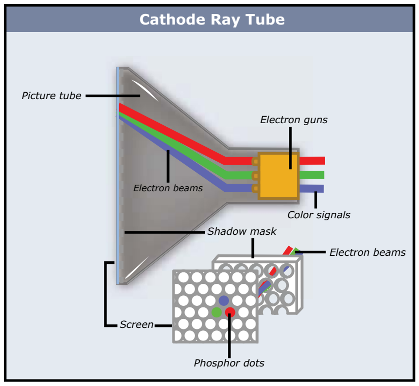
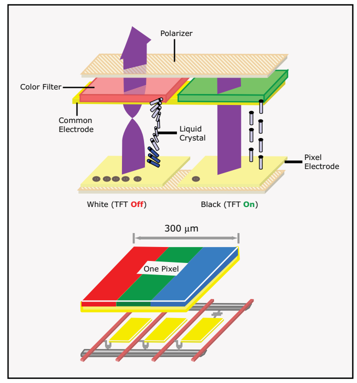
Lecture 25: Input/Output Technology

Today's Topics

- Displays
- Pointing devices

CRT vs. LCD





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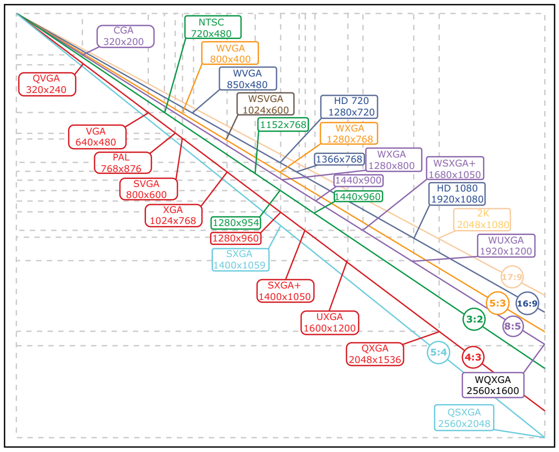
Properties of Displays

- Diagonal size
- Pixel dimensions & aspect ratio
- Pixel density
- Refresh rate
- Color depth (# colors or grays)
- Color gamut
- Gamma

Pixel Dimensions



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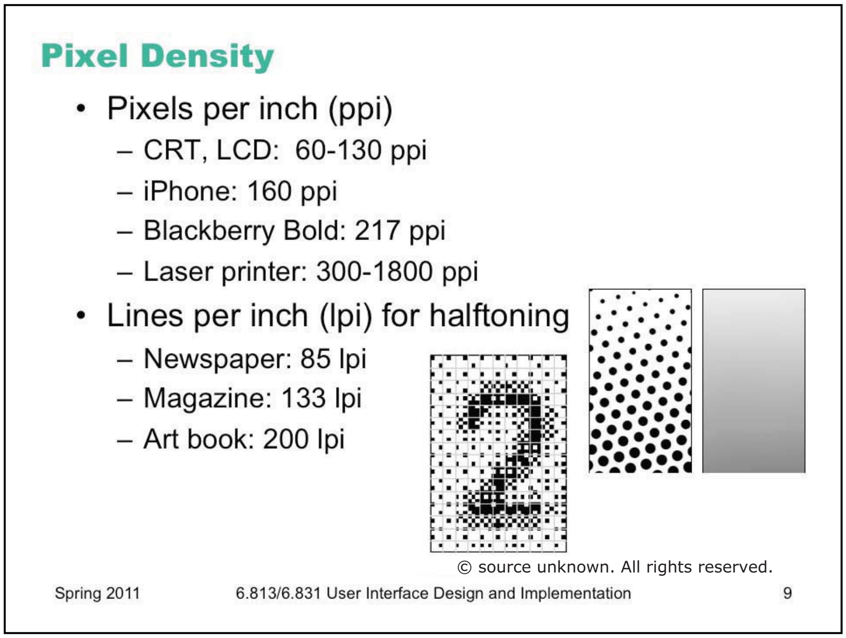
how CRTs can make pixels larger or smaller by changing frequency of scan (analog resampling), but LCD pixels are fixed

