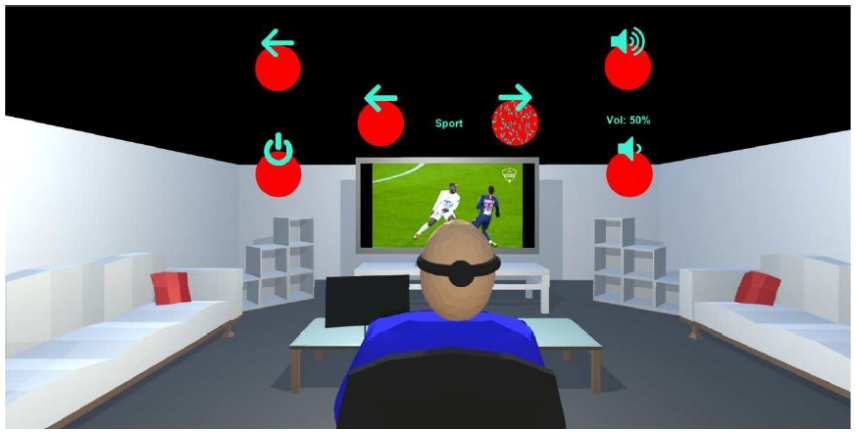


J. Magee, T. Felzer, I.S. MacKenzie, Camera mouse + ClickerAID: dwell vs. single-muscle click actuation in mouse-replacement interfaces, in: Proc HCII '15 (LNCS 9175), Springer, Switzerland, 2015, pp. 74–84.

Brain Signals

- NextMind
  - a head-mounted sensor with nine comb-shaped dry electrodes pick up electroencephalogram (EEG) signals and send them to a host computer
  - Selection using motor-imagery (e.g., making a fist)

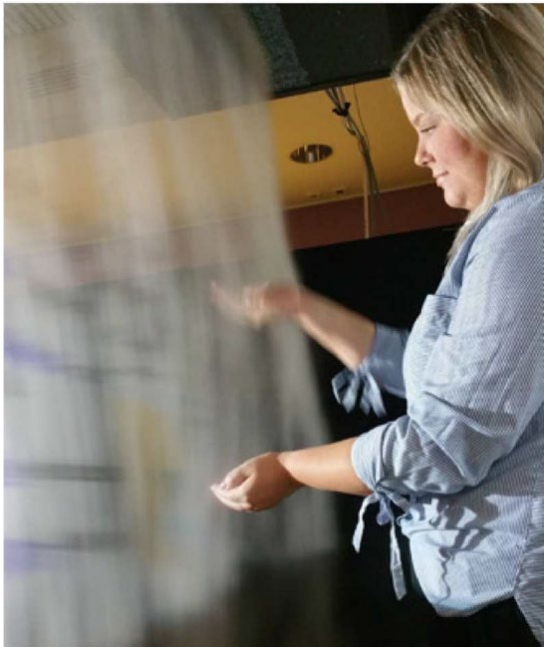


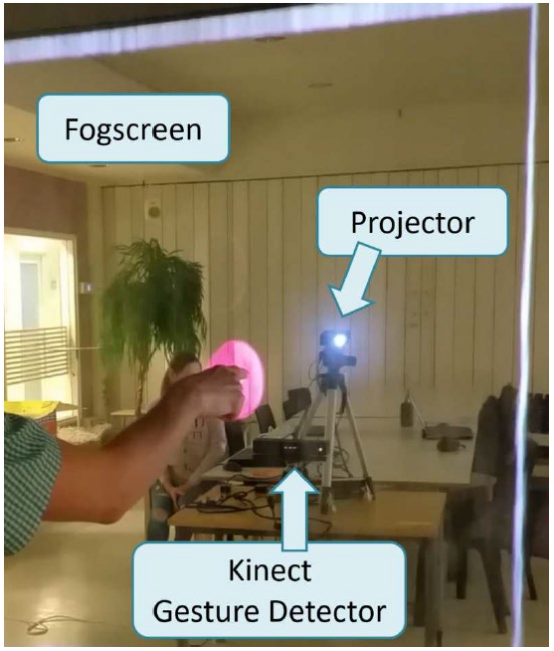


B.J. Hou, J.P. Hansen, C. Uyanik, P. Bækgaard, S. Puthusserypady, J.M. Araujo, I.S. MacKenzie, Feasibility of a device for gaze interaction by visually-evoked brain signals, in: Proc ETRA '22, ACM, New York, 2022, pp. 62.1–62.7.

Fogscreen

- An immaterial mid-air display formed from a flowing sheet of light-scattered particles (like fog)
- Users reach into or walk through the display
- Interaction uses a Kinect gesture detector

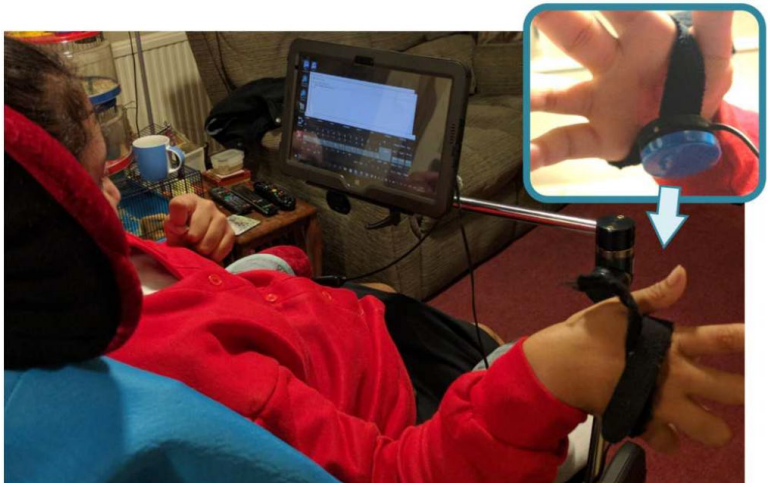




V. Remizova, A. Sand, I.S. MacKenzie, O. Špakov, K. Nyyssönen, I. Rakkolainen, A. Kylliäinen, V. Surakka, Y. Gizatdinova, Mid-air gestural interaction with a large fogscreen, Multimodal Technologies and Interaction 7 (63) (2023) 1–18.

Single-Switch Scanning

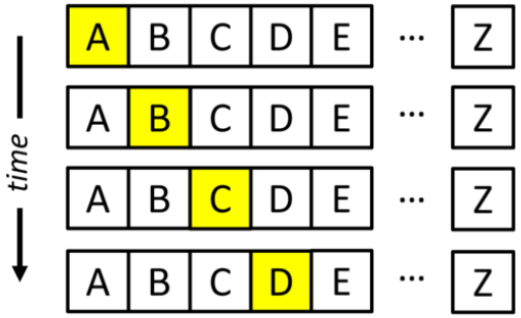
- Common in accessible computing
- The user activates a selection signal using a single switch or other means
- Switch example:



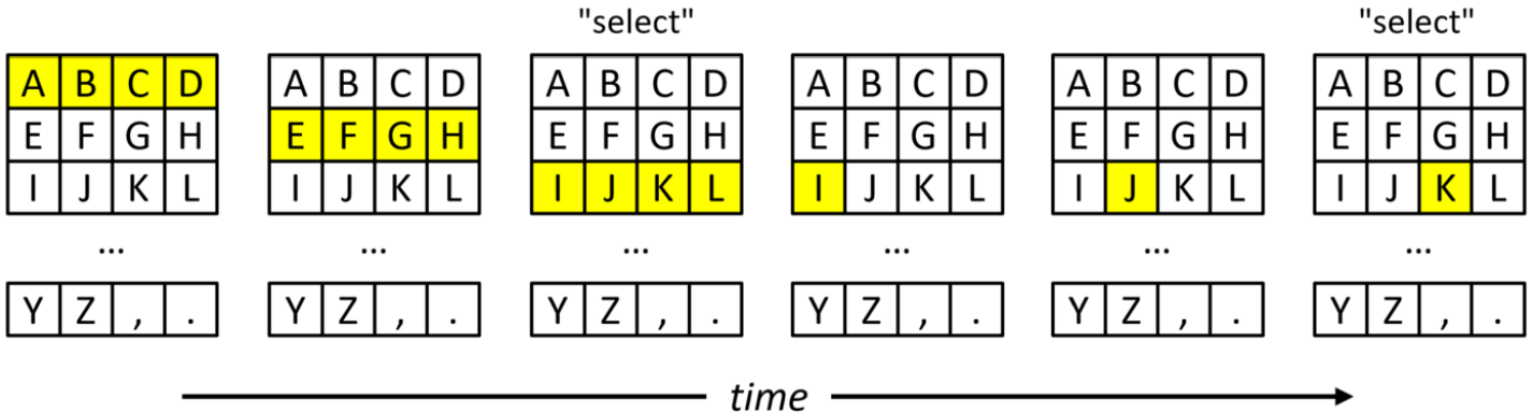
- Common application → text entry (next slide)

Scanning Keyboard

- Linear scanning
  - very slow



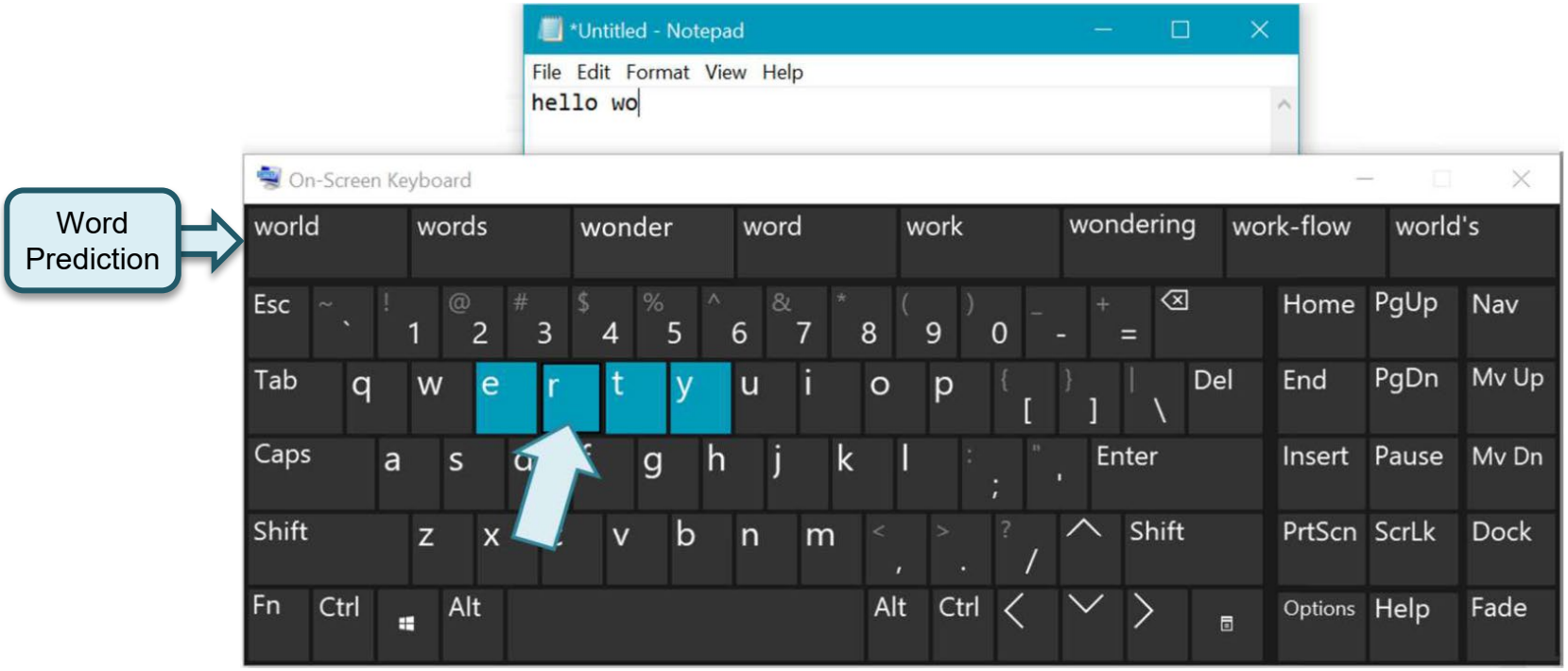
- Two-tier scanning
  - faster but requires two switch activations per character



On-Screen Keyboard (OSK)

- Included in Microsoft Windows

Demo



Note: three-tier scanning

Scansteps Per Character (SPC)

- An analytic metric, like KSPC, but for scanning
- Enter "world" (5 characters):

Letter-by-Letter Input

Letter	Input	Scansteps
w	..RG..w	7
o	..R..G..o	9
r	..R.G.r	7
l	...R..G..l	10
d	...R.G.d	8
	Total:	41

With Word Prediction

Letter	Input	Scansteps
w	..RG..w	7
o	..R..G..o	9
rld	RW	2
	Total:	18

18 scansteps produce 5 characters, therefore

SPC = 18 / 5 = 3.6

Note: Under Input, "." is a passive scanstep, "R" is a row selection, "G" is a group selection, "W" is a word selection, and a lowercase character is a letter selection.

