Lecture 8-1: Input Devices

- Taxonomy (“Design Space”)
- Keyboards
- Pointing Devices
- Matching Devices to Work

Taxonomy of Input Devices

- Keyboards
  - QWERTY and Dvorak keyboards
  - Chorded keyboards
- Pointing Devices
  - Mice, trackballs, and touchpads
  - Joysticks
- Tablets and Pen Devices
  - Graphics tablets
  - Pen input devices
  - Handwriting recognition
- Voice recognition
- Assistive Technologies

Discrete Entry Devices (Keyboards)

Continuous Entry Devices (Pointing Devices; Tablets and Pen Devices)

		Number of Dimensions							
		1		2				3	
Property Sensed	Position	Rotary Pot	Sliding Pot	Tablet & Puck	Tablet & Stylus	Light Pen	Floating Joystick	3D Joystick	M
				Touch Tablet		Touch Screen			T
	Motion	Continuous Rotary Pot	Treadmill	Mouse			Trackball	3D Trackball	M
			Ferinstat				X/Y Pad		T
	Pressure	Torque Sensor					Isometric Joystick		T

Figure 12: Taxonomy of Input Devices.
Continuous manual input devices are categorized. The first order characterization is property sensed (rows) and number of dimensions (columns) Sub-rows distinguish between devices that have a mechanical intermediary (such as a stylus) between the hand and the sensing mechanism, and those which are touch-sensitive. Sub-columns distinguish among devices that use comparable motor control for their operation (From Buxton, 1983).

Figure from http://www.billbuxton.com/input04.Taxonomies.pdf

Keyboard Design Considerations

- Physical Design
  - Size of keys
  - Spacing of keys
  - Size and contrast of symbols
  - Key / switch mechanism
    - Electromechanical switches
      - Rubber dome technology
    - Membrane keyboards
      - Useful in dirty environments
      - Feedback is extremely important to usability
- Keyboard Layout
  - Arrangement of keys

Keyboard Layouts

- QWERTY Keyboard
- Dvorak Keyboard
- Alphabetic Keyboards

Dvorak Keyboard Layout

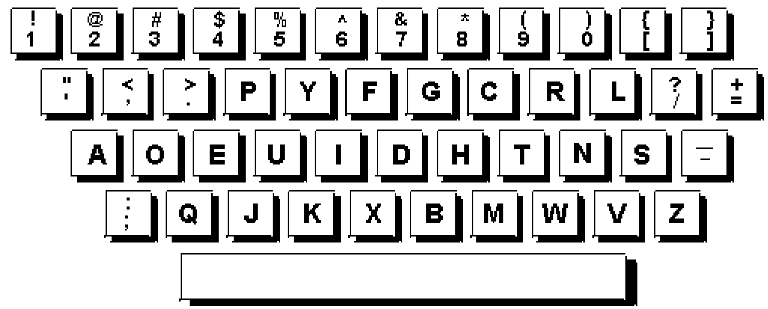
QWERTY Keyboards

- QWERTY name for top left key row sequence
  - Sholes = inventor (sometimes called the Sholes keyboard)
- Became popular in 1874 after several prototypes
- Arrangement reduced jamming of keys in manual typewriters
  - S, T, and H are far apart even though they occur together frequently
  - Difficult to track down documentation of this story
  - Levered hammers have disappeared: jamming does not occur in electric and electronic keyboard devices
- ANSI standard
- Universal in typewriter and computer keyboards
  - Not so for specialty devices, handheld devices, technical instruments, plane cockpit controls and devices
  - Alphabetic layouts compete for QWERTY in these devices
  - Implicit theory = nonprofessional typists can use alphabetic order to more quickly find letters, thus typing is easier