display's natural resolution always looks sharpest

square vs. nonsquare pixels

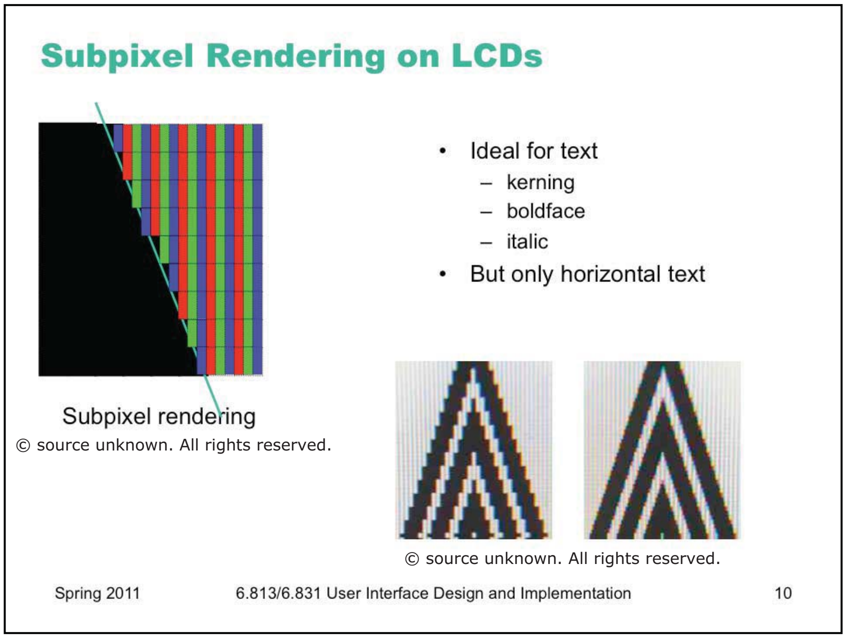


Note that DPI and PPI are sometimes used confusingly - sometimes the quoted "dpi"for an LCD panel is actually three times its true ppi, because they're counting the three subpixels

Smartphone PPI: http://pocketnow.com/index.php?a=portal_detail&t=news&id=4341

Lines per inch refers to number of halftone grid lines per inch. Digital halftoning uses a subgrid of pixels instead of different sizes of dots. So for 100 shades of gray, you'd need 10x10 pixel grid squares, so a 600 ppi printer would only be able to get 60 lpi halftoning.

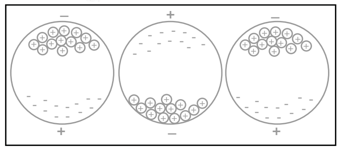
So a bad rule of thumb is to multiply the lpi by 10 to find the equivalent ppi. Magazine printing using digital halftoning can be up to 2500 ppi!



Subpixel rendering takes this a step further. Every pixel on an LCD screen consists of three discrete pixels side-by-side: red, green, and blue. So we can get a horizontal pixel density which is three times the nominal pixel density of the screen, simply by choosing the colors of the pixels along the edge so that the appropriate subpixels are light or dark. It only works on LCD screens, not CRTs, because CRT pixels are often arranged in triangles, and because CRTs are analog, so the blue in a single "pixel" usually consists of a bunch of blue phosphor dots interspersed with green and red phosphor dots. You also have to be careful to smooth out the edge to avoid color fringing effects on perfectly vertical edges. And it works best for high-contrast edges, like this edge between black and white. Subpixel rendering is ideal for text rendering, since text is usually small, high-contrast, and benefits the most from a boost in horizontal resolution. Windows XP includes ClearType, an implementation of subpixel rendering for Windows fonts. (For more about subpixel rendering, see Steve Gibson, "Sub-Pixel Font Rendering Technology", http://grc.com/cleartype.htm)

Electronic Paper

- Electrophoretic display
  - charged white particles in a dark-colored oil
  - made by E Ink
  - used by Amazon Kindle & Sony Reader



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- Only consumes power to change display
- Low refresh rate (1-2 Hz), low contrast
- Kindle is 167 ppi, 16 levels grayscale