- Examples above are instructive, but SPC is more relevant if calculated using a letter- or word-frequency list
- Result is an overall average for a language (e.g., for English)
- Formula (next slide)

SPC Formula

- Using a letter-frequency list:

$$\text{SPC} = \frac{\Sigma(S_c \times F_c)}{\Sigma(N_c \times F_c)}$$

  - S_c is the number of scansteps to enter character c
  - F_c is the frequency count for c in a corpus
  - $N_c = 1$ (the number of characters in a letter)

- Using a word-frequency list
  - Same formula except for words, substitute w for c
  - N_w is the number of letters in the word (+1 for a space following the word)

Scanning Optimization

- Put frequent letters in top-left to reduce SPC

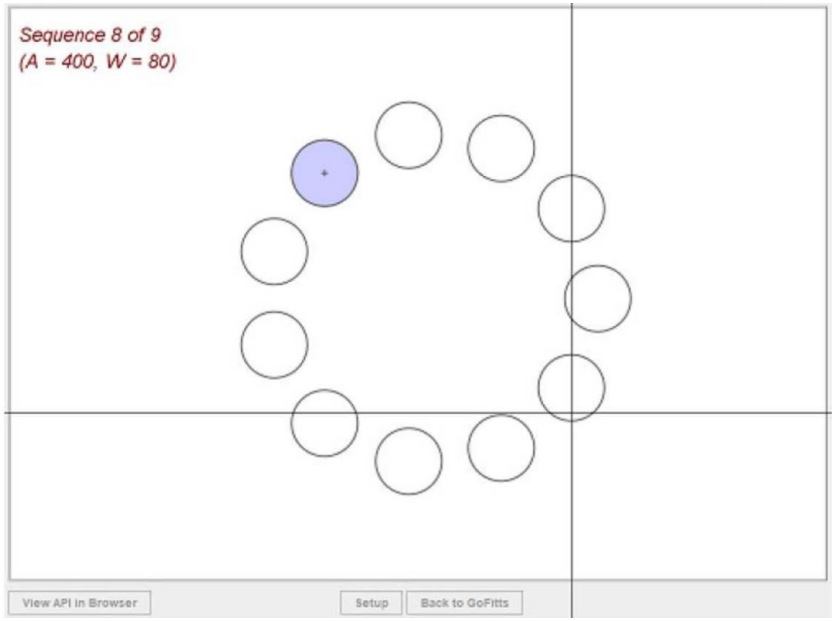
Word	e	a	r	d	u	v
Word	t	o	i	l	g	k
Word	n	s	f	y	x	q
Word	h	c	p	j	w	z
Word	m	b				
Word						
Space						

- Word keys for word predictions (based on current word stem)
- Blank keys are other inputs (e.g., BKSP)

F. Shein, G. Hamann, N. Brownlow, J. Treviranus, M.Milner, P. Parnes, WiViK: a visual keyboard for Windows 3.0, in: Proc RESNA '91, RESNA, Arlington, VA, 1991, pp. 160–162.

Scanning for Target Selection

- Two-bar single-switch scanning (TBS^3)
- Input only uses SPACEBAR
- Very slow; for users with motor limitations



Interaction:

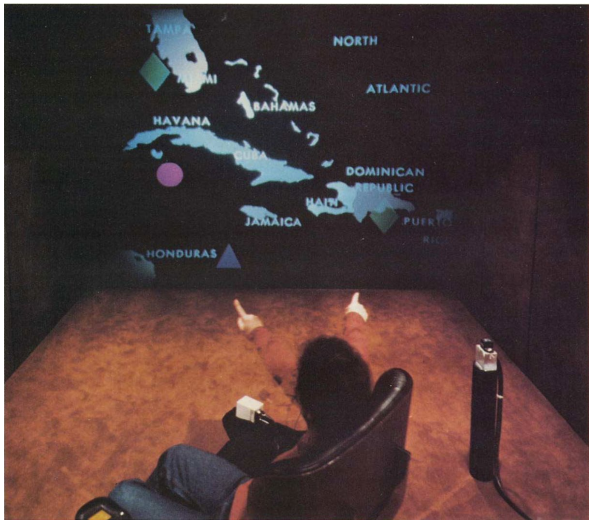
1. Press SPACEBAR to begin movement of vertical bar.
2. Press SPACEBAR a 2nd time to stop vertical bar and begin movement of horizontal bar.
3. Press SPACEBAR a 3rd time to stop horizontal bar. This also initiates a target selection at the intersection of the vertical and horizontal bars.
4. Repeat

Note: Many possibilities to speed-up the interaction

M. Raynal, I.S. MacKenzie, TBS3: two-bar single-switch scanning for target selection, in: Proc ICCHP ’22 (LNCS 13341), Springer, Cham, 2022, pp. 338–346.

Gesture Input

- Gestures are “movements to communicate”
- Encompass all interactions with computers (possible exception, BCI)
- Dating (at least) to 1980 with Bolt’s “Put That There” demo[1]

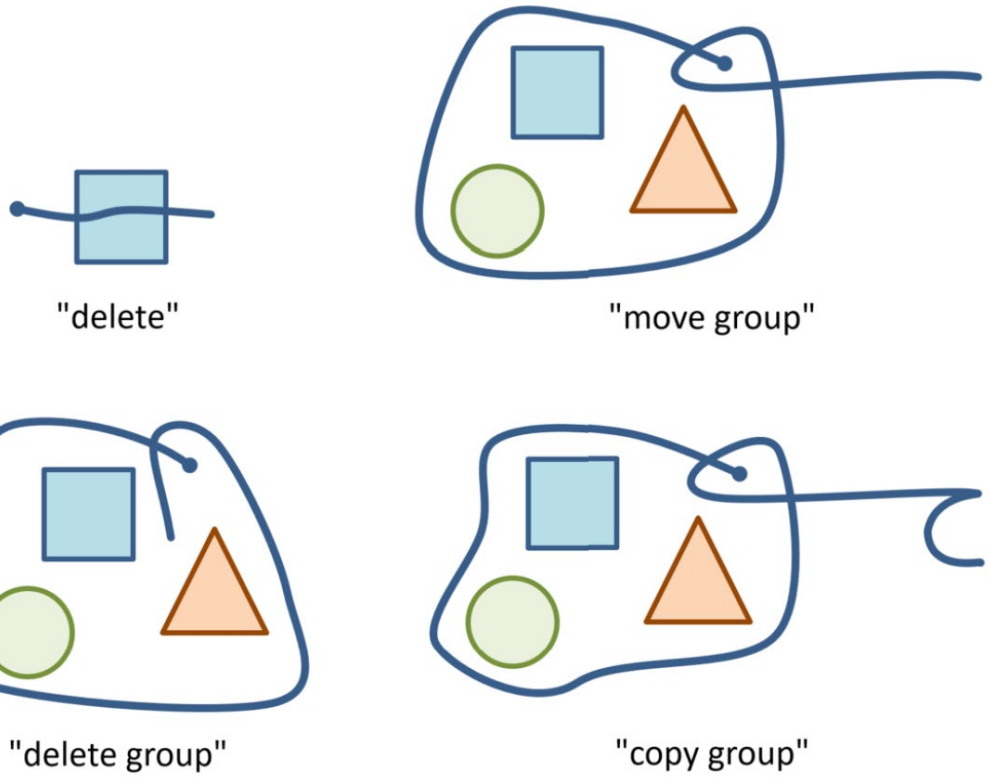


VRs first “Cave”?

[1] R.A. Bolt, “Put-That-There”: voice and gesture at the graphics interface, in: Proc SIGGRAPH ’80, ACM, New York, 1980, pp. 262–270.

Gestures for Graphics Editing

- GEdit:



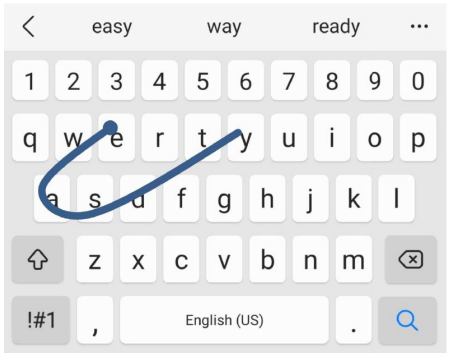
G. Kurtenbach, B. Buxton, GEdit: a test bed for editing by contiguous gestures, SIGCHI Bulletin 23 (2) (Mar. 1991), pp. 22–26.

Gestures for Text Entry

- Many possibilities
  - Unistrokes, Graffiti, EdgeWrite, Cirin, WatchMI, etc.
- "Easy" in Graffiti:

Demo

- "Easy" in Shape Writing:



Showing soft keyboard underneath gesture

Use software from the book's web site:
http://www.yorku.ca/mack/HCIbook2e/

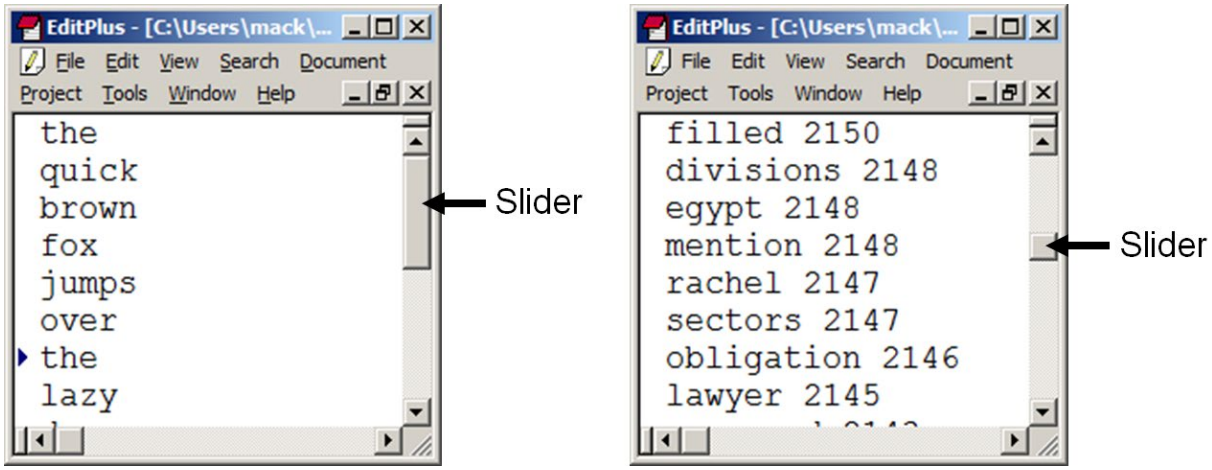
Hard Controls, Soft Controls

- In the past, 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
- Consider controls to format ***this*** (see below)

Soft controls are also displays!

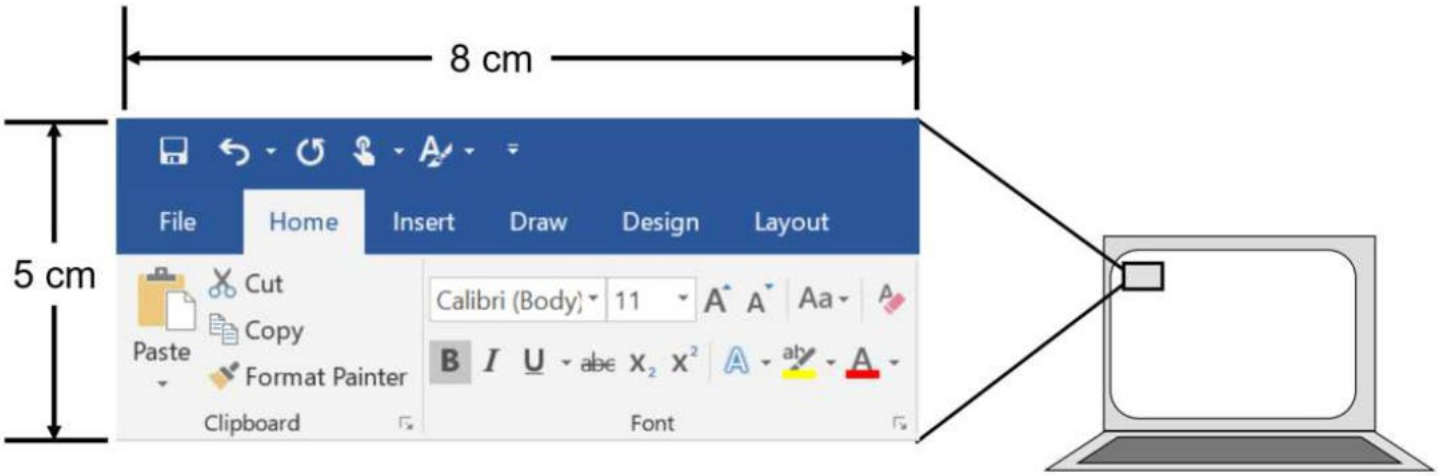
Scrollbar Slider

- 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



GUI Malleability

- Below is a 30 cm^2 view into a GUI
- >20 soft controls (or are they displays?)

