Human Computer Interaction

Computer and Information Model

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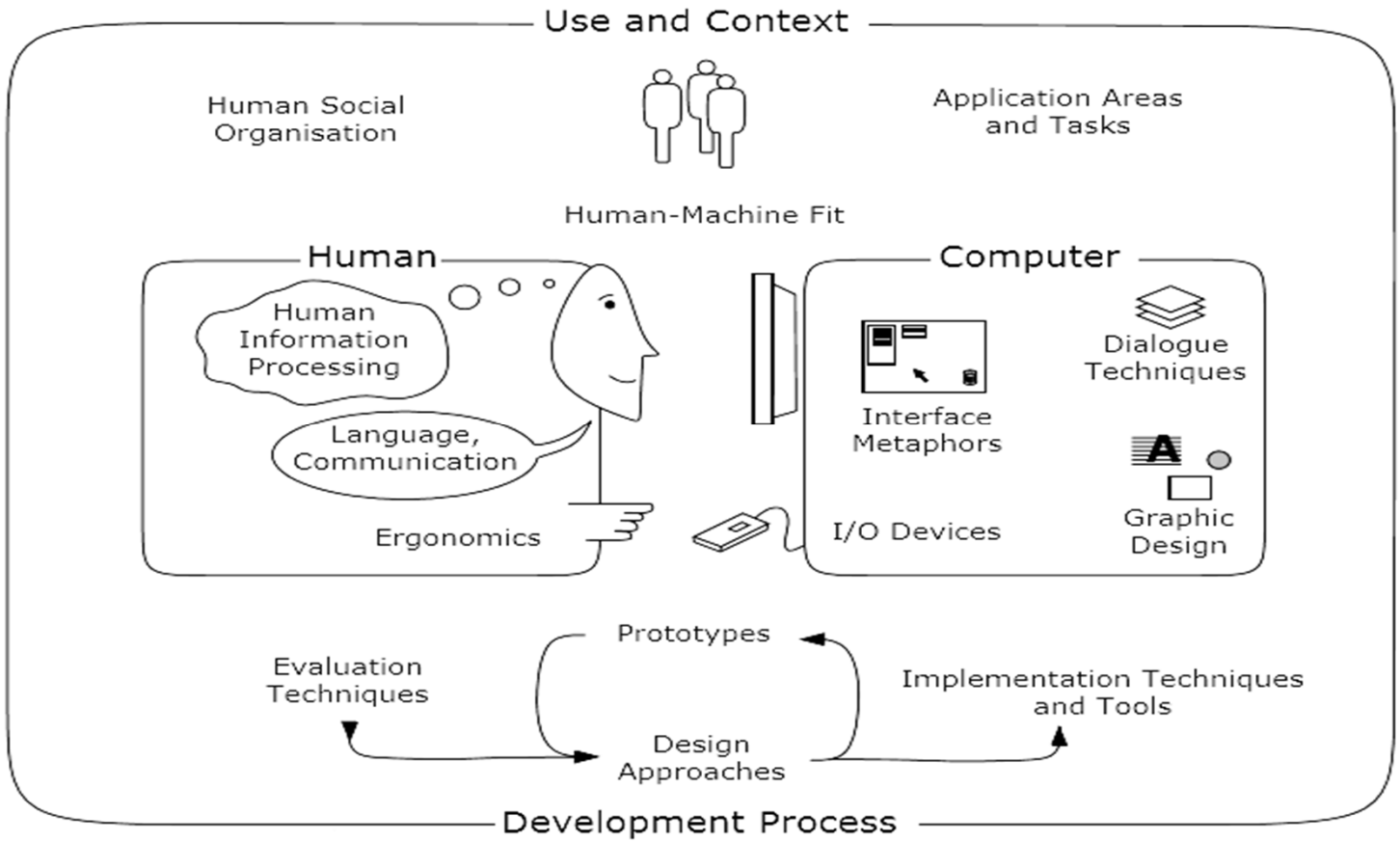
Content



The nature of Human-Computer Interaction. Adapted from the ACM SIGCHI Curricula for Human-Computer Interaction [Hewett et al., 2002]

Reference

- DonaldNorman, **The Design of Everyday Things, MITPress, 23 Dec 2013**
- Dix, Finlay…, **Human-Computer Interaction**, 3nd

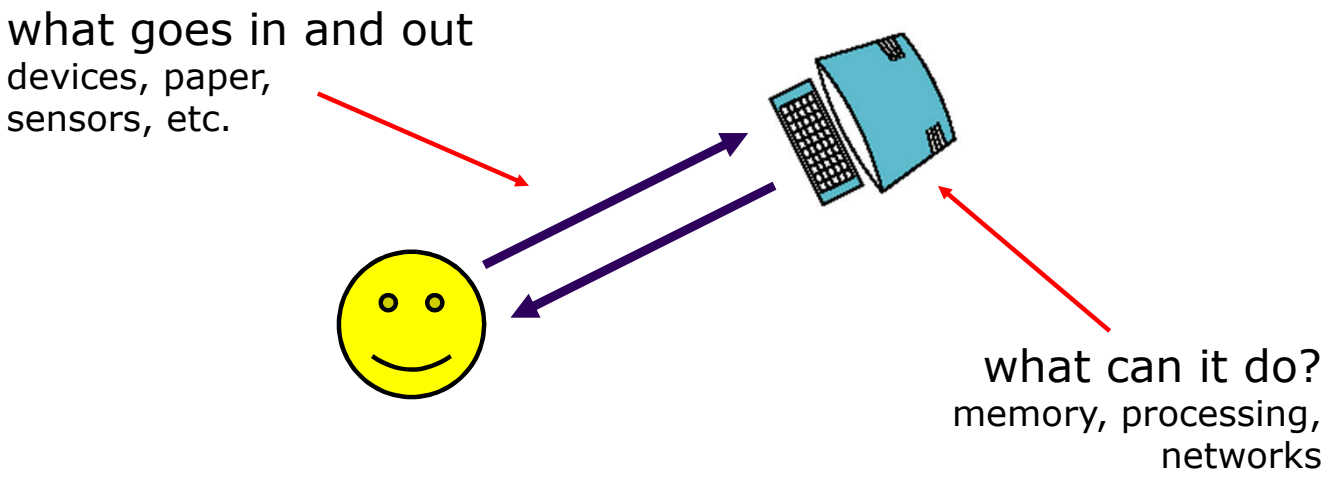
Agenda

- Computer
- Input Devices
- Display devices

Interacting with computers

to understand human–*computer* interaction

… need to understand computers!