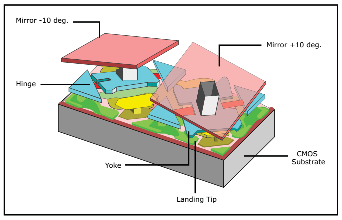
white particles are titanium dioxide (about a micron in size)

Multiple Monitors and Very Wide Displays

- Multiple monitors are increasingly common
- Microsoft DSharp prototype
  - made with 3 LCD projectors = 3072 x 768 pixels
  - curved, 48” wide, 12” high, 4:1 aspect
- Problems with multiple monitors
  - losing mouse pointer
  - clutching
  - bezels & seams
  - locus of attention

Projectors

- LCD projector
  - basically LCD panel with very bright backlight
- DLP (“digital light processing”)
  - uses a digital micromirror device instead of LCD



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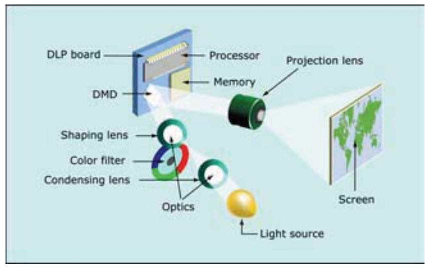

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Today's Topics

✓ Displays
- Pointing devices

Mouse

Touchpad

Trackpoint

Trackball

Focusing on indirect pointing devices today - Friday's lecture will say more about direct touch on the screen

Properties of Pointing Devices

- Direct vs. indirect
  - Direct touch on screen
  - Indirect control of mouse pointer
- Relative vs. absolute
- Throughput
- Control/display (C/D) ratio

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more about direct touch on Friday

mouse vs. trackball: Mackenzie et al. "A Comparison of Input Devices in Elemental Pointing and Dragging Tasks." CHI 1990.

mouse vs. trackball vs. touchpad vs. joystick: MacKenzie et al, "Accuracy Measures for Evaluating Computer Pointing Devices", CHI 2001.

http://www.yorku.ca/mack/CHI01.htm

Throughput

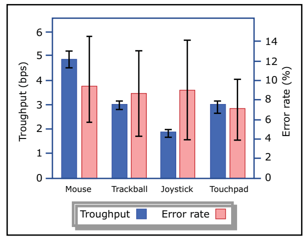
- Throughput
  - also called index of performance

    T = a + b log (D/S + 1) *seconds*

    ID = log (D/S + 1) *bits*

    IP = 1/b *bits/second*

  - mouse: 5 bits/sec
  - trackball: 3 bits/sec
  - touchpad: 3 bits/sec
  - joystick: 2 bits/sec



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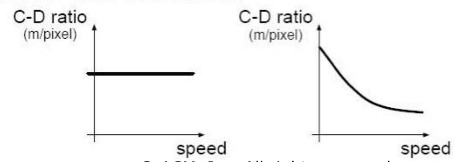
Control/Display Ratio

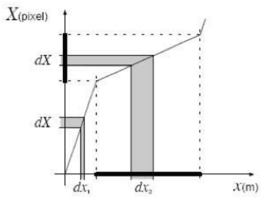
- Control: how far user's hand moves
  - in meters
- Display: how far cursor moves on screen
  - in pixels
- Direct touch: C/D = 1
- Mouse acceleration



No acceleration With acceleration

Semantic Pointing

- Adapt the C/D ratio to the targets on screen
  - Highly likely targets have high C/D ratio => pointer moves more slowly, target feels sticky
  - Less likely targets have low C/D ratio => pointer moves fast, slips over them



"Look" is unchanged

...but "feel" is different

Blanch et al. "Semantic pointing: improving target acquisition with control-display ratio adaptation." CHI 2004.