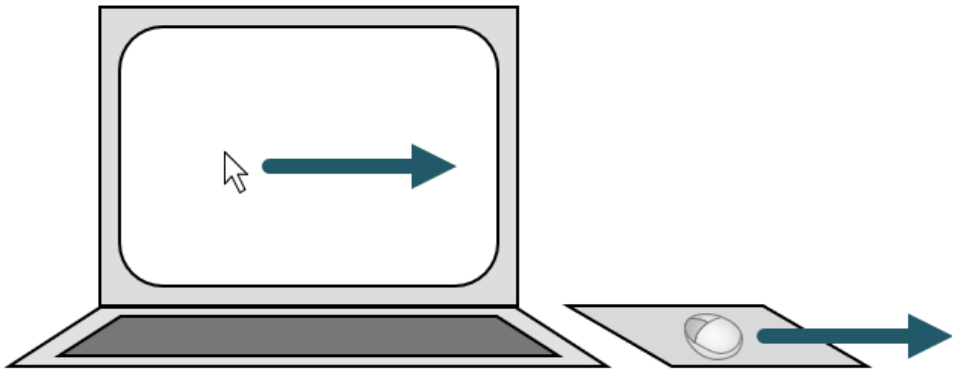


- Click a button and this space is morphed into a completely different set of soft controls/displays

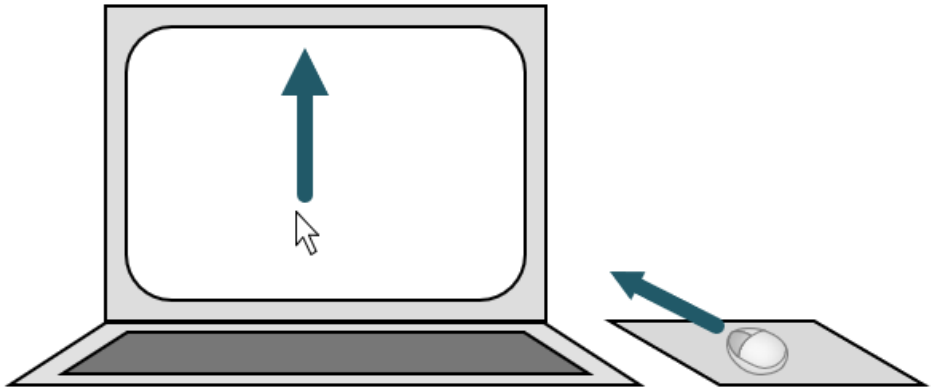
Control-Display Relationships

- 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

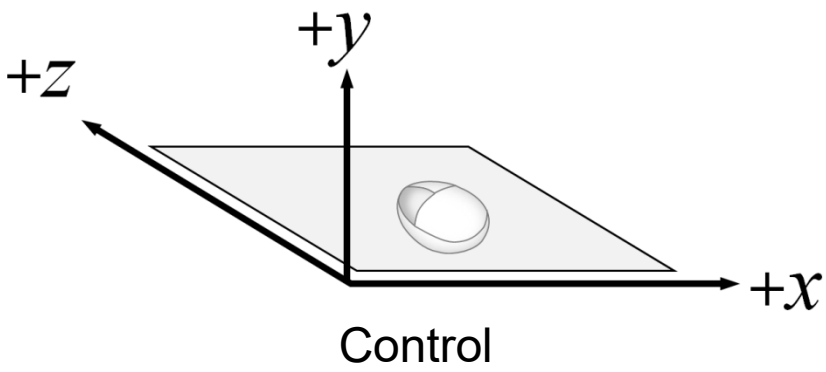


Spatial congruence
Control: right
Display: right

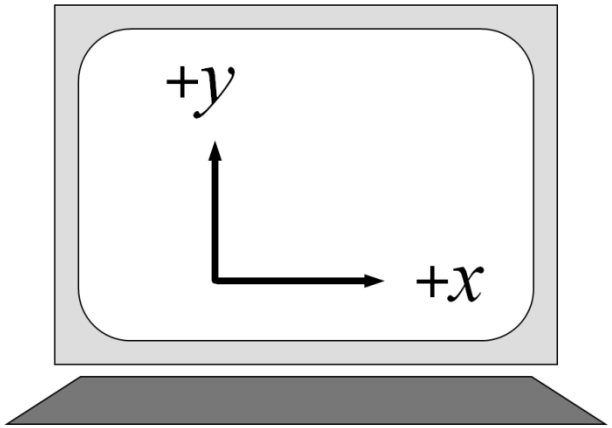


Spatial transformation
Control: forward
Display: up

Axis Labeling



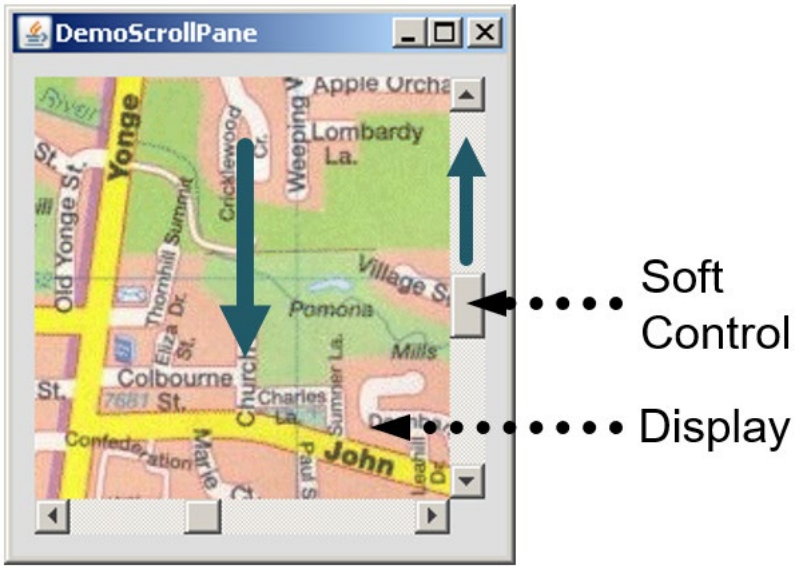
Control



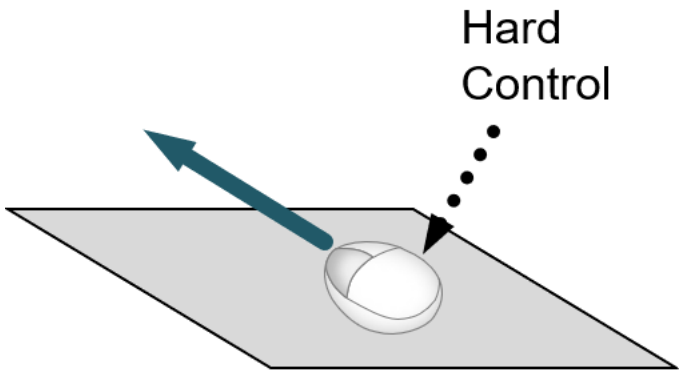
Display

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

Third Tier



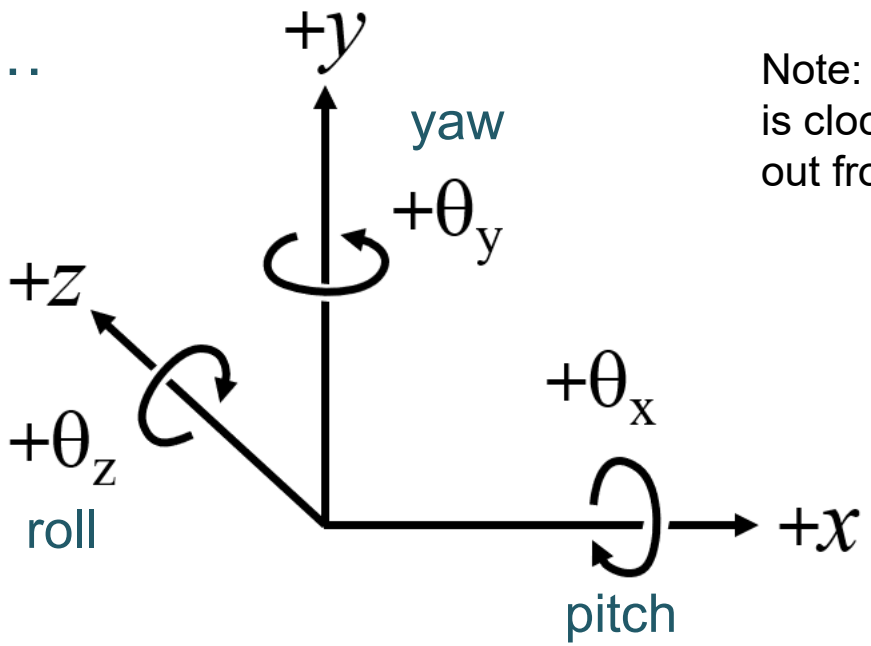
DOF	Hard Control	Soft Control	Display
x			
y		+	-
z	+		
θ_x			
θ_y			
θ_z			



3D

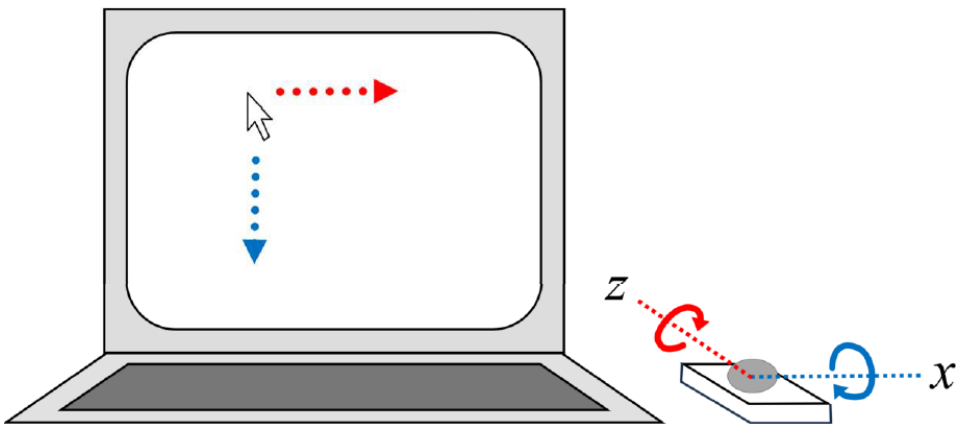
- In 3D there are 6 degrees of freedom (DOF)
  - 3 DOF for position (x, y, z)
  - 3 DOF for orientation $(\theta_x, \theta_y, \theta_z)$

In aeronautics…



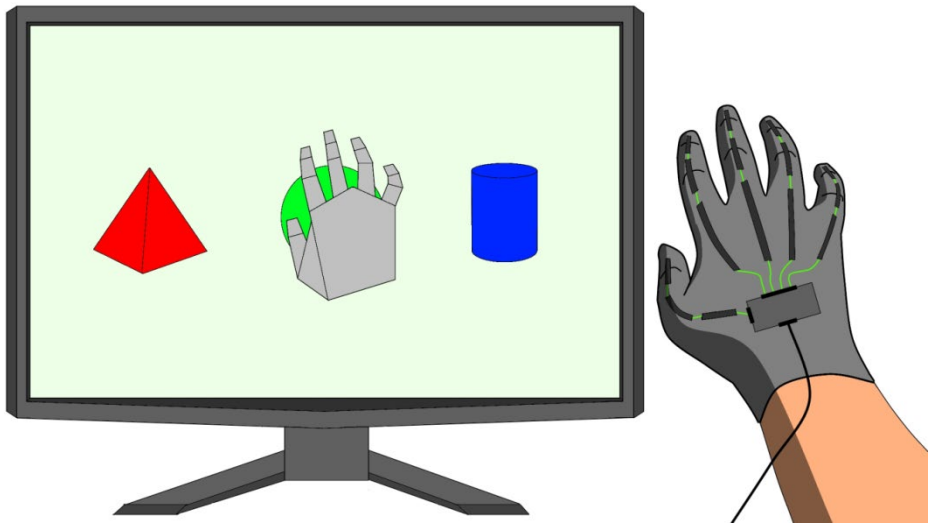
Note: plus (+) rotation is clockwise, looking out from the origin