The Computer

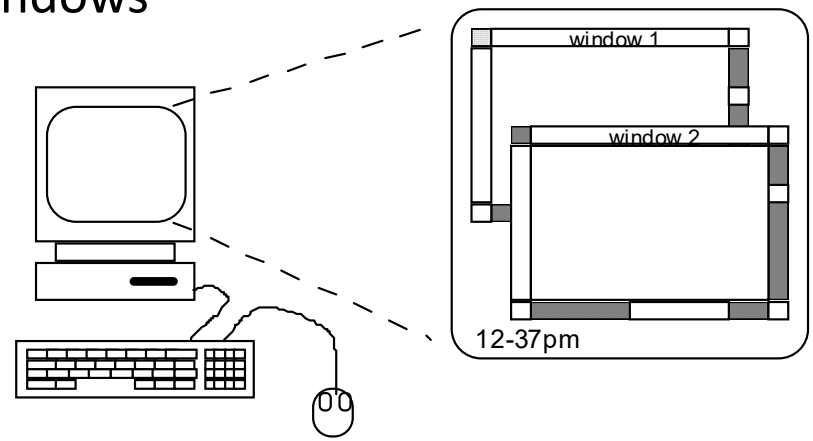
- A computer system is made up of various elements

- Each of these elements affects the interaction
  - Input devices – text entry and pointing
  - Output devices – screen (small & large), digital paper
  - Virtual reality – special interaction and display devices
  - Physical interaction – e.G. Sound, haptic, bio-sensing
  - Paper – as output (print) and input (scan)
  - Memory – RAM & permanent media, capacity & access
  - Processing – speed of processing, networks

A ‘typical’ computer system

- screen or monitor, on which there are windows
- keyboard
- mouse/trackpad

- variations
  - desktop
  - laptop
  - PDA



the devices dictate the styles of interaction that the system supports

If we use different devices, then the interface will support a different style of interaction

How many …

- computers in your house?
  - hands up, …
    … none, 1, 2 , 3, more!!

- computers in your pockets?

are you thinking …
… PC, laptop, PDA ??

How many computers …

in your house?

- PC
- TV, VCR, DVD, HiFi, cable/satellite TV
- microwave, cooker, washing machine
- central heating
- security system

can you think of more?

in your pockets?

- PDA
- phone, camera
- smart card, card with magnetic strip?
- electronic car key
- USB memory

try your pockets and bags

Interactivity?

Long ago in a galaxy far away … *batch* processing

- punched card stacks or large data files prepared
- long wait ….
- line printer output

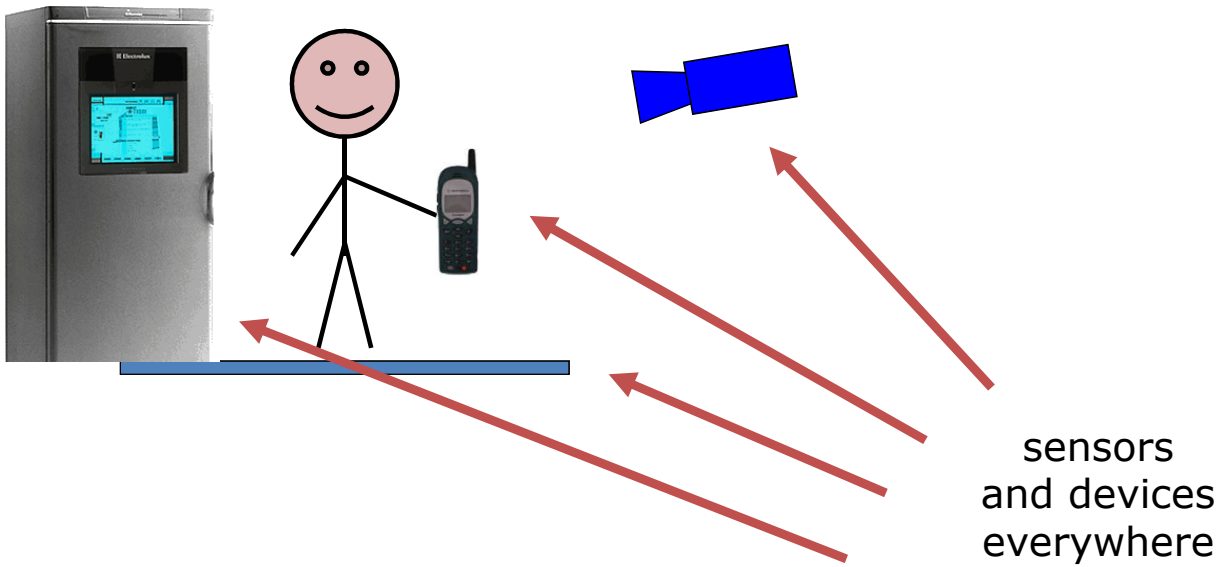
  … and if it is not right …

Now most computing is interactive

- rapid feedback
- the user in control (most of the time)
- doing rather than thinking …

Is faster always better?

Richer interaction



Text entry devices

- Keyboards (QWERTY et al.)
- Chord keyboards, phone pads
- Handwriting, speech

Keyboards

- Most common text input device
- Allows rapid entry of text by experienced users

- Keypress closes connection, causing a character code to be sent
- Usually connected by cable, but can be wireless

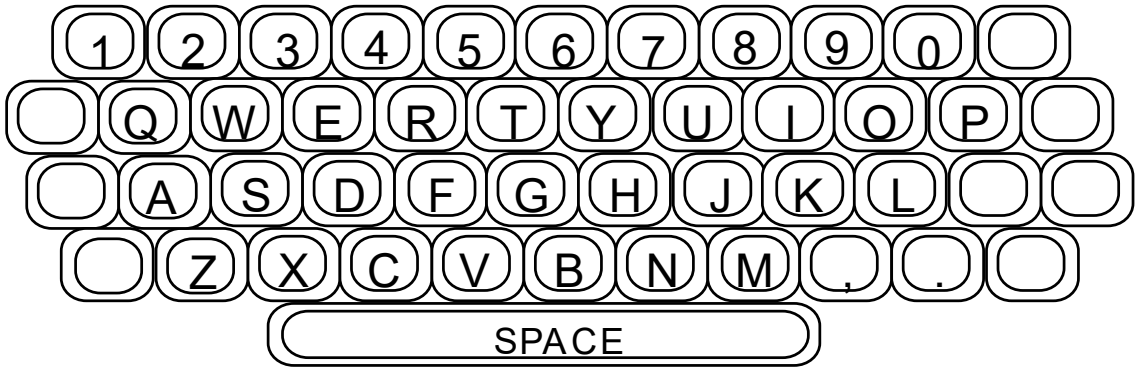
layout – QWERTY

- Standardised layout

  but …
  - non-alphanumeric keys are placed differently
  - accented symbols needed for different scripts
  - minor differences between UK and USA keyboards

- QWERTY arrangement not optimal for typing
  - layout to prevent typewriters jamming!
- Alternative designs allow faster typing but large social base of QWERTY typists produces reluctance to change.