QWERTY versus Alphabetic

- Michaels (1971) Bell Labs study -- Human Factors vol. 12, p. 419
- Compared
  - QWERTY
  - 3-Row Alphabetic arrangement
- Novice and Expert users:
  - 10 half hour sessions
  - Half started with QWERTY first, half alphabetic first
  - Entered names and addresses from telephone directory
- Results
  - Measured work output, keying speed, error rate
  - QWERTY better for skilled and semi-skilled typists
    - Slow-down for skilled typists on alphabetic keyboard is “drastic”
  - No difference for novice typists (the very lowest skilled)

Dvorak Simplified Keyboard



- August Dvorak, 1932 patent
- Applied human factors to keyboard layout
  - Arranged on basis of frequency of letter use and patterns in English
- Vowels and frequent consonants on home row
  - 70% of words can be typed only on home row
  - Alternating hands is faster, so vowels and consonants on opposite sides of the row
- Claims have been made to be as much as 60% faster (not substantiated)

QWERTY vs. Dvorak

- Norman & Fisher (1982) “Why alphabetic keyboards are not easy to use: Keyboard layout doesn’t much matter.”
- Compared keyboards
  - QWERTY
  - Dvorak
  - Alphabetic (5 versions)
  - Random
- Novice users
  - Alphabetic keyboard only slightly better than random
  - QWERTY better than alphabetic even with just slight knowledge of it
- Expert typists (computer simulation)
  - Dvorak only 5% improvement over QWERTY
- Conclusions
  - Novice typists resort to visual search -- not to knowledge of the alphabet
  - Recommend against changing layout
  - Keyboards can be improved primarily by attention to physical design

Keyboard Conclusions

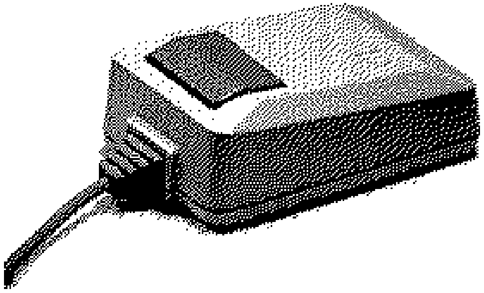
- Norman (1983) “The DVORAK revival: is it really worth the cost?”
  - Skeptical of claims of 60% improvement, finds 5-10% in his research
  - Even a 10-20% improvement does not matter, typists varying ifrom 60-70 wpm (17% different) are not considered different in offices
  - Costs of changing QWERTY are enormous and impractical
  - Unlikely to be ease of learning differences
- Alphabetic keyboards
  - Norman and Michaels studies suggest that novice users gain nothing by having alphabetic layout (other studies as well)
  - Skilled typists are several penalized by alphabetic layouts
    - However, this assumes a keyboard which you can touch-type
  - Is there any reason to ever use and alphabetic keyboard?

Chorded Keyboards

- Chorded Keyboard
  - Like playing chord on piano
  - Several keys must be presented at once to enter a single character
- Advantages and Disadvantages
  - Many fewer keys, keyboard fits into smaller space
  - One-handed operation
  - Requires often steep training curve
  - Some claims that highly trained chord keyboarders can enter data faster than skilled typists on standard keyboard
- Gopher (1980s)
  - Make chord sequences resemble letter shapes in their positional locations (Hebrew letters)

Pointing Devices

- Mouse
  - First mice (Xerox, Bell Labs) were large, round, and had 3 buttons
  - Apple mouse: one button
  - Two button mouse (Windows)
  - Three button mouse (Unix workstations)



Mice and Trackballs (1)

- "Augmented" Mice
  - Buttons, scroll wheels
- Mouse Operation
  - Ball
  - Optical
  - Cordless

CAD cursor: 4 programmable buttons

Wheel scrolls text in windows

Optical - no ball

Cordless

Mouse Simplicity

- Alan Kay (~1988)
  - Speculates mouse is easy to use because it uses a more primary mode of thinking than logical, symbol manipulation
  - Piaget’s sensorimotor thinking
  - Children pick up use of mouse very early, prior to literacy
- Apple one-button mouse
  - Best design (improvement on original Doug Englebart mouse) simple point and click -- no ambiguity as to which button to press (Norman)
- Apple Pro Mouse (2001) has no buttons
  - Body pivots up and down
  - Entire upper enclosure is button
  - Clicking performed with any number of fingers or palm
  - Accommodates different hand shapes and sizes
  - Question: is “no button” an affordance problem?

