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)

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

http://www.mwbrooks.com/dvorak/layout.html

http://www.mwbrooks.com/dvorak/dvorkeys.pdf

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

http://www.mwbrooks.com/dvorak/dvorkeys.pdf

- 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

Cordless

Wheel scrolls text in windows

Optical - no ball

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.)

Tactile feedback track point
(IBM, experimental)

Wingman force feedback mouse

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

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

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

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