QWERTY (ctd)



Alternative keyboard layouts

Alphabetic

- keys arranged in alphabetic order
- not faster for trained typists
- not faster for beginners either!

Dvorak

- common letters under dominant fingers
- biased towards right hand
- common combinations of letters alternate between hands
- 10-15% improvement in speed and reduction in fatigue
- But - large social base of QWERTY typists produce market pressures not to change

Special keyboards

- Designs to reduce fatigue for RSI
- For one handed use

  E.G. The maltron left-handed keyboard

Chord keyboards

Only a few keys - four or 5

Letters typed as combination of keypresses

Compact size

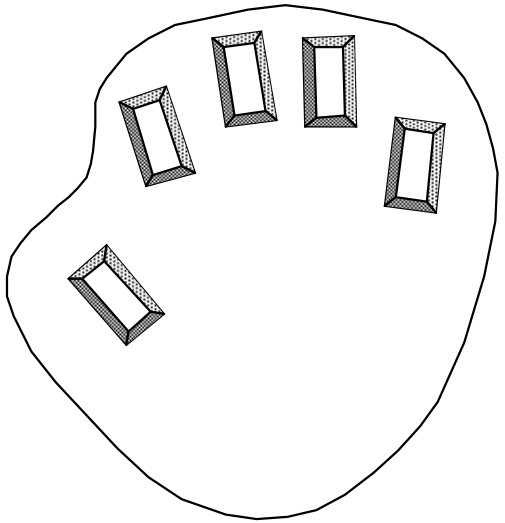
- Ideal for portable applications

Short learning time

- keypresses reflect letter shape

Fast

- Once you have trained



But - social resistance, plus fatigue after extended use

NEW – niche market for some wearables

Phone pad and T9 entry

- use numeric keys with multiple presses

  2 – a b c 6 - m n o
  3 - d e f 7 - p q r s
  4 - g h i 8 - t u v
  5 - j k l 9 - w x y z

  hello = 4433555[pause]555666

  surprisingly fast!

- T9 predictive entry
  - type as if single key for each letter
  - use dictionary to ‘guess’ the right word
  - hello = 43556 …
  - but 26 -> menu ‘am’ or ‘an’

Handwriting recognition

- Text can be input into the computer, using a pen and a digesting tablet
  - natural interaction
- Technical problems:
  - capturing all useful information - stroke path, pressure, etc. in a natural manner
  - segmenting joined up writing into individual letters
  - interpreting individual letters
  - coping with different styles of handwriting
- Used in PDAs, and tablet computers …
  … leave the keyboard on the desk!

Speech recognition

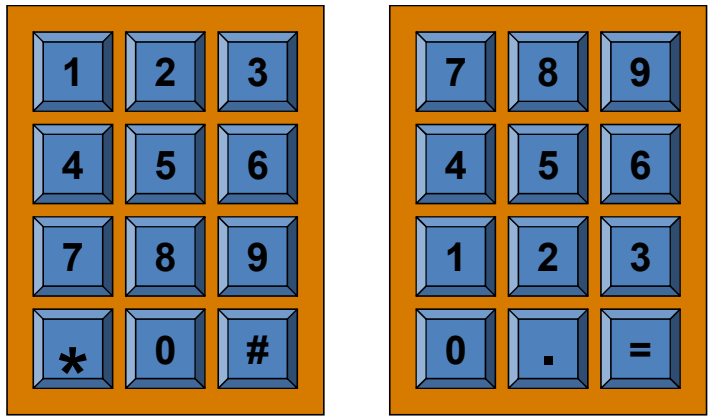
- Improving rapidly
- Most successful when:
  - single user – initial training and learns peculiarities
  - limited vocabulary systems
- Problems with
  - external noise interfering
  - imprecision of pronunciation
  - large vocabularies
  - different speakers

Numeric keypads

- For entering numbers quickly:
  - Calculator, PC keyboard
- For telephones

Not the same!!

Atm like phone



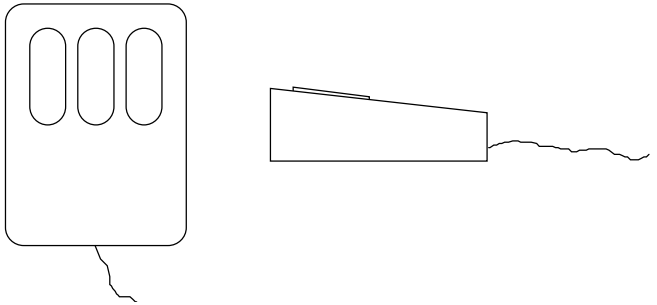
telephone calculator

Positioning, Pointing and Drawing

- mouse, touchpad trackballs, joysticks etc. touch screens, tablets, eyegaze, cursors

The mouse

- Handheld pointing device
  - very common
  - easy to use



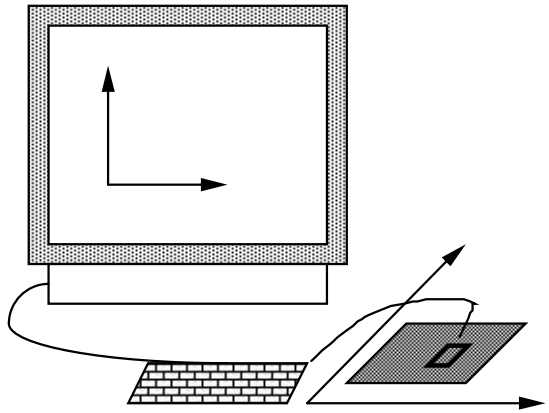
- Two characteristics
  - planar movement
  - buttons

    (usually from 1 to 3 buttons on top, used for making a selection, indicating an option, or to initiate drawing etc.)

The mouse (ctd)

Mouse located on desktop

- requires physical space
- no arm fatigue



Relative movement only is detectable.

Movement of mouse moves screen cursor

Screen cursor oriented in (x, y) plane,
mouse movement in (x, z) plane …

… an *indirect* manipulation device.

- device itself doesn't obscure screen, is accurate and fast.
- hand-eye coordination problems for novice users

How does it work?