Mouse Madness

- Multiple buttons reveal extended menus in windowing systems
  - Not optional in Unix system, multiple button menus are required
  - Second and third buttons reveal menus necessary for normal use
- Programmable buttons -- where does it all end?
  - PowerMouse (~1989) touts "38 small programmable buttons"
- Late 90s - Early 00's adds the scroll wheel
  - Scroll wheel doubles as a 3rd button
  - Logitech adds side buttons and trackballs to top and sides in some models

Mice and Trackballs (2)

- Trackballs
  - Often described as "reverse mouse"
  - Pointing experience is different from mouse
  - User moves ball with fingers or palm instead of sliding across surface
  - Preferred by some
  - Data is scant, but supports mouse as most accurate device
- Combined Devices

Trackballs

Combination Trackball / Mouse

Top

Side

Mouse Shapes (1)

- Little attention paid at first to ergonomic shape
  - First mice were large and uncomfortable
  - First apple mice box-shaped, early windows mice rounded rectangle
- Followed by wide experimentation in “ergonomic” designs
  - Differentiation in market driving variations
  - Actual ergonomic nature is questionable, more a matter of industrial design
- Empirical research indicates “bar of soap” shape is preferable

One so-called “ergo-mouse”

Mouse Shapes (2)

- Customised left and right handed mice
- Customized for hand size
  - Mice sized for children
  - Microsoft “home” mouse fit “in between” size for adults and children

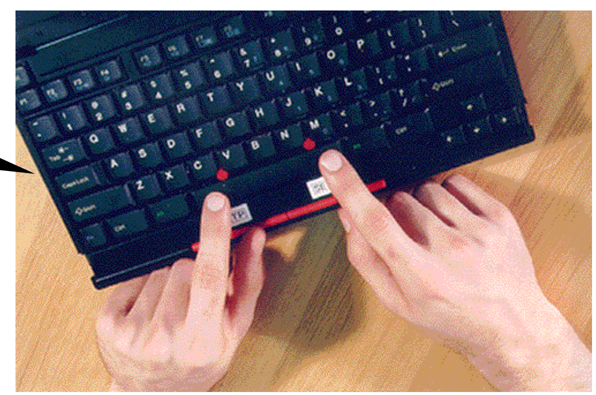
Touchpads

- Laptop device
  - Started on keyboards
  - Replaced trackballs and IBM's track point mouse as favorite laptop alternative
- Movement of finger across surface moves cursor
  - Relative movement like trackball

IBM Track Point Mouse

- Track Point Mouse
  - A.K.A. “Eraser-head mouse”
  - Developed at Watson Research Center
  - Standard on IBM Laptops and a few other brands
- “Nudging” movement of eraser-like ball moves cursor

Experimental two-handed track point developed at IBM Almaden Research Center



Joysticks

- Now primarily a game device
- Predates mouse and other pointing devices

Combined Devices

Track point mouse (IBM)

Scroll point mouse (IBM)
Joystick / Mouse combination

Touchpad / Mouse
(Not to mention buttons
and cursor keys)

Tactile Feedback Pointing Devices

- Tactile feedback device exerts varying pressure back to user
- Used as game feedback device -- “virtual reality” function
- Or, tactile feedback represents windowing system elements (“bump” over window edge, etc.)