Trackball



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

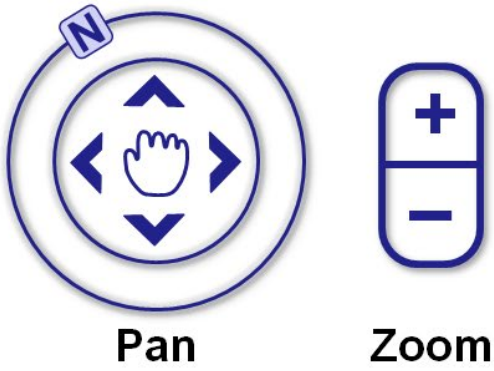
Spatial Congruence in 3D



DOF	Control	Display
x	+	+
y	+	+
z	+	+
θ_x	+	+
θ_y	+	+
θ_z	+	+

3D in Interactive Systems

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



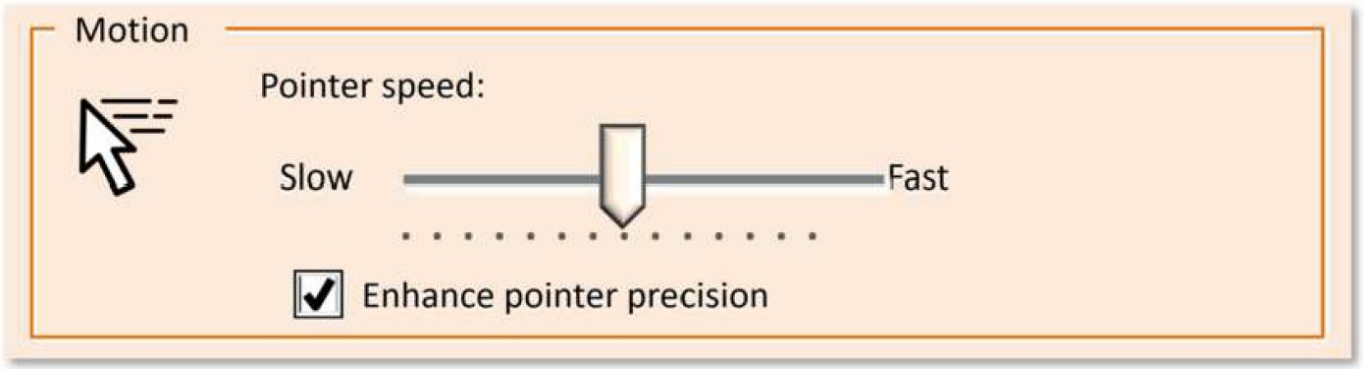
Panning in Google StreetView

- (Switch to Google StreetView and demonstrate panning with the mouse)
- Spatial transformations:

DOF	Control	Display
x	+	
y		
z	+	
θ_x		+
θ_y		-
θ_z		

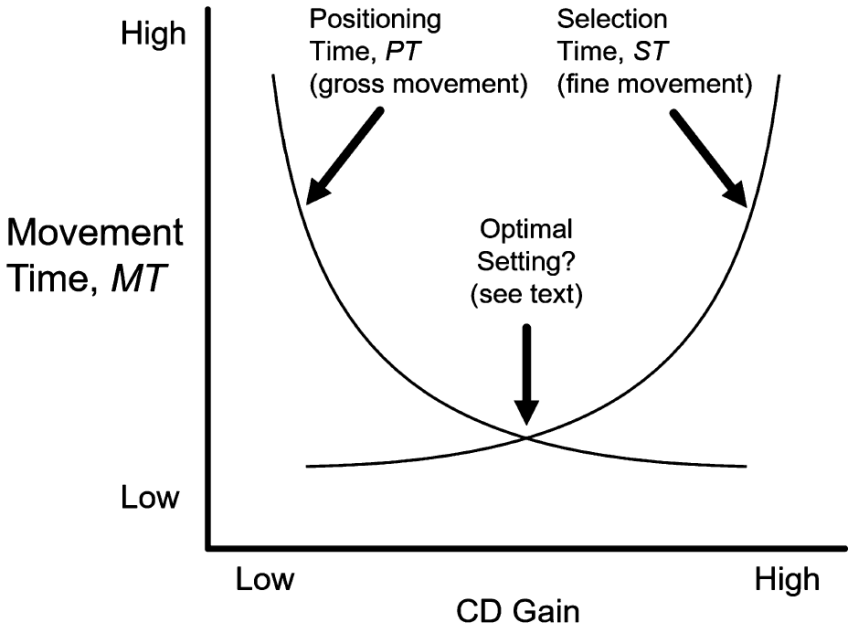
CD Gain

- 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
- Typical control panel to adjust CD gain:



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:



MT = PT + ST

Latency

- *Latency* (aka *lag*) is the delay between an input action and the corresponding response on a display
- Usually negligible on interactive systems (e.g., cursor positioning, editing)
- May be "noticeable" in some settings; e.g.,
  - Remote manipulation
  - Internet access (and other "system" response situations)
  - Virtual reality (VR)
- Human performance issues appropriate for empirical research

VR Controllers

- 6 DOF controllers common in VR and other 3D environments
- Considerable processing requirements
- Lag often an issue
- E.g., Polhemus G^{4}™ (see below)
- Lag specified as <10 ms (which is low)
- But the user experiences the complete system

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)

Joystick

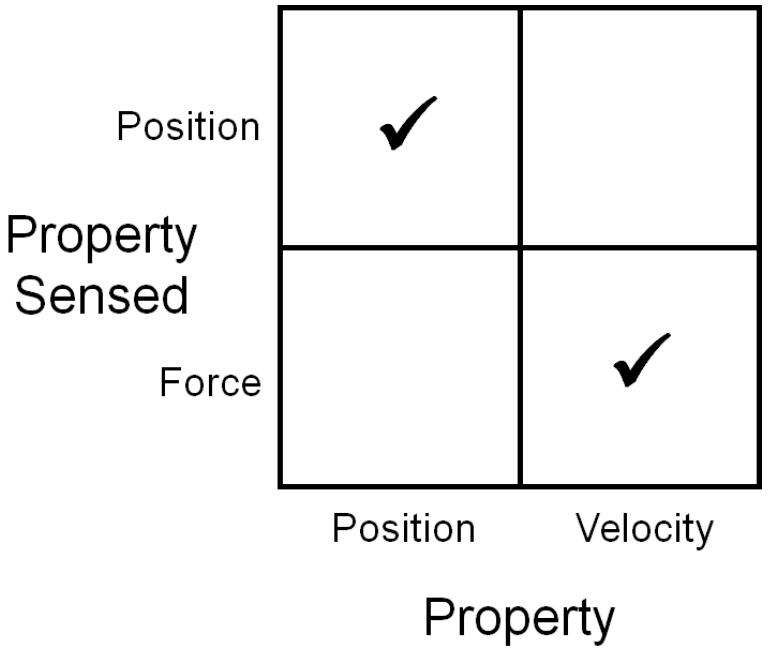
- Two types
  - Isotonic (senses displacement of stick)
  - Isometric (senses force applied to stick)

Isotonic joystick

Isometric joystick

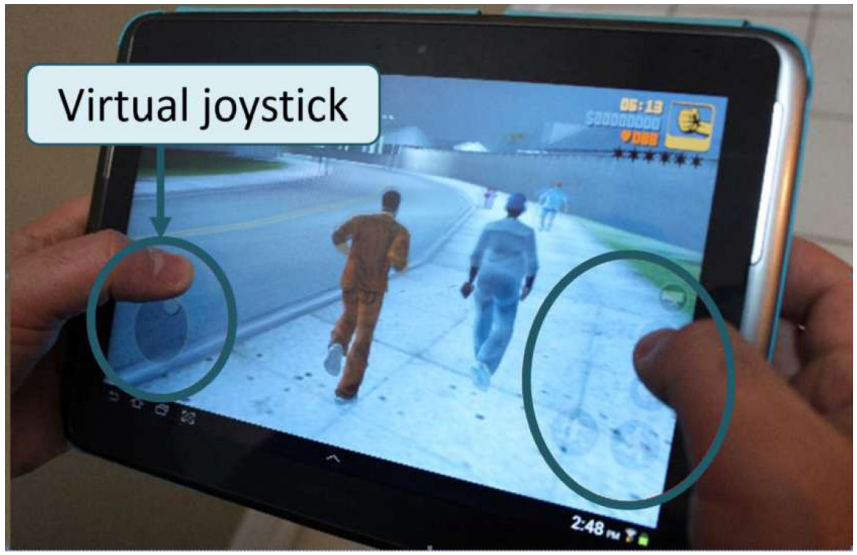
Joysticks (2)

- Optimal mappings
  - Isotonic joystick → position control
  - Isometric joystick → velocity control



Virtual Joystick Example

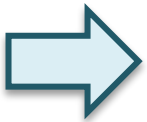
- The virtual joystick controls player position
- Which mapping performs best? (click for answer)
  - [x] Velocity control
  - [ ] Position control



R.J. Teather, A. Roth, I.S. MacKenzie, Tilt-touch synergy: input control for "dual-analog" style mobile games, Entertainment Computing 21 (2017) 33–43.

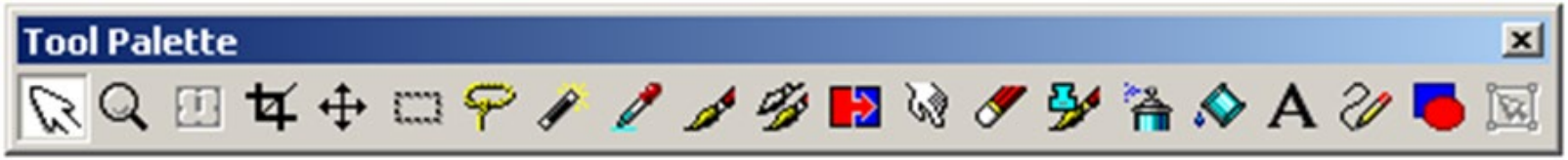
Mental Models, Metaphors

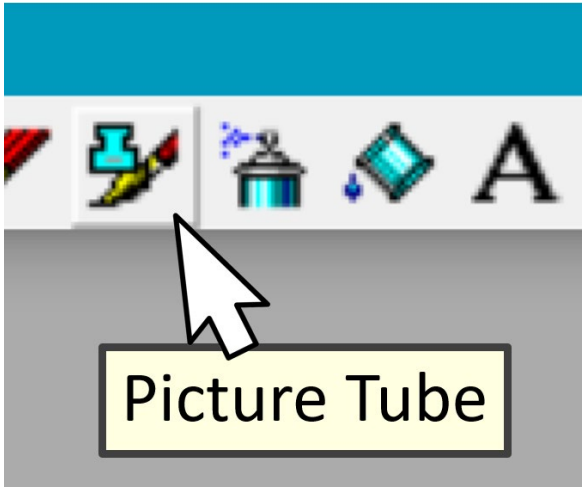
- Related terms: *physical analogy*, *metaphor*, *conceptual models*
- Definition: a physical understanding of an interface or interaction technique based on real-world experience
- Scroll pane: slider up, view up ("up-up" is a conceptual model that helps our understanding)
- *Desktop metaphor* is most 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

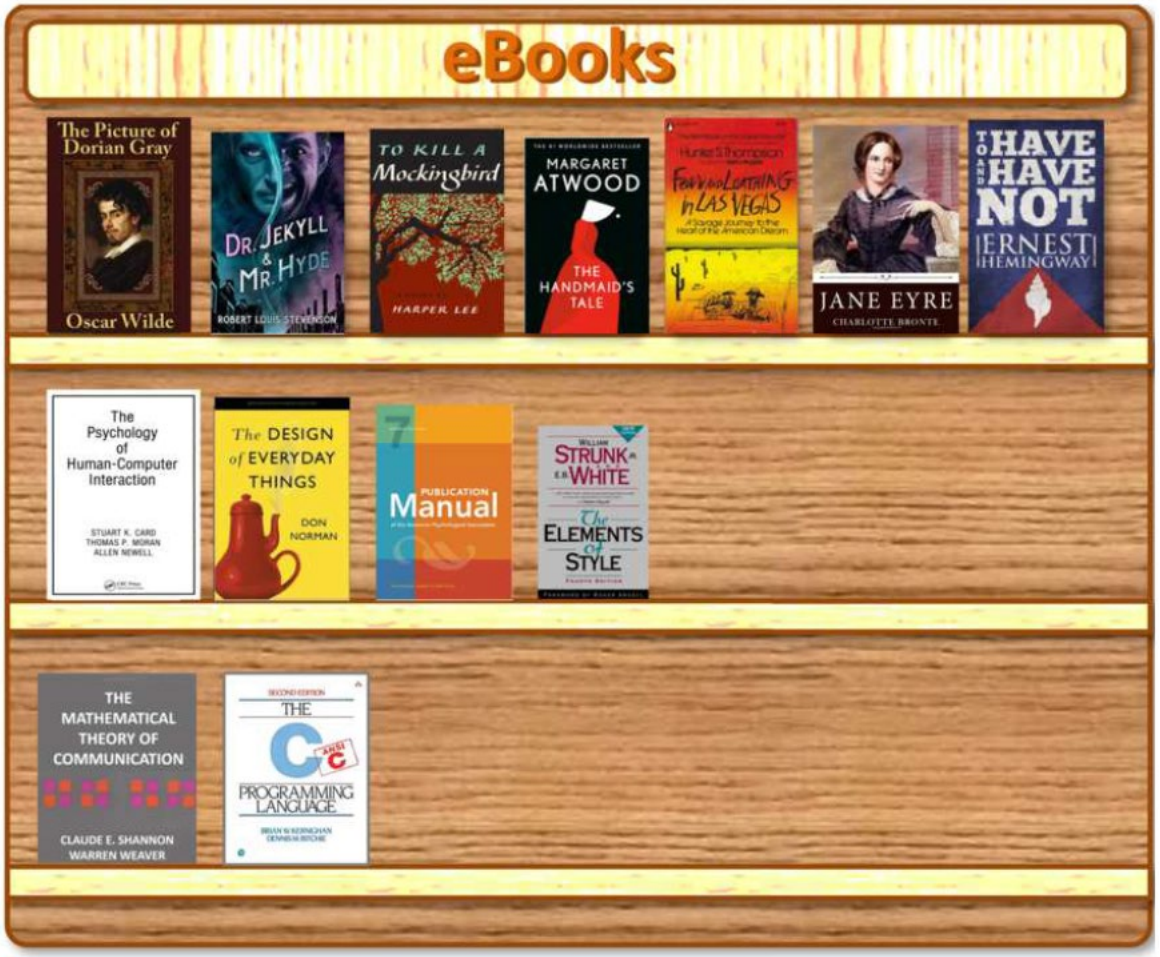
- Icons attempt to leverage real-world experiences with painting, drawing, sketching, etc.