Two methods for detecting motion

- Mechanical
  - Ball on underside of mouse turns as mouse is moved
  - Rotates orthogonal potentiometers
  - Can be used on almost any flat surface
- Optical
  - light emitting diode on underside of mouse
  - may use special grid-like pad or just on desk
  - less susceptible to dust and dirt
  - detects fluctuating alterations in reflected light intensity to calculate relative motion in (x, z) plane

Even by foot …

- Some experiments with the *footmouse*
  - Controlling mouse movement with feet …
  - Not very common :-)

- But foot controls are common elsewhere:
  - Car pedals
  - Sewing machine speed control
  - Organ and piano pedals

Touchpad

- Small touch sensitive tablets
- ‘Stroke’ to move mouse pointer
- Used mainly in laptop computers

- Good ‘acceleration’ settings important
  - Fast stroke
    - Lots of pixels per inch moved
    - Initial movement to the target
  - Slow stroke
    - Less pixels per inch
    - For accurate positioning

Trackball and thumbwheels

Trackball

- ball is rotated inside static housing
  - like an upsdie down mouse!
- relative motion moves cursor
- indirect device, fairly accurate
- separate buttons for picking
- very fast for gaming
- used in some portable and notebook computers.

Thumbwheels …

- for accurate CAD – two dials for X-Y cursor position
- for fast scrolling – single dial on mouse

Joystick and keyboard nipple

Joystick

- indirect
  pressure of stick = velocity of movement
- buttons for selection
  on top or on front like a trigger
- often used for computer games
  aircraft controls and 3D navigation

Keyboard nipple

- for laptop computers
- miniature joystick in the middle of the keyboard

Touch-sensitive screen

- Detect the presence of finger or stylus on the screen.
  - works by interrupting matrix of light beams, capacitance changes or ultrasonic reflections
  - *direct* pointing device
- Advantages:
  - fast, and requires no specialised pointer
  - good for menu selection
  - suitable for use in hostile environment: clean and safe from damage.
- Disadvantages:
  - finger can mark screen
  - imprecise (finger is a fairly blunt instrument!)
    - difficult to select small regions or perform accurate drawing
  - lifting arm can be tiring

Stylus and light pen

Stylus

- small pen-like pointer to draw directly on screen
- may use touch sensitive surface or magnetic detection
- used in PDA, tablets PCs and drawing tables

Light Pen

- now rarely used
- uses light from screen to detect location

BOTH …

- very direct and obvious to use
- but can obscure screen

Digitizing tablet

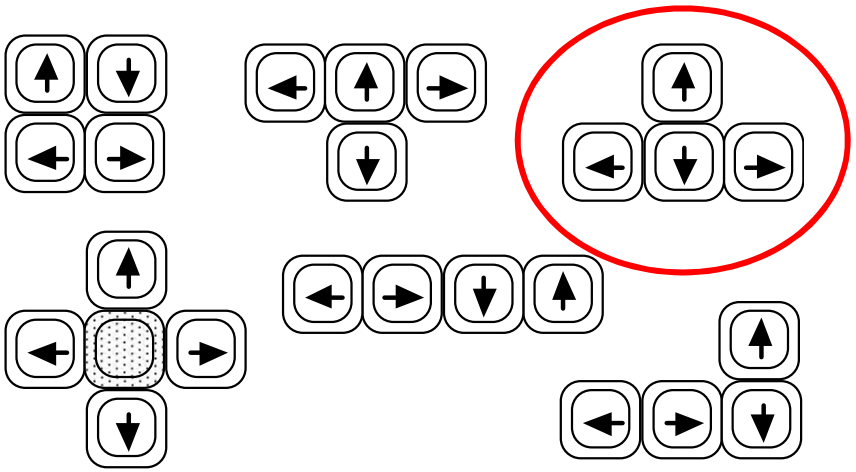
- Mouse like-device with cross hairs
- used on special surface
  - rather like stylus
- very accurate
  - used for digitizing maps

Eyegaze

- Control interface by eye gaze direction
  - E.G. Look at a menu item to select it
- Uses laser beam reflected off retina
  - … A very low power laser!
- Mainly used for evaluation (ch x)
- Potential for hands-free control
- High accuracy requires headset
- Cheaper and lower accuracy devices available
  sit under the screen like a small webcam

Cursor keys

- Four keys (up, down, left, right) on keyboard.
- Very, very cheap, but slow.
- Useful for not much more than basic motion for text-editing tasks.
- No standardised layout, but inverted “T”, most common



Discrete positioning controls

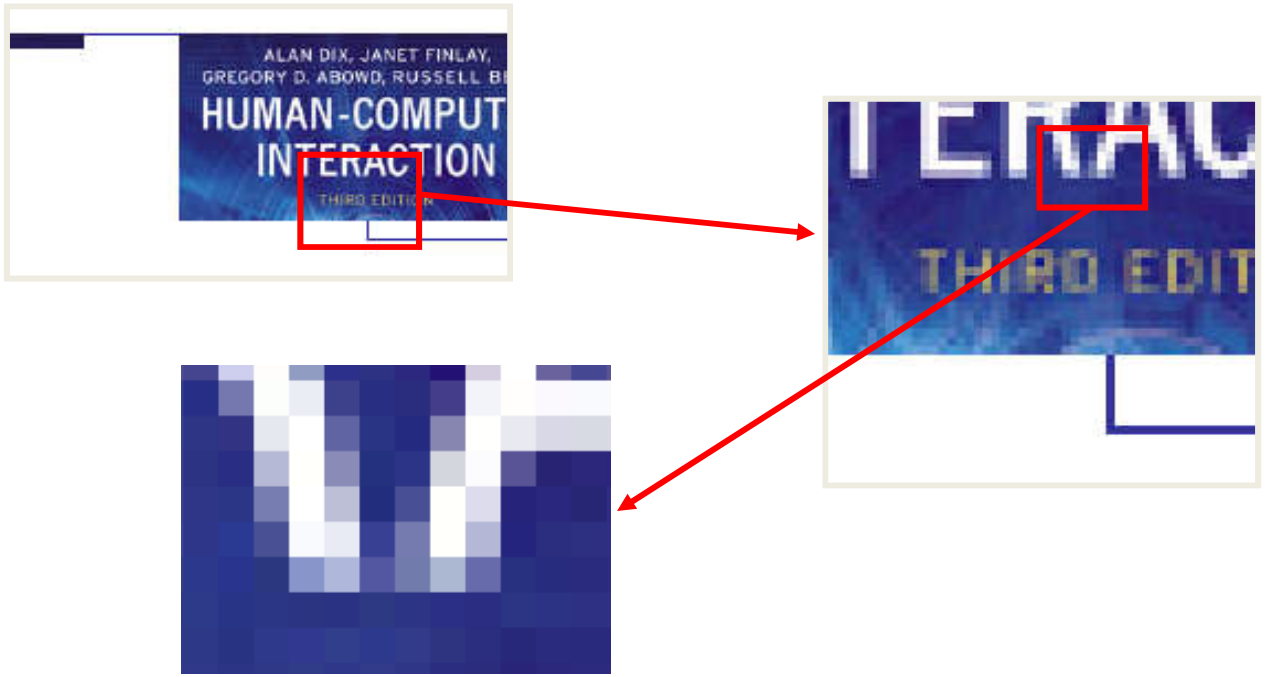
- In phones, TV controls etc.
  - Cursor pads or mini-joysticks
  - Discrete left-right, up-down
  - Mainly for menu selection