Wingman force feedback mouse

Tactile feedback track point (IBM, experimental)

Graphics Tablets

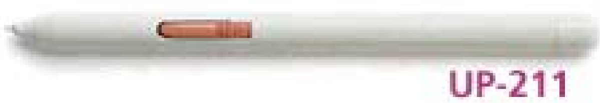
- Pen and paper like surface
  - Pen movements echoed on monitor
  - Can also do mouse-like cursor and selection movements
  - Primary application as artist tool
  - Some models combine mouse with tablet doubling as mouse pad

LCD Pen Tablet (Wacom) combines pen surface with LCD monitor

Pen Input

- Handwriting Recognition
  - Newton, EO: Recognition technology not accurate enough for usability
  - Palm, Visor, Windows CE handhelds: Graffitti alphabet
  - User conforms to machine limitations by using rigidly defined order of strokes resembling, but not matching, normal letter formation
  - Nevertheless, accuracy makes this class of device usable

Pen input has a long history: "Light pens" considerably predate mice



Other Input Devices (1)

- Touchscreens
  - Used for public displays, open public kiosks
  - Libraries, malls, museums, Internet kiosks
  - Solves problem of theft or ware on attached device such as mouse
  - More “intuitive” than use of mouse, self-explanatory (“touch here”)
  - Special considerations in user interface design
    - sufficient size for finger movements and accuracy
    - timings for finger “bounces”
    - spacing
    - feedback

Other Input Devices (2)

- Virtual Reality Devices
  - Data Glove
  - “Flying Mouse”
    - 3D sensor like that in data glove embedded in mouse
    - Mouse can move up in space as well as on flat tabletop space

- Voice Recognition (ASR = Automatic Speech Recognition
  - Spoken commands control menus, launch applications, enter text
  - Covered in more detail later in course
- Eye tracking and head tracking
  - Finds most common application in accessibility device
  - Attempts to make more common -- IBM video
- Mole (foot controlled mouse)

Assistive Devices

- Allow users with movement or visual disabilities to use or more effectively use computers
- Voice recognition
- Eye and head movement input
  - Eye "typer"
    - eye movement monitored with camera device
    - keyboard displayed on screen, user looks at desired letter
- Mouth-held sticks to press keys
- Head-mounted pointer replaces mouse
- Adaptation of existing input devices
  - Keyboard equivalents to mouse movements
  - Alter sensitivity of keys, mouse, for limited mobility, tremors, etc.
    - BounceKeys -- set keystroke delay
    - StickyKeys -- Chorded key movements (e.g. Ctrl-Alt-Del) accomplished by sequential keying

Fitts' Law

- Paul Fitts (1954)
  - In ergonomics, a predictive model of motor movements to visual targets of different sizes and distances
  - Fitts' Law applies to pointing devices and touch screens
- Predict time to move distance D to target of width W
- Pointing time is a function of distance and width
  - Targets that are farther away take longer to point to
  - Smaller targets take longer to point to
- Speed-Accuracy Trade-off
- Original Task: Repetitive tapping task
  - Note: No cognitive planning load → focus on pure motor action (Buxton, 2003)