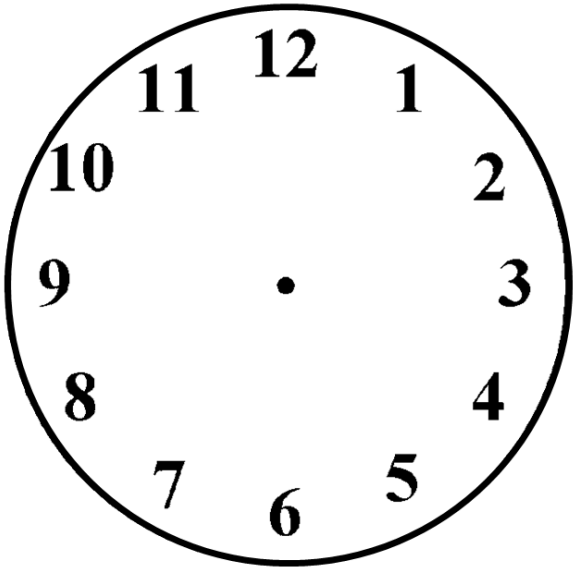
tooltips help for obscure features

Bookshelf Metaphor



Clock Metaphor

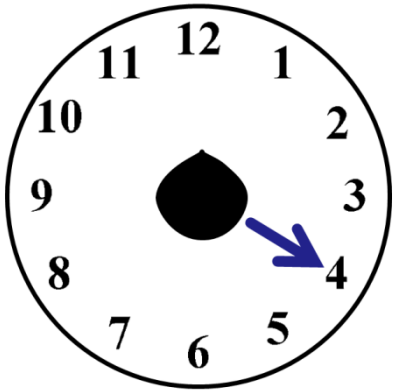
- Numeric entry on PDA[1]
- Users make straight-line strokes in direction of digit on clock face

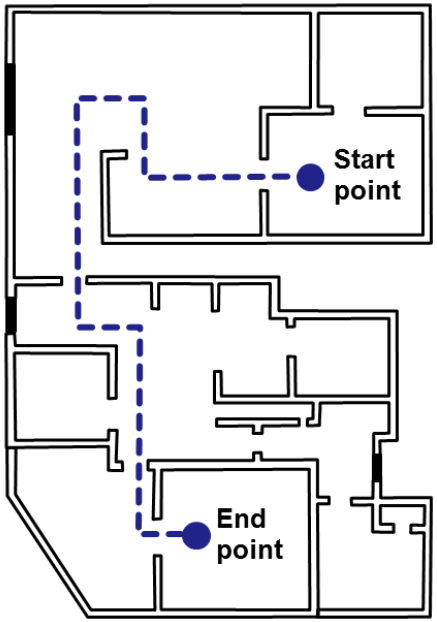


C. McQueen, I.S. MacKenzie, S.X. Zhang, An extended study of numeric entry on pen-based computers, in: Proceedings of GI ’95, Canadian Information Processing Society, Toronto, 1995, pp. 215–222.

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”)

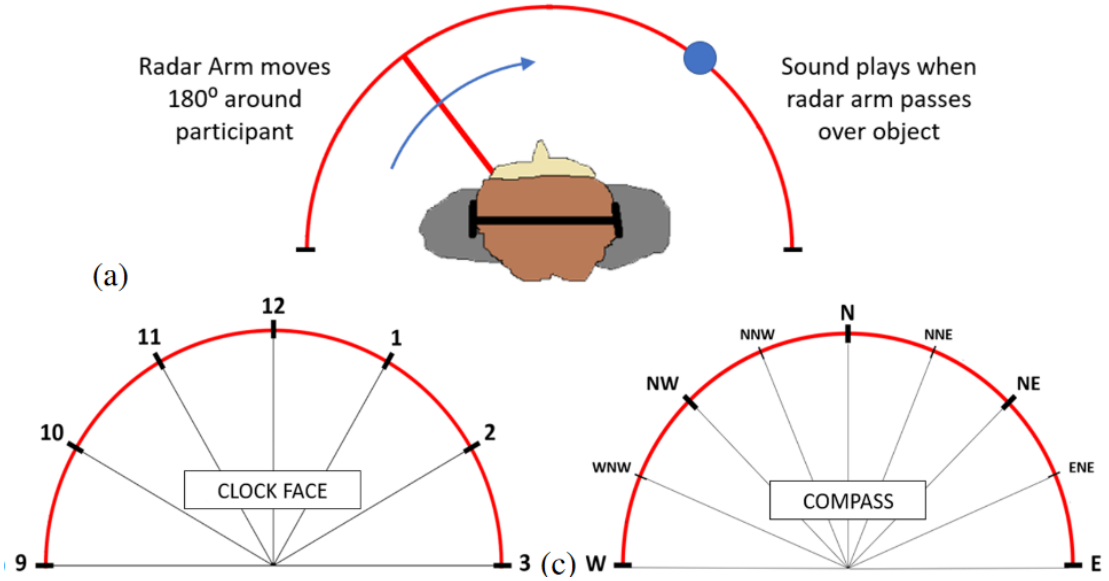




M. Sáenz, J. Sánchez, Indoor position and orientation for the blind, in: Proceedings of HCII ’07 (LNCS 5616), Springer, Berlin, 2009, pp. 236–245.

Radar Sweep Metaphor

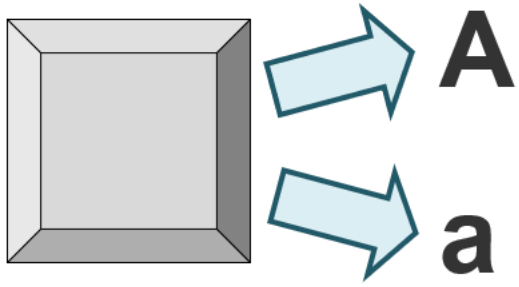
- Device presents a three-second 180° radar sweep using clock, compass, scale, or noise metaphors[1]
- A beep indicates location of object within sweep
- Users identified object location within 2° accuracy



B. Cassidy, J.C. Read, I.S. MacKenzie, An evaluation of radar metaphors for providing directional stimuli using non-verbal sound, in: Proceedings of CHI '19, ACM, New York, 2019, pp. 59:1–59:8.

Modes

- A *mode* is a functioning arrangement or condition
- Modes are everywhere (and in most cases are unavoidable)
- Office phone light: *on* = message waiting, *off* = no messages
- Computer keyboards have modes
  - ≈100 keys + SHIFT, CTRL, ALT ➔ ≈800 key variations



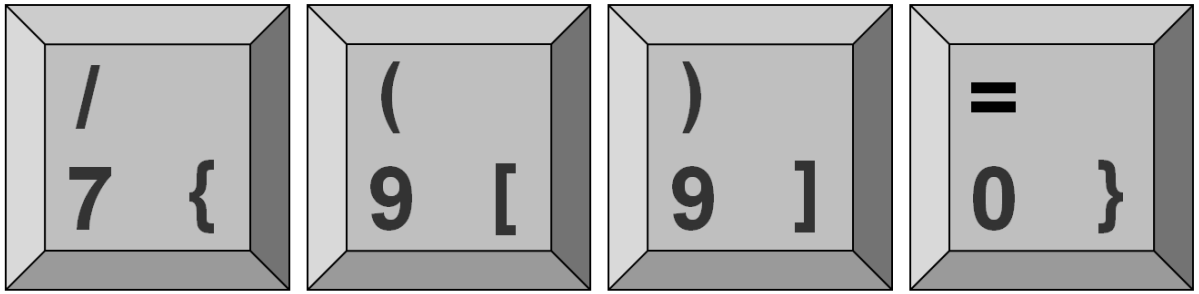
F9 – Microsoft Word (2019)

- At least six interpretations, depending on mode:

F9 →	Update selected fields
SHIFT+F9 →	Switch between a field code and its result
CTRL+F9 →	Insert an empty field
CTRL+SHIFT+F9 →	Unlink a field
ALT+F9 →	Switch between all field codes and their results
ALT+SHIFT+F9 →	Run GOTOBUTTON or MACROBUTTON from the field that displays the field results

International Keyboards

- Some keys bear three symbols
- How to access the third symbol?
- German keyboard example:



Mobile Phone Example

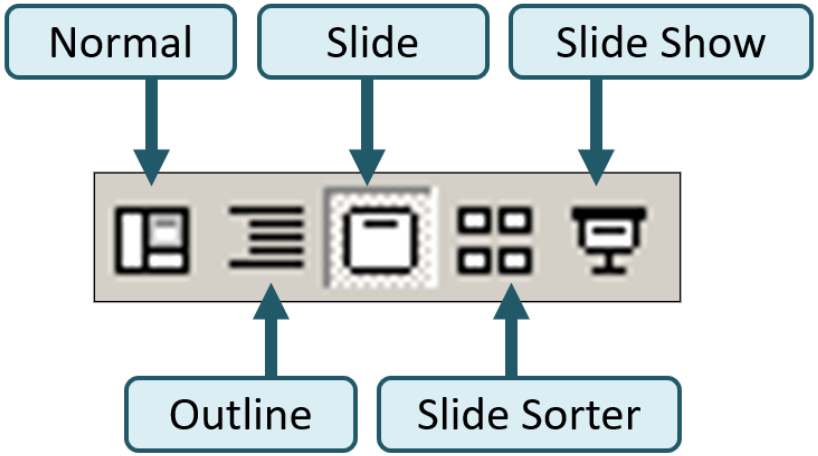
- Navi key (first introduced in 1999 on Nokia *3210*)
- Mode revealed by word above
- At least 15 interpretations: Menu, Select, Answer, Call, End, OK, Options, Assign, Send, Read, Use, View, List, Snooze, Yes

Contemporary LCD Monitor

- Similar to Navi key idea
- No labels for the four buttons above power button
- Function revealed on display when button pressed
- Possibilities explode

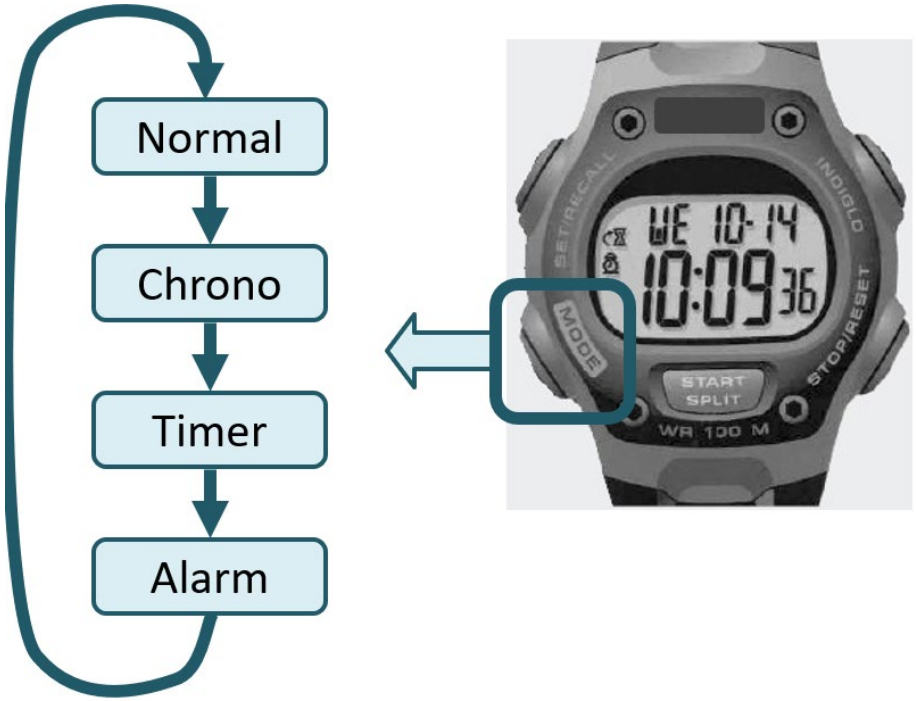
Mode Switching

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



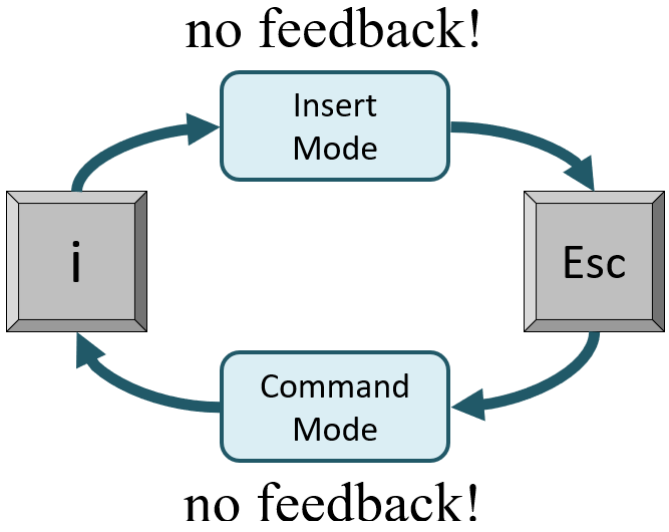
Mode Switching (2)

- Sports watch
- Single button cycles through modes



Mode Visibility

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

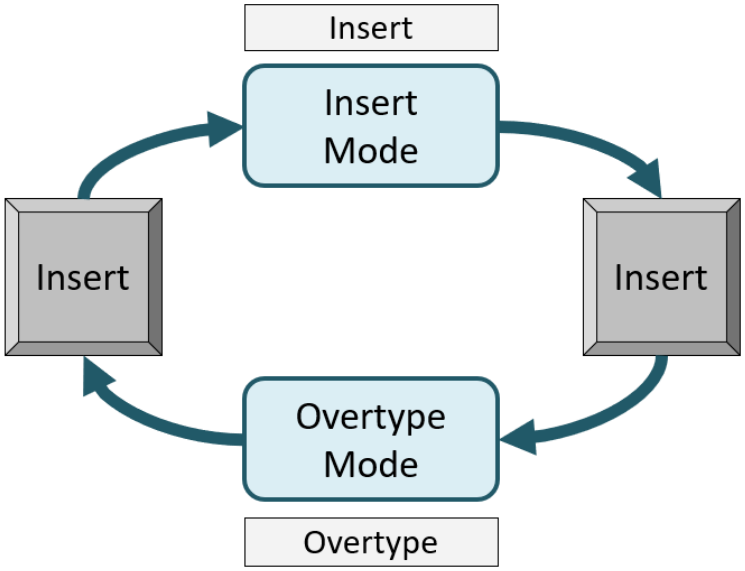


[1] B. Shneiderman, C. Plaisant, Designing the User Interface: Strategies for Effective Human-Computer Interaction, 4th ed. Edition, Pearson, New York, 2005.