Display devices

- Bitmap screens (CRT & LCD)
- Large & situated displays
  digital paper

bitmap displays

- Screen is vast number of coloured dots



resolution and colour depth

- Resolution … used (inconsistently) for
  - number of pixels on screen (width x height)
    - e.g. SVGA 1024 x 768, PDA perhaps 240x400
  - density of pixels (in pixels or dots per inch - dpi)
    - typically between 72 and 96 dpi
- Aspect ratio
  - ration between width and height
  - 4:3 for most screens, 16:9 for wide-screen TV
- Colour depth:
  - how many different colours for each pixel?
  - black/white or greys only
  - 256 from a pallete
  - 8 bits each for red/green/blue = millions of colours

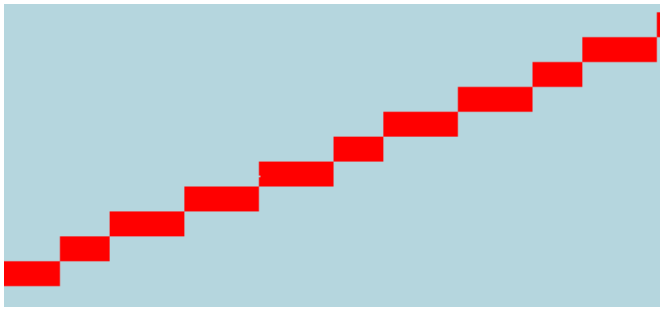
Anti-aliasing

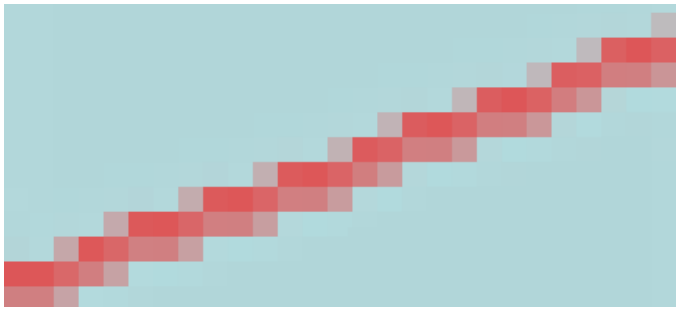
Jaggies

- diagonal lines that have discontinuities in due to horizontal raster scan process.

Anti-aliasing

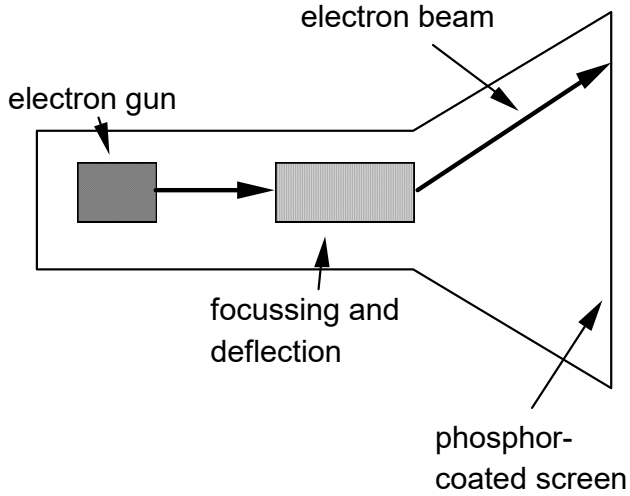
- softens edges by using shades of line colour
- also used for text





Cathode ray tube

- Stream of electrons emitted from electron gun, focused and directed by magnetic fields, hit phosphor-coated screen which glows
- Used in tvs and computer monitors



Health hazards of CRT !

- X-rays: largely absorbed by screen (but not at rear!)
- UV- and IR-radiation from phosphors: insignificant levels
- Radio frequency emissions, plus ultrasound (~16kHz)
- Electrostatic field - leaks out through tube to user. Intensity dependant on distance and humidity. Can cause rashes.
- Electromagnetic fields (50Hz-0.5MHz). Create induction currents in conductive materials, including the human body. Two types of effects attributed to this: visual system - high incidence of cataracts in VDU operators, and concern over reproductive disorders (miscarriages and birth defects).

Health hints …

- Do not sit too close to the screen
- Do not use very small fonts
- Do not look at the screen for long periods without a break
- Do not place the screen directly in front of a bright window
- Work in well-lit surroundings

★ Take extra care if pregnant.
but also posture, ergonomics, stress

Liquid crystal displays

- Smaller, lighter, and … no radiation problems.

- Found on pdas, portables and notebooks,
  … and increasingly on desktop and even for home tv

- Also used in dedicted displays:
  digital watches, mobile phones, hifi controls

- How it works …
  - Top plate transparent and polarised, bottom plate reflecting.
  - Light passes through top plate and crystal, and reflects back to eye.
  - Voltage applied to crystal changes polarisation and hence colour
  - N.B. Light reflected not emitted => less eye strain

Special displays

Random Scan (Directed-beam refresh, vector display)

- draw the lines to be displayed directly
- no jaggies
- lines need to be constantly redrawn
- rarely used except in special instruments

Direct view storage tube (DVST)

- Similar to random scan but persistent => no flicker
- Can be incrementally updated but not selectively erased
- Used in analogue storage oscilloscopes

Large displays

- Used for meetings, lectures, etc.
- Technology
  - Plasma – usually wide screen
  - Video walls – lots of small screens together
  - Projected – RGB lights or LCD projector
    - Hand/body obscures screen
    - May be solved by 2 projectors + clever software
  - Back-projected
    - Frosted glass + projector behind

Situated displays

- Displays in ‘public’ places
  - Large or small
  - Very public or for small group
- Display only
  - For information relevant to location
- Or interactive
  - Use stylus, touch sensitive screem
- In all cases … the location matters
  - Meaning of information or interaction is related to the location

Hermes a situated display

- Small displays beside office doors
- Handwritten notes left using stylus
- Office owner reads notes using web i