Fitts' Tapping Task

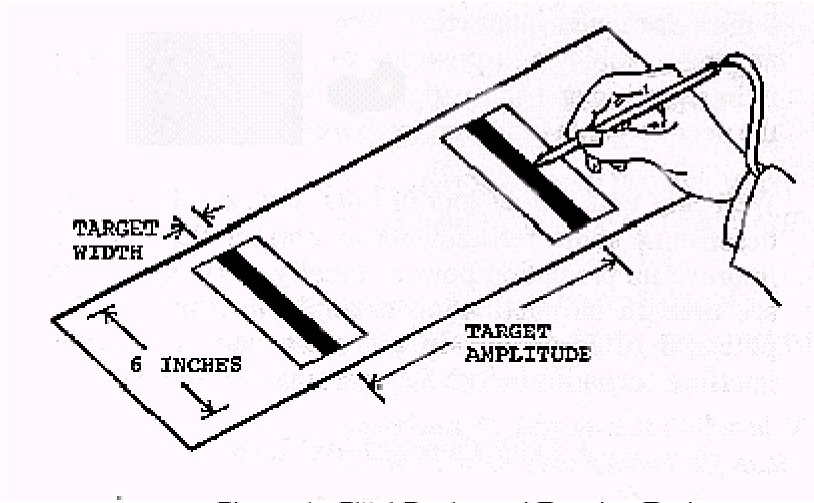


Figure 1: Fitts' Reciprocal Tapping Task
Subjects tapped between the two bars as quickly as possible. The width of the bars and the distance between them were experimental variables. (From MacKenzie, 1991).

Fig. From W. Buxton: http://www.billbuxton.com

Fitts' Law

- Index of difficulty = $\log_2$ (2D / W)
- Time to perform pointing action = $C_1 + C_2$ (Index of difficulty)
  - C_1 and C_2 are device-dependent constants
- Buxton (2003):
  - Fitts' Law applied to 'target acquisition tasks'
  - Recent research shows it can be applied to dragging
    - Gillian et al. (1990), MacKenzie et al. (1991)

Fitts' Law Applied to Mouse Movements

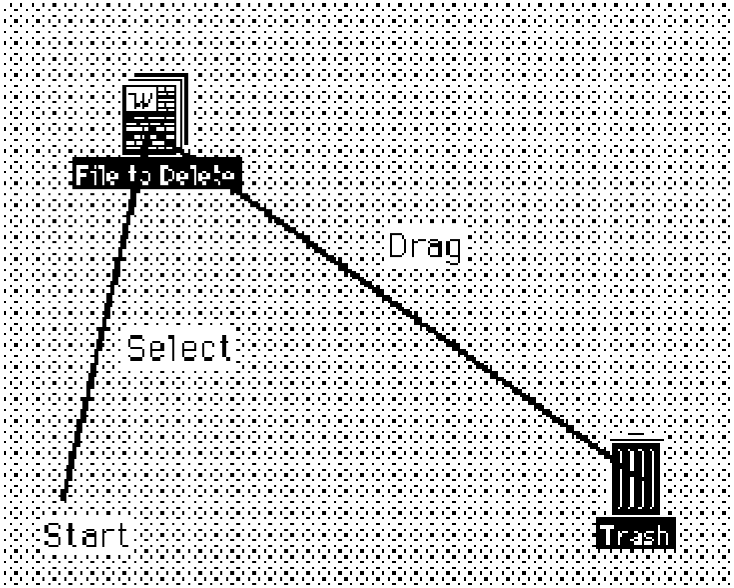


Figure 5: Deletion as Compound Fitts Task

Deleting an icon on the Macintosh computer can be considered two Fitts' Law tasks. The first is a standard target acquisition task. As illustrated, this is composed of moving from the start position and acquiring the icon of the file. The second is the acquisition of the trash icon, starting from the position of the icon to be deleted. The main difference between the two tasks is whether the mouse button is up or down during the task performance.

Fig. From W. Buxton: http://www.billbuxton.com

The Steering Law

- Accot & Zhai (1997) → Linked to Fitts' Law
- Moving along trajectories
  - Nested menus
  - Drawing curves