[2] D.A. Norman, The Design of Everyday Things, Basic Books, New York, 1988.

Mode Visibility (2)

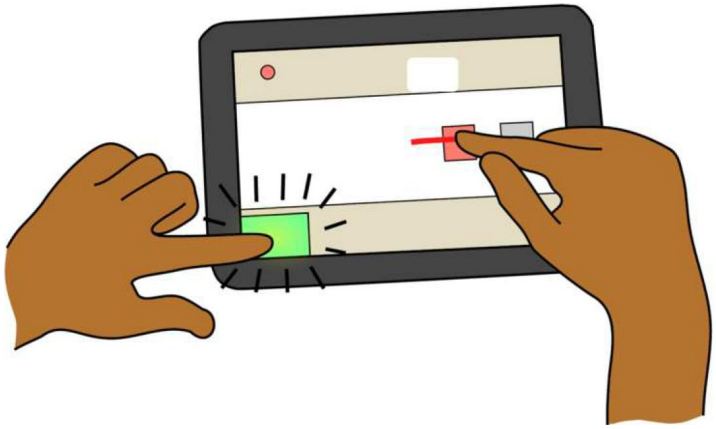
- Insert vs. Overtype mode on MS/Word
- Some variation by version, but the user is in trouble most of the time



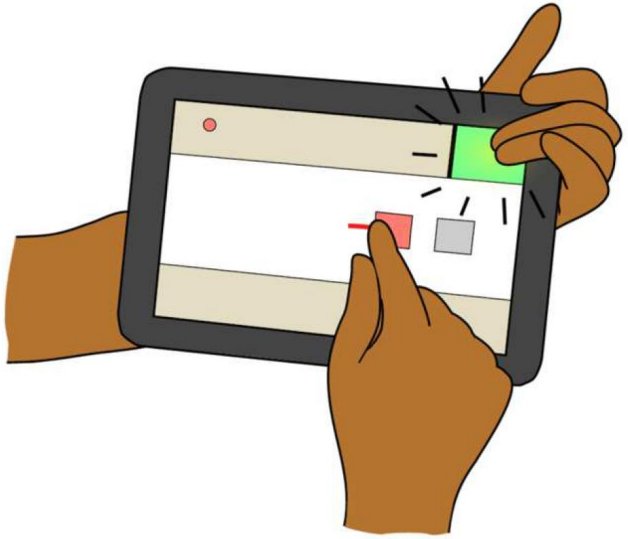
Touch-based Mode Switching

- A mode-switch region (green) is positioned for activation by the user's non-dominant hand

Location if the device is in a supported position



Location if the user is standing



H.B. Surale, F. Matulic, D. Vogel, Experimental analysis of mode switching techniques in touch-based user interfaces, in: Proceedings of CHI '17, ACM, New York, 2017, pp. 3267–3280.

Modes and Degrees of Freedom

- If control DOF < display DOF, modes are necessary to fully access the display DOF
- Consider a mouse (2 DOF) and a desktop display (3 DOF)
- *x*-*y* control (no problem):

Modes and Degrees of Freedom

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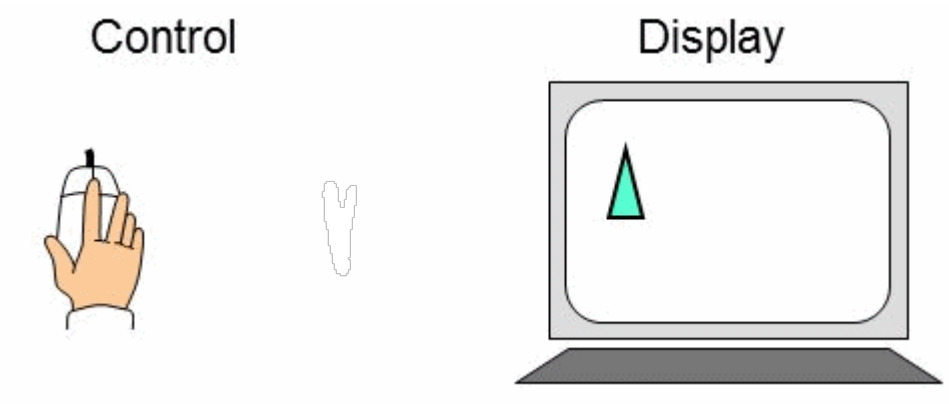
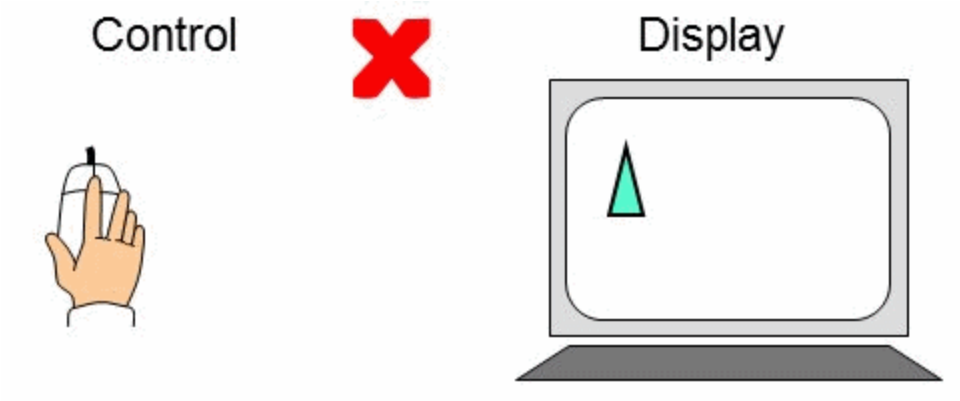


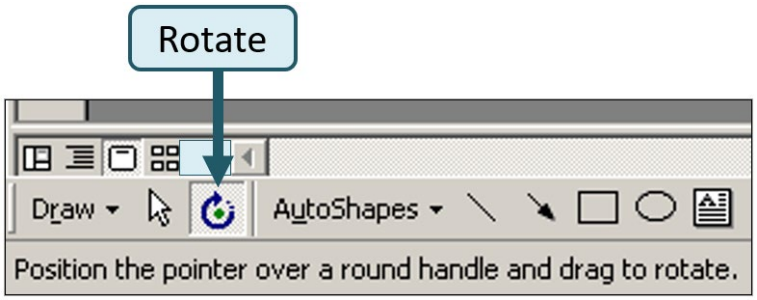
but…

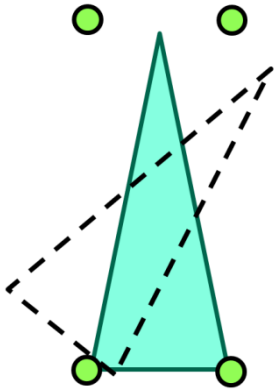
- Rotation is a problem:



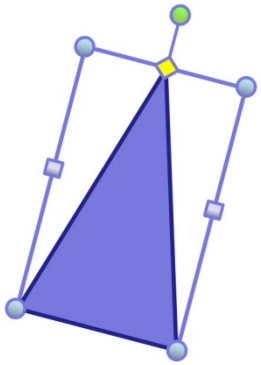
Rotate Mode

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





  - Embedded rotate mode:



Could be avoided with…

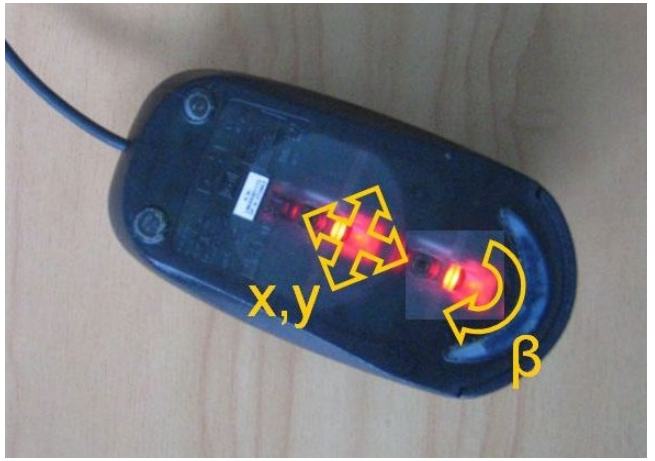
3 DOF Mouse

- Lots of research:

1

2

3



- But no commercial products (yet!)

[1] I.S. MacKenzie, R.W. Soukoreff, C. Pal, A two-ball mouse affords three degrees of freedom, in: Extended Abstracts of CHI '97, ACM, New York, 1997, pp. 303–304.
[2] R. Almeida, P. Cubaud, Supporting 3D window manipulation with a yawing mouse, in: Proceedings of NordiCHI '06, ACM, New York, 2006, pp. 477–480.
[3] J. Hannagan, TwistMouse for simultaneous translation and rotation, B. Comm. Dissertation, University of Otego, Dunedin, New Zealand, 2007.

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].

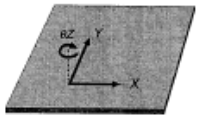


Figure 1. A mouse pad is a two-dimensional surface with three degrees of freedom: *x*, *y*, and θz.

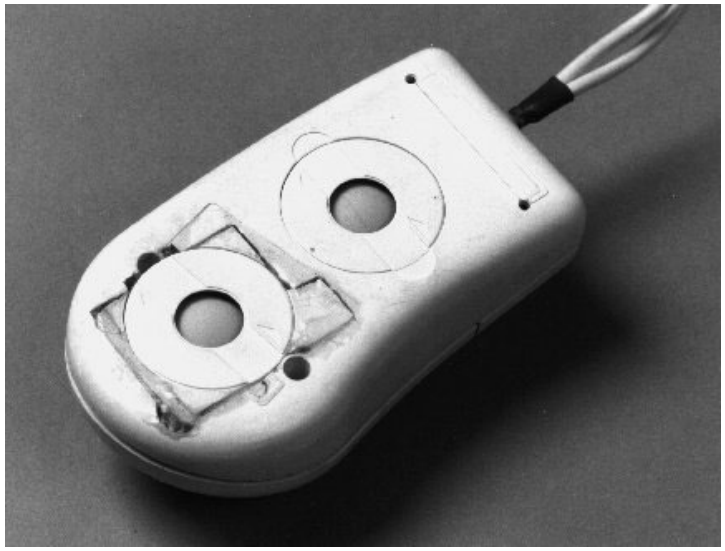
	Degree of Freedom	Mouse	2-ball Mouse	Other A	B	C	D
2D	*x*	●	●	●	●	●	●
	y	●	●	●	●	●	●
	θz	○	●	○	●	○	●
3D	*z*	○	○	●	●	○	○
	θx	○	○	○	●	●	●
	θy	○	○	○	●	●	●