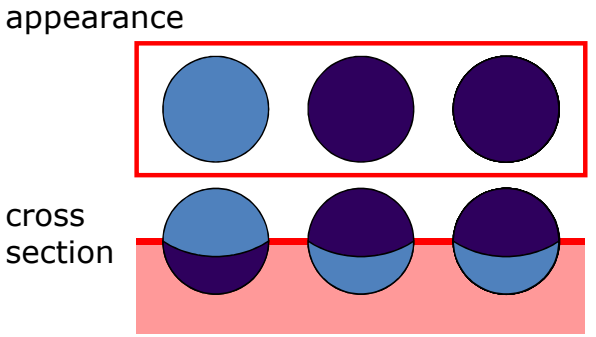
small displays beside office doors

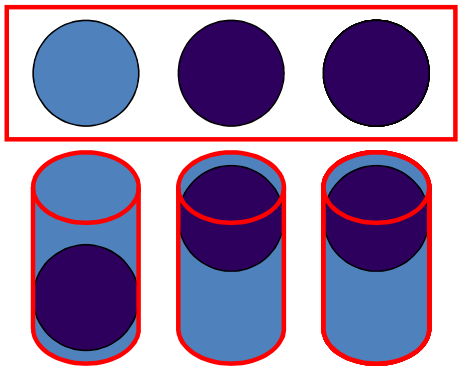
handwritten notes left using stylus

office owner reads notes using web interface

Digital paper

- What?
  - Thin flexible sheets
  - Updated electronically
  - But retain display
- How?
  - Small spheres turned
  - Or channels with coloured liquid and contrasting spheres
  - Rapidly developing area





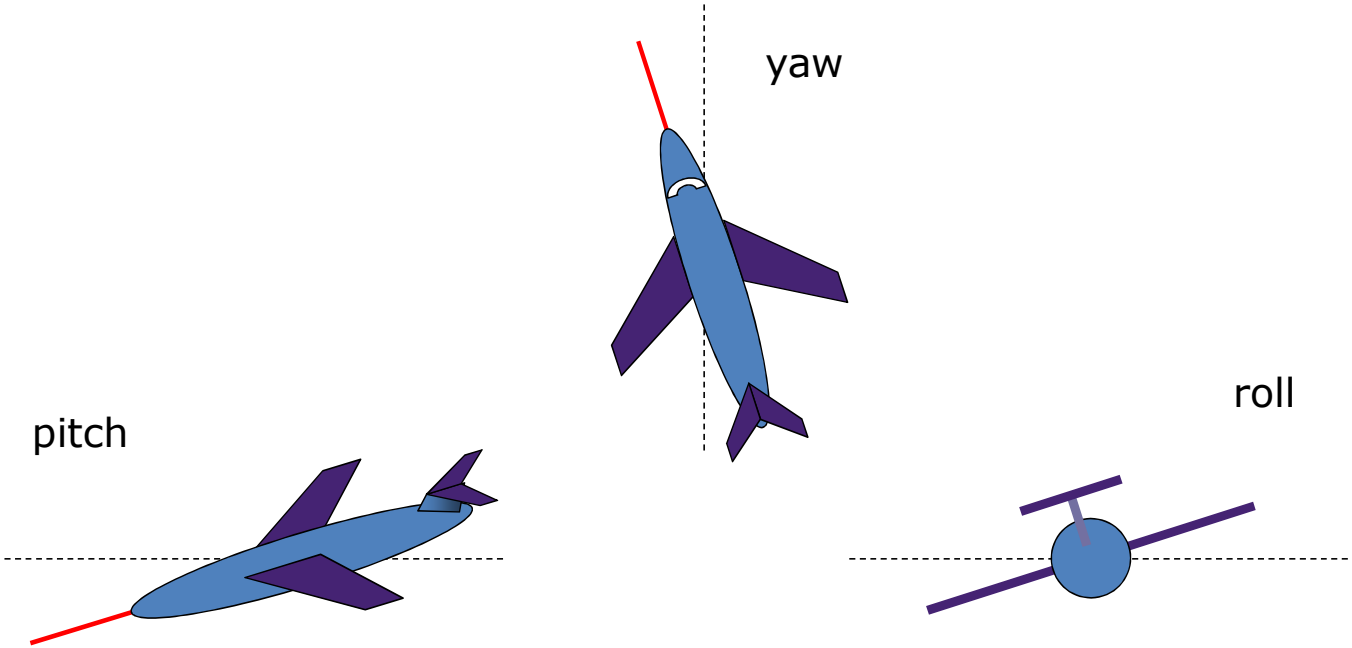
Virtual reality (VR) and 3D interaction

- Positioning in 3D space
  moving and grasping
- Seeing 3D (helmets and caves)

Positioning in 3D space

- Cockpit and virtual controls
  - Steering wheels, knobs and dials … just like real!
- The 3d mouse
  - Six-degrees of movement: x, y, z + roll, pitch, yaw
- Data glove
  - Fibre optics used to detect finger position
- VR helmets
  - Detect head motion and possibly eye gaze
- Whole body tracking
  - Accelerometers strapped to limbs or reflective dots and video processing

Pitch, yaw and roll



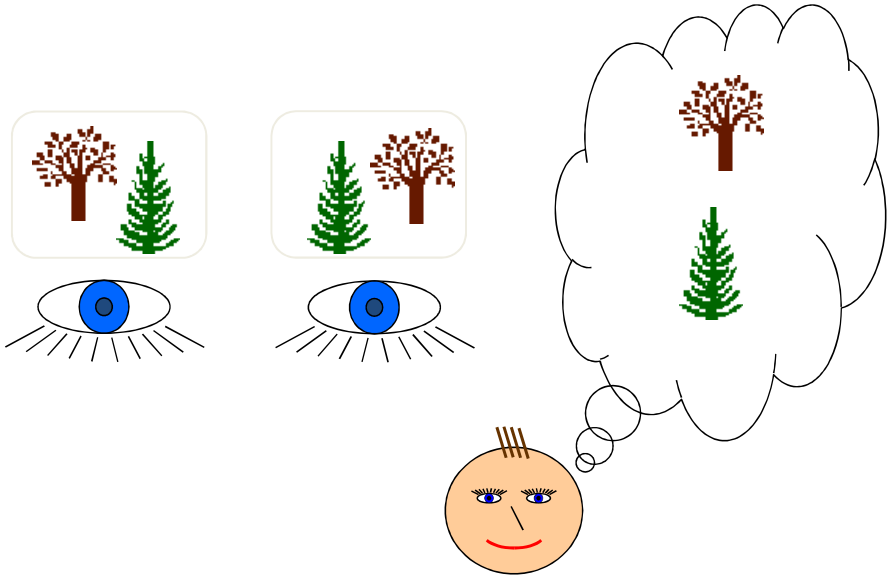
3D displays

- Desktop VR
  - Ordinary screen, mouse or keyboard control
  - Perspective and motion give 3D effect
- Seeing in 3D
  - Use stereoscopic vision
  - VR helmets
  - Screen plus shuttered specs, etc.