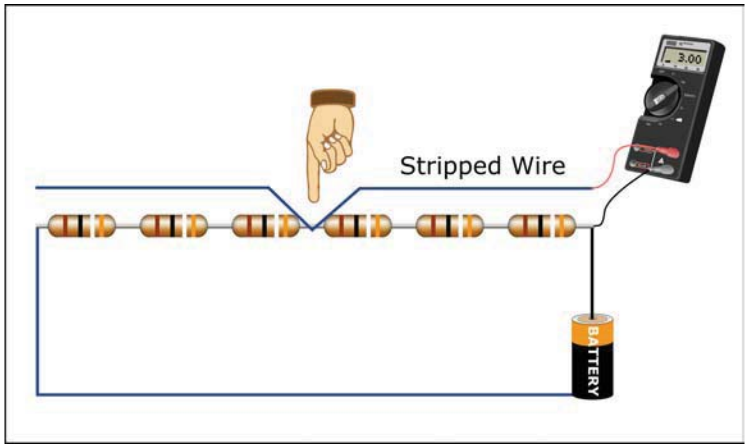
Direct Touch

- Mouse = indirect pointing
- Stylus or finger = direct pointing

Technology for Direct Touch

- Resistive
  - Two conductive sheets with a gap between
  - Responds to finger, stylus, any object
- Capacitive
  - Human skin changes surface capacitance
  - Responds only to bare skin
- Inductive
  - EM field from tablet induces signal from stylus
  - Responds only to special (expensive!) stylus
- Optical
  - Camera watches the surface
  - Responds to anything

Resistive Touch Sensing



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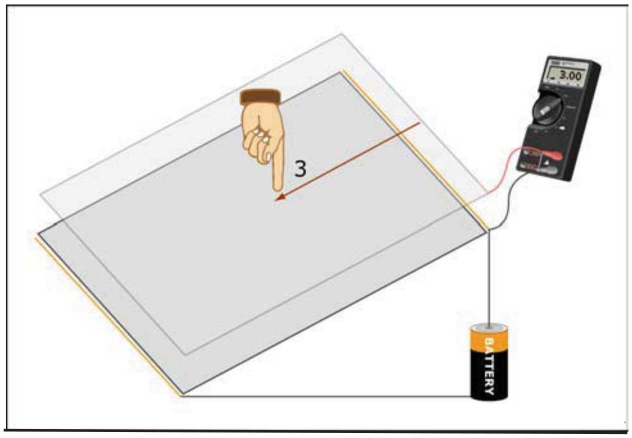
Resistive Touch Sensing



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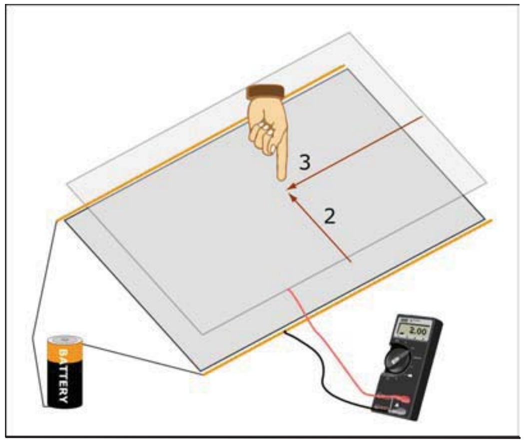
Resistive Touch Sensing



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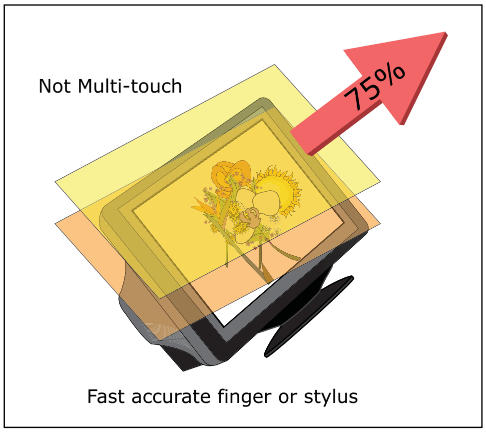
Resistive Touch Sensing