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

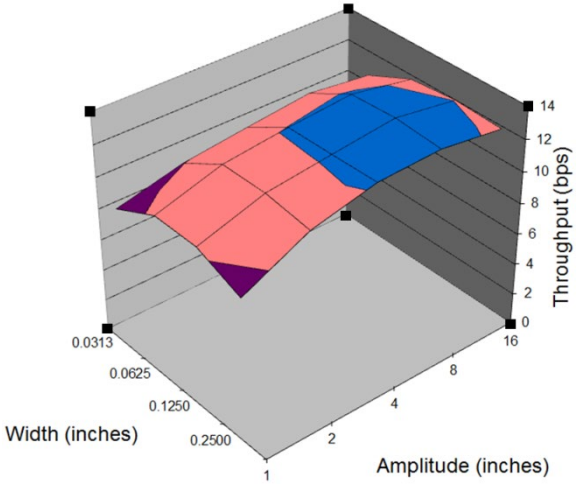


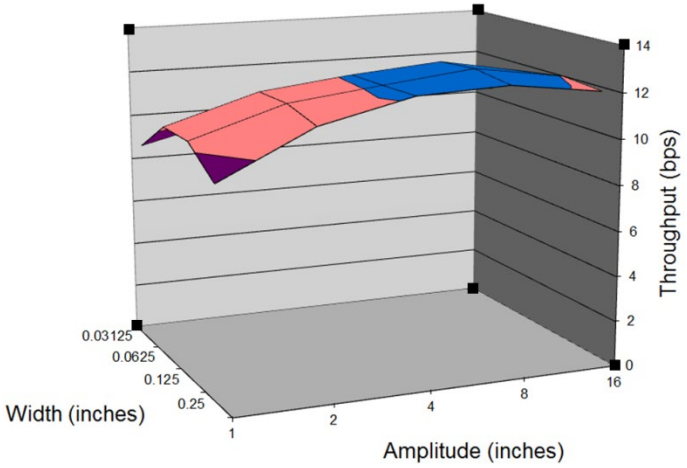
YouTube video

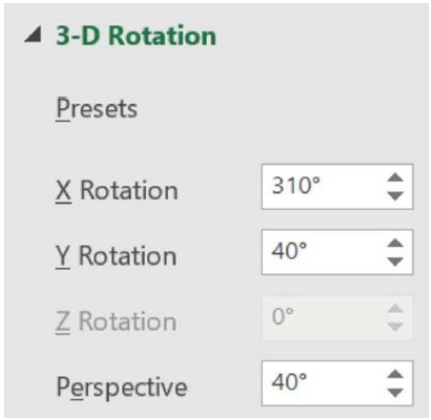
http://www.youtube.com/watch?v=nQvowU_gzpc&feature=youtu.be

3D Rotation

- Mapping controller *x*-*y* to display θ_x-θ_y-θ_z
- Very awkward (to be polite)



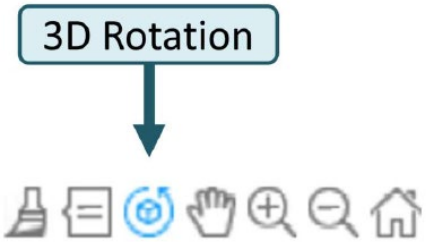


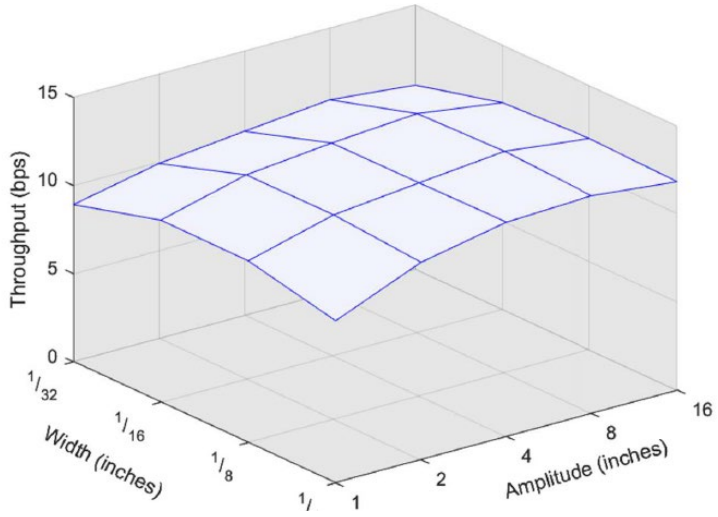


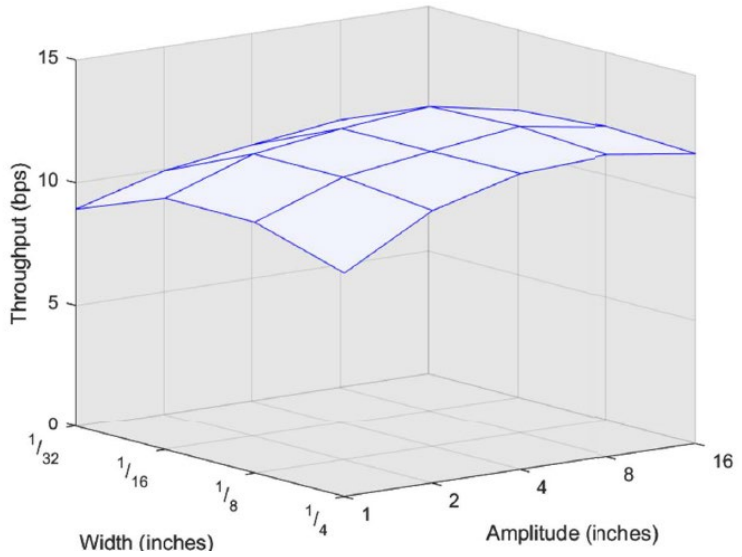
Demo using Excel spreadsheet
(available on this book's web site)

3D Rotation in MATLAB

- Slightly better, but still a challenge



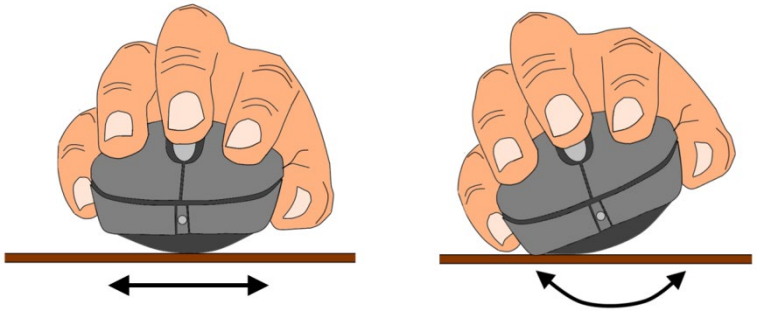




>2 Degrees of Freedom

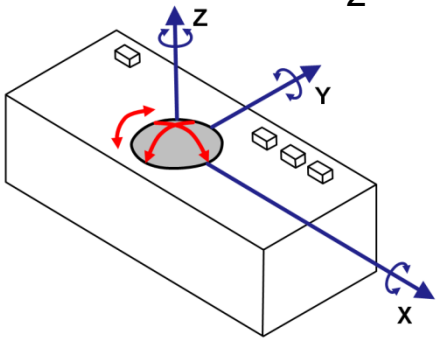
- Examples in the HCI research literature
- 4 DOF *Rockin' Mouse*

1



- Three-axis trackball

2



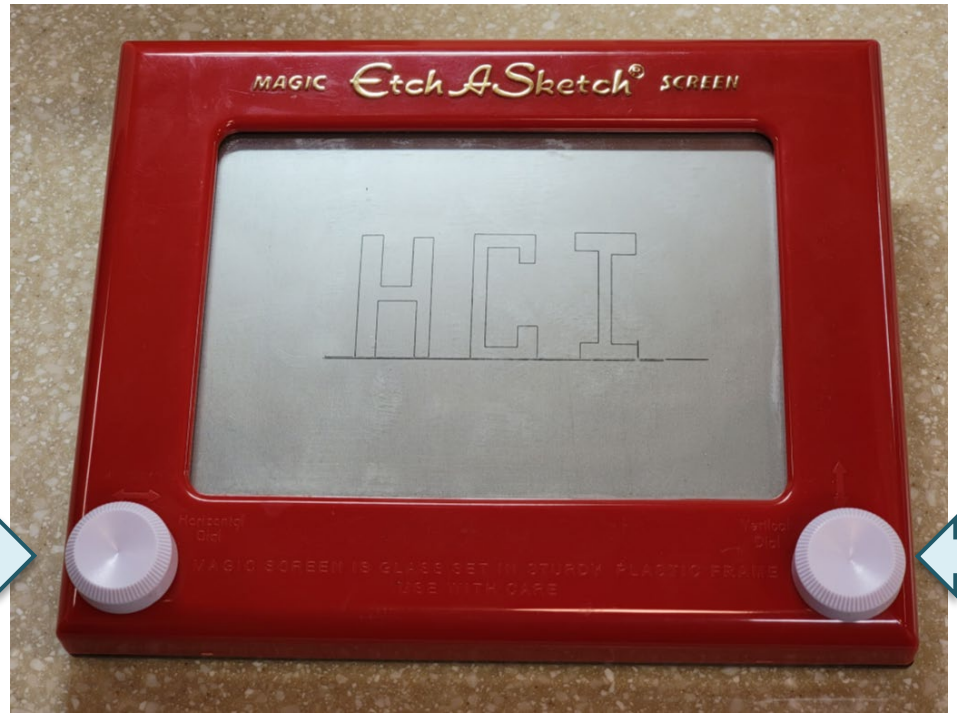
3

Kensington SlimBlade

[1] R. Balakrishnan, T. Baudel, G. Kurtenbach, G. Fitzmaurice, The Rockin'Mouse: integral 3D manipulation on a plane, in: Proceedings of CHI '97, ACM, New York, 1997, pp. 311–318.
[2] K.B. Evans, P.P. Tanner, M.Wein, Tablet-based valuators that provide one, two, or three degrees of freedom, Computer Graphics 15 (3) (1981) 91–97.
[3] T. Canham, I.S. MacKenzie, R.F. Murray, M.S. Brown, The effect of perceptual optimization on color space navigability, in: Proc GI '23, Canadian Information Processing Society, Toronto, 2023, pp. 14.1–14.10.

Separating the Degrees of Freedom

- More DOF is not necessarily better
- Must consider the context of use
- Etch-A-Sketch: separate 1 DOF *x* and *y* controllers:



1 DOF *x*-axis motion

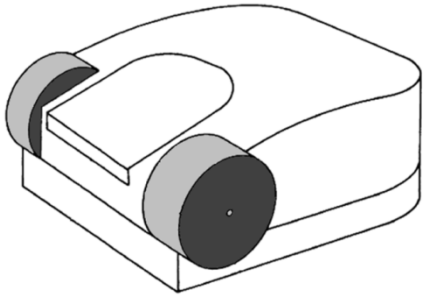
1 DOF *y*-axis motion

Wheel Mouse

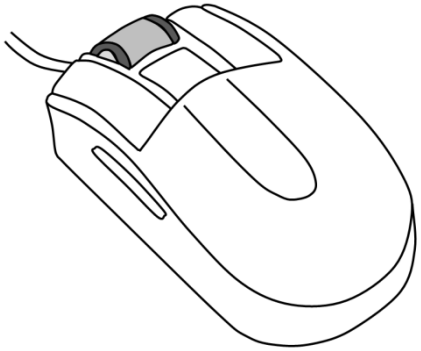
- Separate DOF via a wheel
- Successful introduction by Microsoft in 1996 with the *IntelliMouse* →

- Preceded by…

RollerMouse[1]



ProAgio[2]



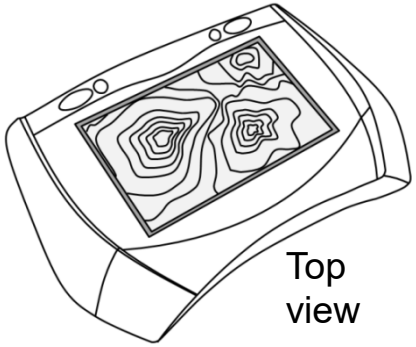
[1] D. Venolia, Facile 3D manipulation, in: Proc INTERCHI '93, ACM, New York, 1993, pp. 31–36.

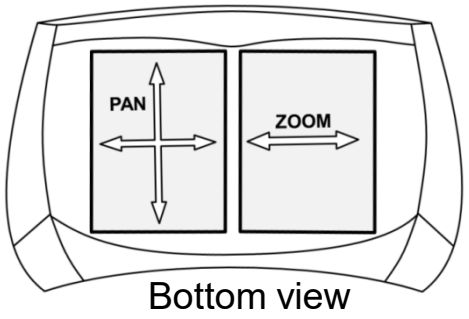
[2] W.G. Gillick, C.C. Lam, Roller mouse for implementing scrolling in windows applications (U. S. Patent 5,530,455), 1994.

Adding a Touch Sensor

PadMouse[1]

Panning and Zooming Display[2]





Multitouch+Mouse[3]

[1] R. Balakrishnan, P. Patel, The PadMouse: facilitating selection and spatial positioning for the non-dominant hand, in: Proc CHI '98, ACM, New York, 1998, pp. 9–16.

[2] M. Silfverberg, P. Korhonen, I.S. MacKenzie, Zooming and panning content on a display screen (International Patent WO 03021568 (A1)), 2003.