also see extra slides on 3D vision

VR headsets

- Small TV screen for each eye
- Slightly different angles
- 3D effect

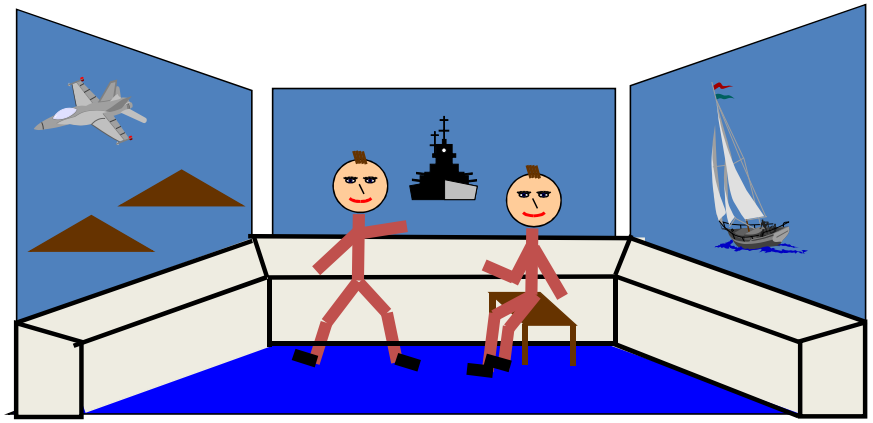


VR motion sickness

- Time delay
  - Move head … lag … display moves
  - *Conflict:* head movement vs. Eyes
- Depth perception
  - Headset gives different stereo distance
  - But all focused in same plane
  - *Conflict:* eye angle vs. Focus
- Conflicting cues => sickness
  - Helps motivate improvements in technology

Simulators and VR caves

- Scenes projected on walls
- Realistic environment
- Hydraulic rams!
- Real controls
- Other people



Physical controls, sensors etc.

- Special displays and gauges
- Sound, touch, feel, smell
- Physical controls
- Environmental and bio-sensing

Dedicated displays

- Analogue representations:
  - Dials, gauges, lights, etc.
- Digital displays:
  - Small LCD screens, LED lights, etc.
- Head-up displays
  - Found in aircraft cockpits
  - Show most important controls
    … depending on context

Sounds

- Beeps, bongs, clonks, whistles and whirrs
- Used for error indications
- Confirmation of actions e.G. Keyclick

Also see chapter 10

Touch, feel, smell

- Touch and feeling important
  - In games … vibration, force feedback
  - In simulation … feel of surgical instruments
  - Called *haptic* devices

- Texture, smell, taste
  - Current technology very limited

BMW idrive

- For controlling menus
- Feel small ‘bumps’ for each item
- Makes it easier to select options by feel
- Uses haptic technology from immersion corp.

Physical controls

- Specialist controls needed …
  - Industrial controls, consumer products, etc.

Large buttons

Clear dials

Tiny buttons

Multi-function control

Easy-clean Smooth buttons

Environment and bio-sensing

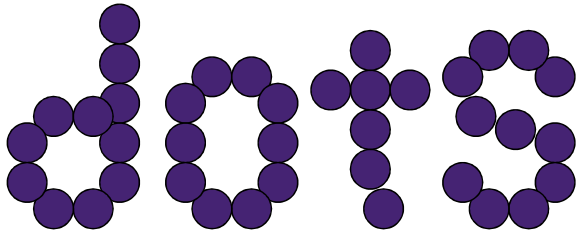
- Sensors all around us
  - Car courtesy light – small switch on door
  - Ultrasound detectors – security, washbasins
  - RFID security tags in shops
  - Temperature, weight, location
- … and even our own bodies …
  - Iris scanners, body temperature, heart rate, galvanic skin response, blink rate

Paper: printing and scanning

- Print technology
- Fonts, page description, WYSIWYG
- Scanning, OCR

Printing

- Image made from small dots
  - Allows any character set or graphic to be printed,
- Critical features:
  - Resolution
    - Size and spacing of the dots
    - Measured in dots per inch (dpi)
  - Speed
    - Usually measured in pages per minute
  - Cost!!



Types of dot-based printers

- Dot-matrix printers
  - Use inked ribbon (like a typewriter
  - Line of pins that can strike the ribbon, dotting the paper.
  - Typical resolution 80-120 dpi
- Ink-jet and bubble-jet printers
  - Tiny blobs of ink sent from print head to paper
  - Typically 300 dpi or better .
- Laser printer
  - Like photocopier: dots of electrostatic charge deposited on drum, which picks up toner (black powder form of ink) rolled onto paper which is then fixed with heat
  - Typically 600 dpi or better.

Printing in the workplace

- Shop tills
  - Dot matrix
  - Same print head used for several paper rolls
  - May also print cheques
- Thermal printers
  - Special heat-sensitive paper
  - Paper heated by pins makes a dot
  - Poor quality, but simple & low maintenance
  - Used in some fax machines

Fonts

- Font – the particular style of text

Courier font
Helvetica font
Palatino font
Times Roman font
- §´∝≡↵ℑ⊗↵~ (special symbol)

- Size of a font measured in points (1 pt about 1/72”)
(vaguely) related to its height

This is ten point Helvetica
This is twelve point
This is fourteen point
This is eighteen point
and this is twenty-four point

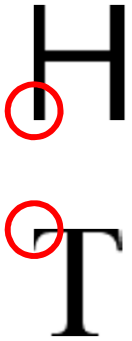
Fonts (ctd)

Pitch

- fixed-pitch – every character has the same width
  e.g. Courier
- variable-pitched – some characters wider
  e.g. Times Roman – compare the 'i' and the "m"

Serif or Sans-serif

- sans-serif – square-ended strokes
  e.g. Helvetica
- serif – with splayed ends (such as)
  e.g. Times Roman or Palatino



Readability of text

- lowercase
  - easy to read shape of words
- UPPERCASE
  - better for individual letters and non-words

    e.g. flight numbers: BA793 vs. ba793
- serif fonts
  - helps your eye on long lines of printed text
  - but sans serif often better on screen

Page Description Languages

- Pages very complex
  - different fonts, bitmaps, lines, digitised photos, etc.
- Can convert it all into a bitmap and send to the printer
  … but often huge !
- Alternatively Use a page description language
  - sends a *description* of the page can be sent,
  - instructions for curves, lines, text in different styles, etc.
  - like a programming language for printing!
- PostScript is the most common

Screen and page

- Wysiwyg
  - What you see is what you get
  - Aim of word processing, etc.
- But …
  - Screen: 72 dpi, landscape image
  - Print: 600+ dpi, portrait
- Can try to make them similar
  but never quite the same
- So … need different designs, graphics etc, for screen and print