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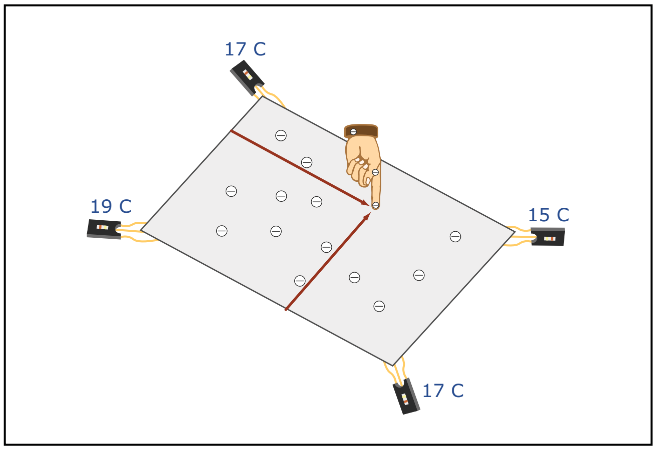
Capacitive Touch Sensing



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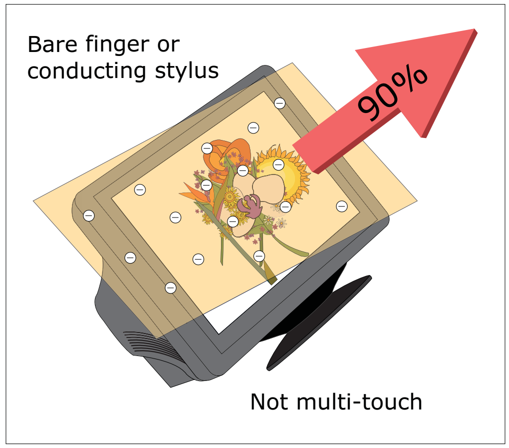
Capacitive Touch Sensing



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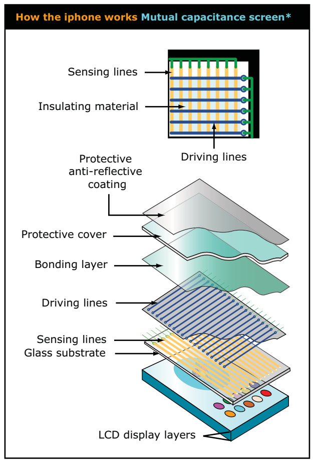
Projected Capacitive Touch Sensing



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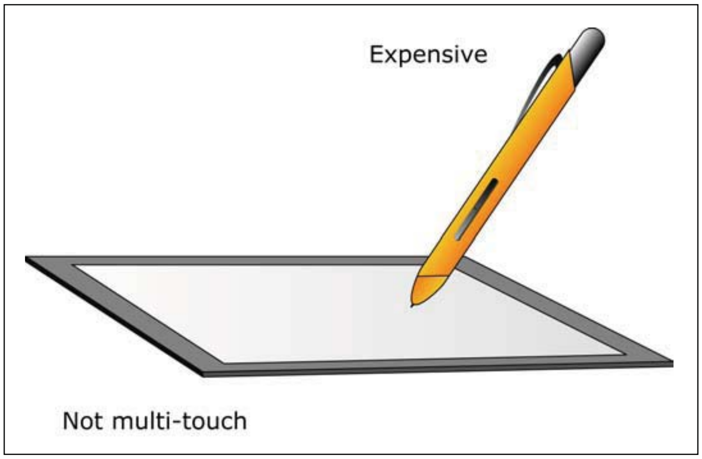
Inductive Touch Sensing