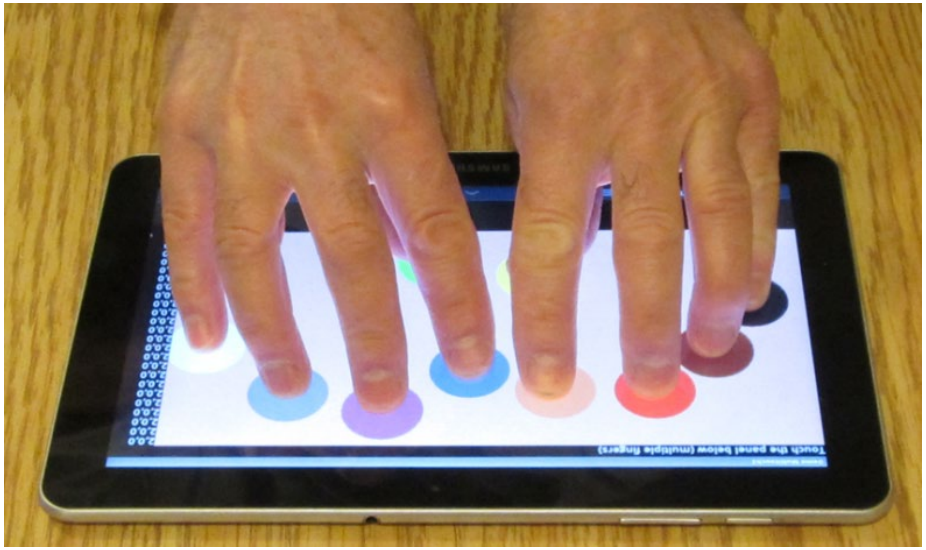
[3] N. Villar, S. Izadi, D. Rosenfeld, H. Benko, J. Helmes, J.Westhues, S. Hodges, E. Ofek, A. Butler, X. Cao, B. Chen, Mouse 2.0: multi-touch meets the mouse, in: Proc UIST '09, ACM, New York, 2009, pp. 33–42..

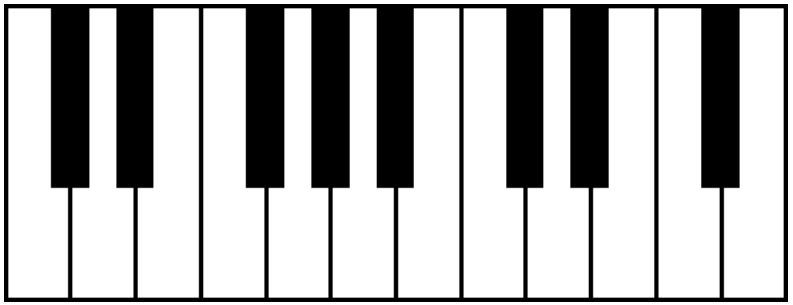
Mobile Context

- Touchscreens are the full embodiment of direct manipulation
- No need for a cursor (cf. indirect input)

Multitouch

Multitouch (>2)





Accelerometers

- Accelerometers enable tilt or motion as an input primitive
- Technology has matured; now common in mobile devices
- Many applications; e.g., spatially aware displays:

Interaction Errors

- Discussions above focused on physical properties of controllers and the interactions they enable
- Interaction involves the human (sensors, brain, responders) and the machine
- Interaction errors are unavoidable (and, hence, are akin to an "interaction element")
- We conclude with a look at interaction errors and their consequences
- Themes: (see **HCI:ERP2e** for discussion)
  - Big, bad errors are high in consequences and therefore get a lot of attention
  - Little errors are low in consequences and therefore tend to linger
  - There is a continuum

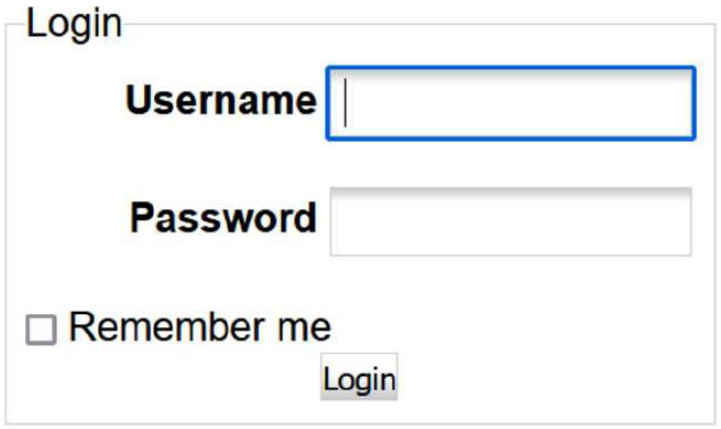
Discard Changes

- Default dialogs to quit an application:

CAPS_LOCK

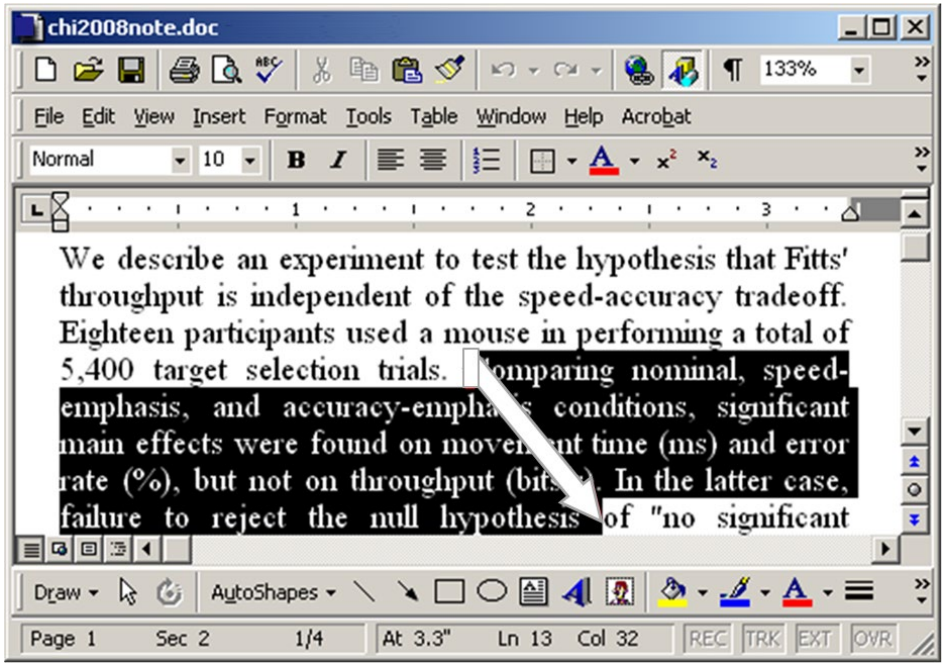
- Some log-in dialogs alert the user if CAPS_LOCK is on…

- while others do not…



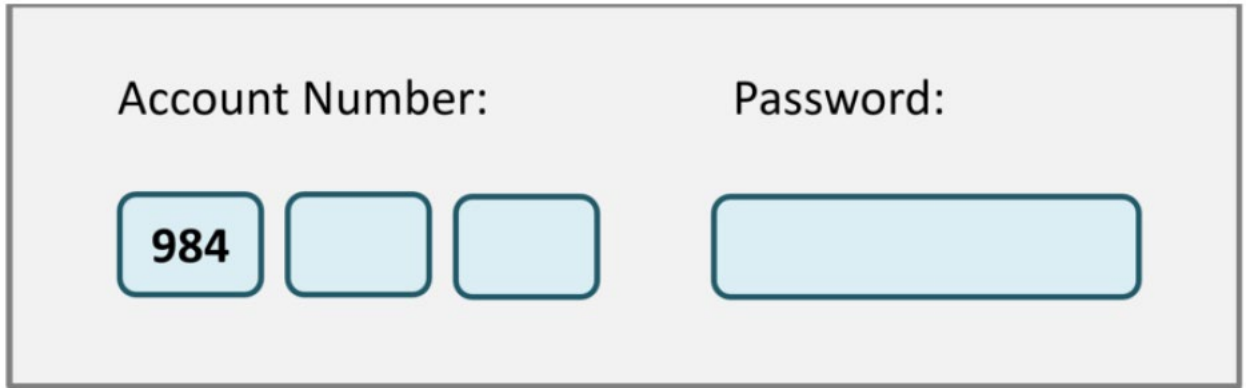
Scrolling Frenzy

- Drag to select a range of text
- As the dragging extent approaches the edge of the scroll pane, the user is venturing into a difficult situation



Focus Uncertainty

- After entering fixed-length data, some interfaces automatically advance focus to the next field…



- while others do not…

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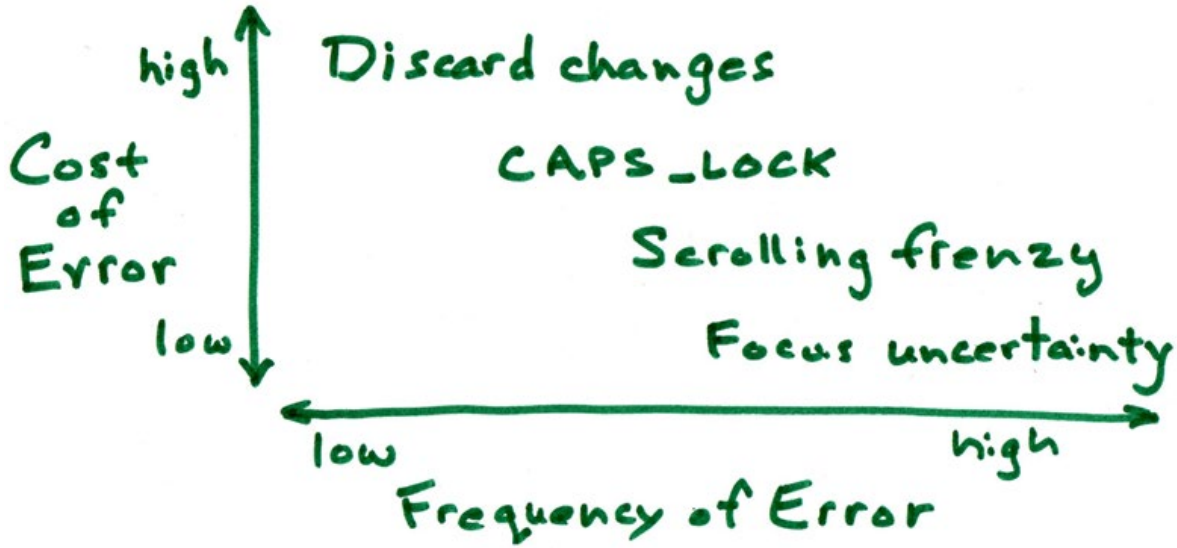
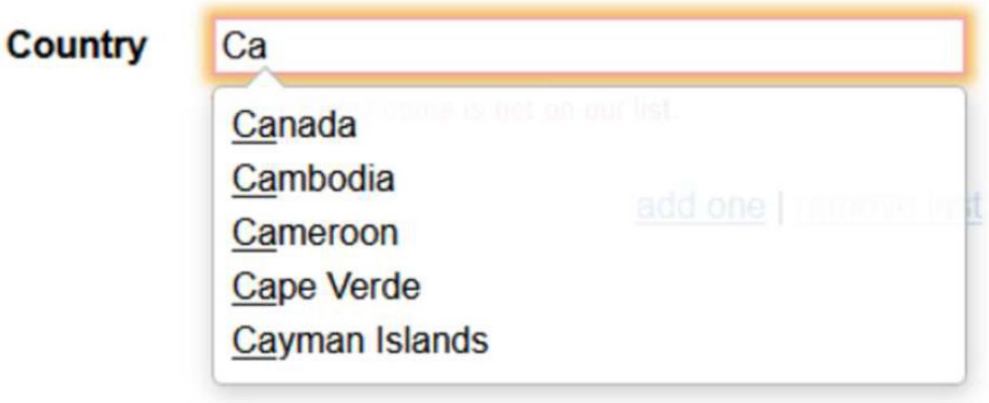
Cost vs. Frequency of Errors

- Message: High frequency / low cost errors are the most interesting
- They…
  - Have evaded the scrutiny of designers
  - Keep users on guard



One Final Example

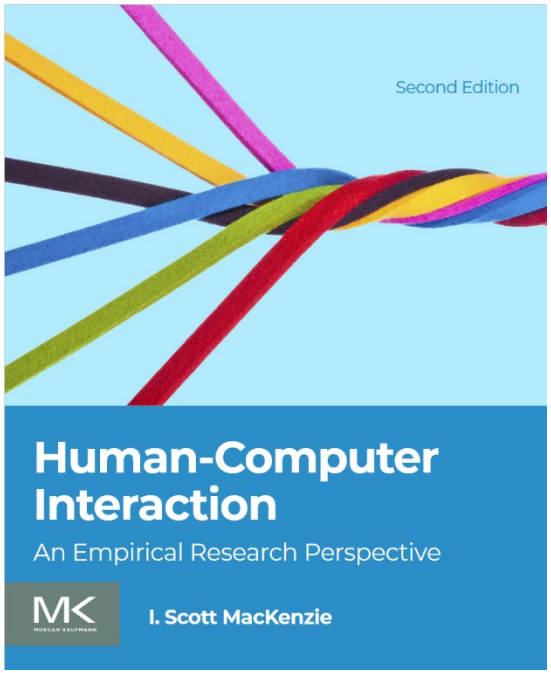
- Auto complete:



- What to do next?
  - TAB?
  - ENTER?
  - Arrow key?

The goal here is not to answer the questions, but simply to challenge that the questions exist.

Thank You



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