Fig. From W. Buxton: http://www.billbuxton.com

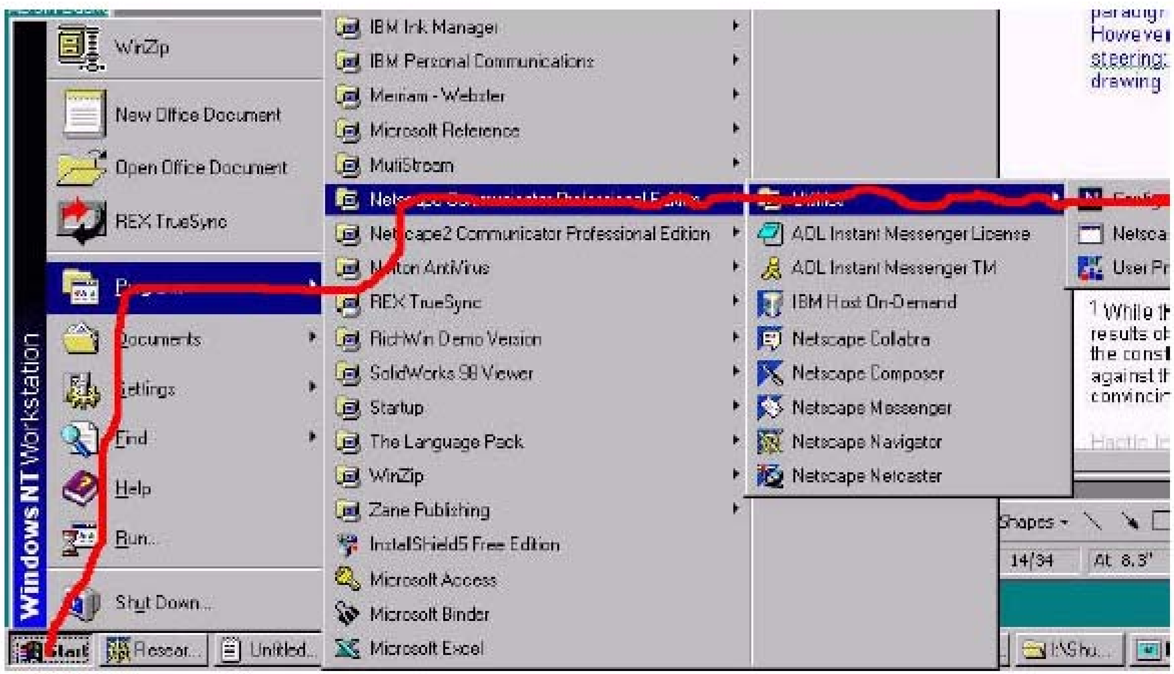


Figure ST1: Traversing nested menus involves multiple segments of steering tasks

Matching Devices to Work (1)

- Input devices differ in advantages and disadvantages depending upon the task
- Buxton (1986) scenarios (See Preece et al. Ch. 11, pg. 221 ff.)
- Scenario 1: Pan over large graphical surface (VLSI array)
  - Trackball pans by rolling hand over ball

    motion → motion
  - Joystick, pans by moving stick off center in desired direction
    - Speed of pan corresponds to distance off center

    position → motion
  - Buxton says trackball is more natural
    - Motion of ball mapped directly to motion over surface
    - With joystick, position is mapped to motion, association must be learned
- Scenario 2: Add simultaneous zooming and panning
  - With joystick, can displace stick than twist to zoom
  - Simultaneous rolling and twisting cannot be done with trackball

Matching Devices to Work (2)

- Scenario 3: Oil refinery GUI – valves need to be adjusted
  - Direct manipulation → adjust valve on screen
    - Trackball vs. joystick with pot mounted on stick
  - Pan then operate on object by twisting without changing x-y position
    - Trackball: move ball, rest finger on bezel, then twist up/down
- Conclusions
  - Must take into accounts movements that may be difficult or impossible with a device
  - Set up natural mappings of device motion to task

Matching Devices to Environment

- Kiosks
  - Attached device such as mouse can be stolen or broken
  - Devices such as mouse or trackball requires some prior skill, or user must begin to learn as they use kiosk
- Laptops
  - Mouse is large, inconvenient, can be lost
  - Devices which can be attached to laptop: touchpad, trackball, eraser point mouse
- Handheld
  - Small device: tiny keyboards are difficult to use, mice are impossible
  - Pen is natural input device, recalls notpad with pen/pencil
- "In the field" -- UPS delivery person
  - Pen-based device replaces clipboard and forms