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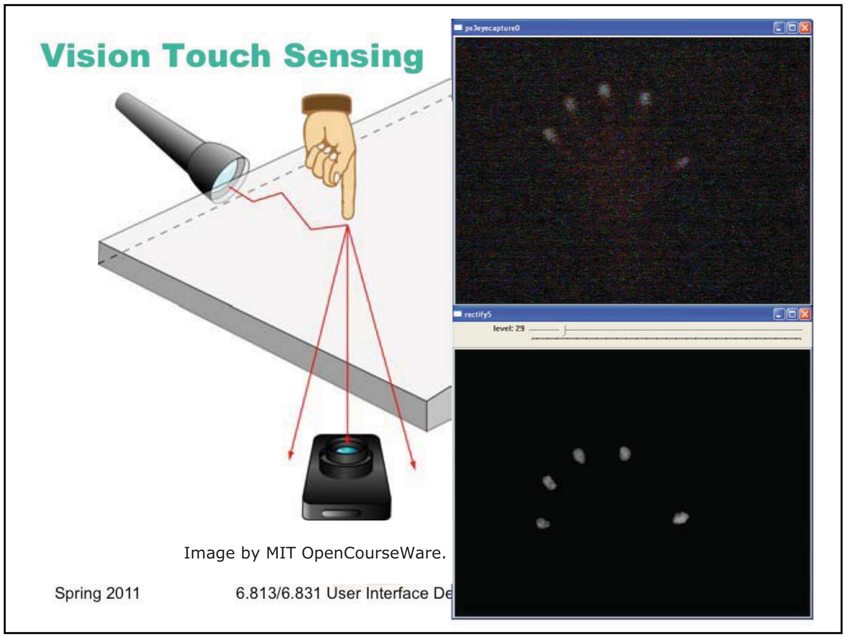

Vision Touch Sensing
ps3eyecapture0
rectify5
level: 29
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Vision Touch Sensing

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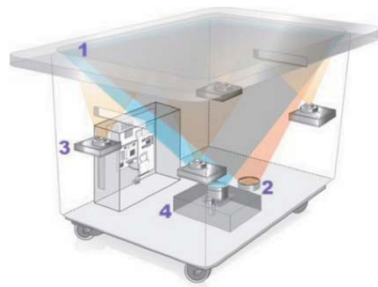
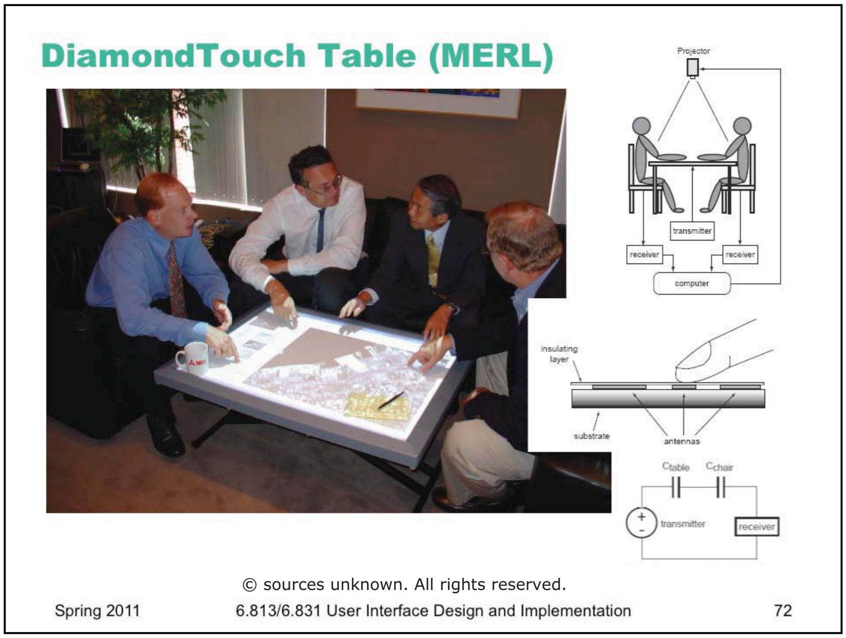
Microsoft Surface





designed for multiple users around a tabletop

rotation becomes an important issue

multiple users (and multiple touches per user) are identified by an array of transmitting antennas in the surface and sensors connected to their chairs

front-projected (because the antenna array is presently opaque), so occlusion of the display is worse

Issues for Direct Touch Technology

- Finger only, stylus only, or both
- Pressure sensitivity
- Hovering vs. clicking
- Occlusion of display by finger or hand
  - "Fat finger" problem
- Multitouch
- Tactile feedback
- Multiple users

Summary

- Displays
  - CRT, LCD, e-paper, projector
  - Dimensions, density, refresh rate, color depth
- Pointing devices
  - Mouse, touchpad, joystick, trackpad
  - Throughput, C/D ratio
- Keyboards
  - QWERTY, Dvorak, alphabetical
  - Typing speed, finger movement