Scanners

- Take paper and convert it into a bitmap
- Two sorts of scanner
  - flat-bed: paper placed on a glass plate, whole page converted into bitmap
  - hand-held: scanner passed over paper, digitising strip typically 3-4” wide
- Shines light at paper and note intensity of reflection
  - colour or greyscale
- Typical resolutions from 600–2400 dpi

Scanners (ctd)

Used in

- desktop publishing for incorporating photographs and other images
- document storage and retrieval systems, doing away with paper storage
+ special scanners for slides and photographic negatives

Optical character recognition

- OCR converts bitmap back into text
- Different fonts
  - Create problems for simple “template matching” algorithms
  - More complex systems segment text, decompose it into lines and arcs, and decipher characters that way
- Page format
  - Columns, pictures, headers and footers

Paper-based interaction

- Paper usually regarded as *output* only
- Can be *input* too – ocr, scanning, etc.
- Xerox paperworks
  - Glyphs – small patterns of /\\//\\\
    - Used to identify forms etc.
    - Used with scanner and fax to control applications
- More recently
  - Papers micro printed - like wattermarks
    - Identify *which* sheet and *where* you are
  - Special ‘pen’ can read locations
    - Know where they are writing

Memory

- Short term and long term
- Speed, capacity, compression
- Formats, access

Short-term Memory - RAM

- Random access memory (RAM)
  - on silicon chips
  - 100 nano-second access time
  - usually volatile (lose information if power turned off)
  - data transferred at around 100 Mbytes/sec

- Some *non-volatile RAM* used to store basic set-up information

- Typical desktop computers:
  64 to 256 Mbytes RAM

Long-term Memory - disks

- Magnetic disks
  - Floppy disks store around 1.4 mbytes
  - Hard disks typically 40 gbytes to 100s of gbytes
    access time ~10ms, transfer rate 100kbytes/s
- Optical disks
  - Use lasers to read and sometimes write
  - More robust that magnetic media
  - CD-ROM
    - same technology as home audio, ~ 600 gbytes
  - DVD - for AV applications, or very large files

Blurring boundaries

- PDAs
  - often use RAM for their main memory
- Flash-Memory
  - used in PDAs, cameras etc.
  - silicon based but persistent
  - plug-in USB devices for data transfer

Speed and capacity

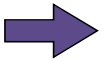
- What do the numbers mean?

- Some sizes (all uncompressed) ...
  - This book, text only ~ 320,000 words, 2mb
  - The bible ~ 4.5 mbytes
  - Scanned page ~ 128 mbytes
    - (11x8 inches, 1200 dpi, 8bit greyscale)
  - Digital photo ~ 10 mbytes
    - (2–4 mega pixels, 24 bit colour)
  - Video ~ 10 mbytes *per second*
    - (512x512, 12 bit colour, 25 frames per sec)

Virtual memory

- Problem:
  - Running lots of programs + each program large
  - Not enough RAM
- Solution - virtual memory :
  - Store some programs temporarily on disk
  - Makes RAM appear bigger
- But … swopping
  - Program on disk needs to run again
  - Copied from disk to RAM
  - S l o w s t h i n g s d o w n

Compression

- Reduce amount of storage required
- Lossless
  - Recover exact text or image – e.G. Gif, zip
  - Look for commonalities:
    - Text: AAAAAAAAAABBBBBCCCCCCCC 10A5B8C
    - Video: compare successive frames and store change 
- Lossy
  - Recover something like original – e.G. Jpeg, mp3
  - Exploit perception
    - JPEG: lose rapid changes and some colour
    - MP3: reduce accuracy of drowned out notes

Storage formats - text

- ASCII - 7-bit binary code for to each letter and character
- UTF-8 - 8-bit encoding of 16 bit character set
- RTF (rich text format)
    - text plus formatting and layout information
- SGML (standardized generalised markup language)
    - documents regarded as structured objects
- XML (extended markup language)
    - simpler version of SGML for web applications

Storage formats - media

- Images:
  - many storage formats :
    (PostScript, GIFF, JPEG, TIFF, PICT, etc.)
  - plus different compression techniques
    (to reduce their storage requirements)
- Audio/Video
  - again lots of formats :
    (QuickTime, MPEG, WAV, etc.)
  - compression even more important
  - also ‘streaming’ formats for network delivery

Methods of access

- Large information store
  - Long time to search => use index
  - What you index -> what you can access
- Simple index needs exact match
- Forgiving systems:
  - Xerox “do what I mean” (DWIM)
  - SOUNDEX – mccloud ~ maccleod
- Access without structure …
  - Free text indexing (all the words in a document)
  - Needs lots of space!!

Processing and networks

- Finite speed (but also moore's law)
- Limits of interaction
- Networked computing

Finite processing speed

- Designers tend to assume fast processors, and make interfaces more and more complicated

- But problems occur, because processing cannot keep up with all the tasks it needs to do
  - cursor overshooting because system has buffered keypresses
  - icon wars - user clicks on icon, nothing happens, clicks on another, then system responds and windows fly everywhere

- Also problems if system is too fast - e.g. help screens may scroll through text much too rapidly to be read

Moore's law

- Computers get faster and faster!
- 1965 …
  - Gordon moore, co-founder of intel, noticed a pattern
  - Processor speed doubles every 18 months
  - Pc … 1987: 1.5 mhz, 2002: 1.5 ghz
- Similar pattern for memory
  - But doubles every 12 months!!
  - Hard disk … 1991: 20mbyte : 2002: 30 gbyte
- Baby born today
  - Record all sound and vision
  - By 70 all life's memories stored in a grain of dust!

/e3/online/moores-law/

The myth of the infinitely fast machine

- Implicit assumption … no delays
  an infinitely fast machine
- What is good design for real machines?
- Good example … the telephone :
  - Type keys too fast
  - Hear tones as numbers sent down the line
  - Actually an accident of implementation
  - Emulate in deisgn

Limitations on interactive performance

Computation bound

- Computation takes ages, causing frustration for the user

Storage channel bound

- Bottleneck in transference of data from disk to memory

Graphics bound

- Common bottleneck: updating displays requires a lot of effort - sometimes helped by adding a graphics co-processor optimised to take on the burden

Network capacity

- Many computers networked - shared resources and files, access to printers etc. - but interactive performance can be reduced by slow network speed

Networked computing

Networks allow access to …

- large memory and processing
- other people (groupware, email)
- shared resources – esp. the web

Issues

- network delays – slow feedback
- conflicts - many people update data
- unpredictability

The internet

- History …
  - 1969: DARPANET US dod, 4 sites
  - 1971: 23; 1984: 1000; 1989: 10000
- Common language (protocols):
  - TCP – transmission control protocol
    - Lower level, packets (like letters) between machines
  - IP – internet protocol
    - Reliable channel (like phone call) between programs on machines
  - Email, HTTP, all build on top of these