



HUMAN-COMPUTER INTERACTION

THIRD
EDITION

DIX
FINLAY
ABOWD
BEALE

chapter 2

the computer

The Computer

a computer system is made up of various elements

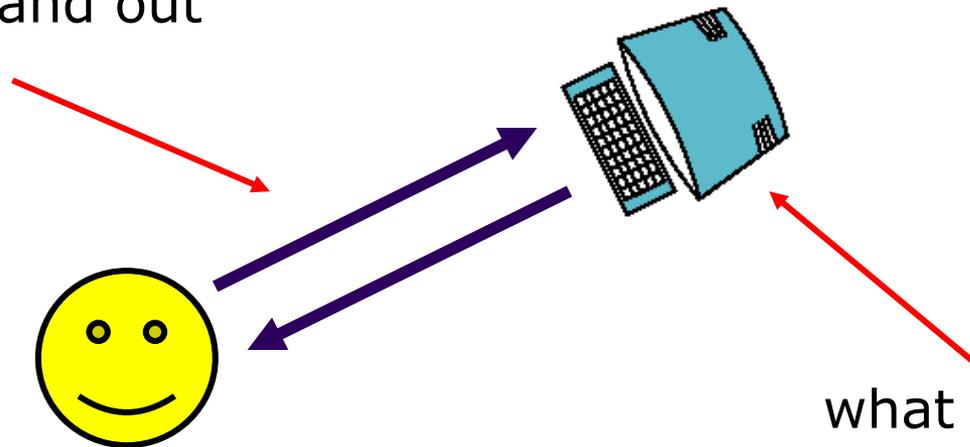
each of these elements affects the interaction

- 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

Interacting with computers

to understand human-*computer* interaction
... need to understand computers!

what goes in and out
devices, paper,
sensors, etc.



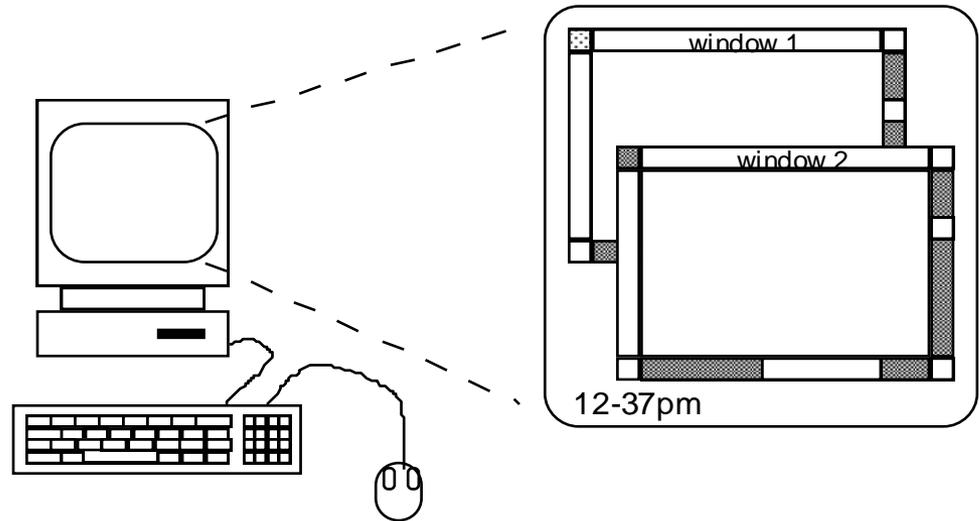
what can it do?
memory, processing,
networks

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

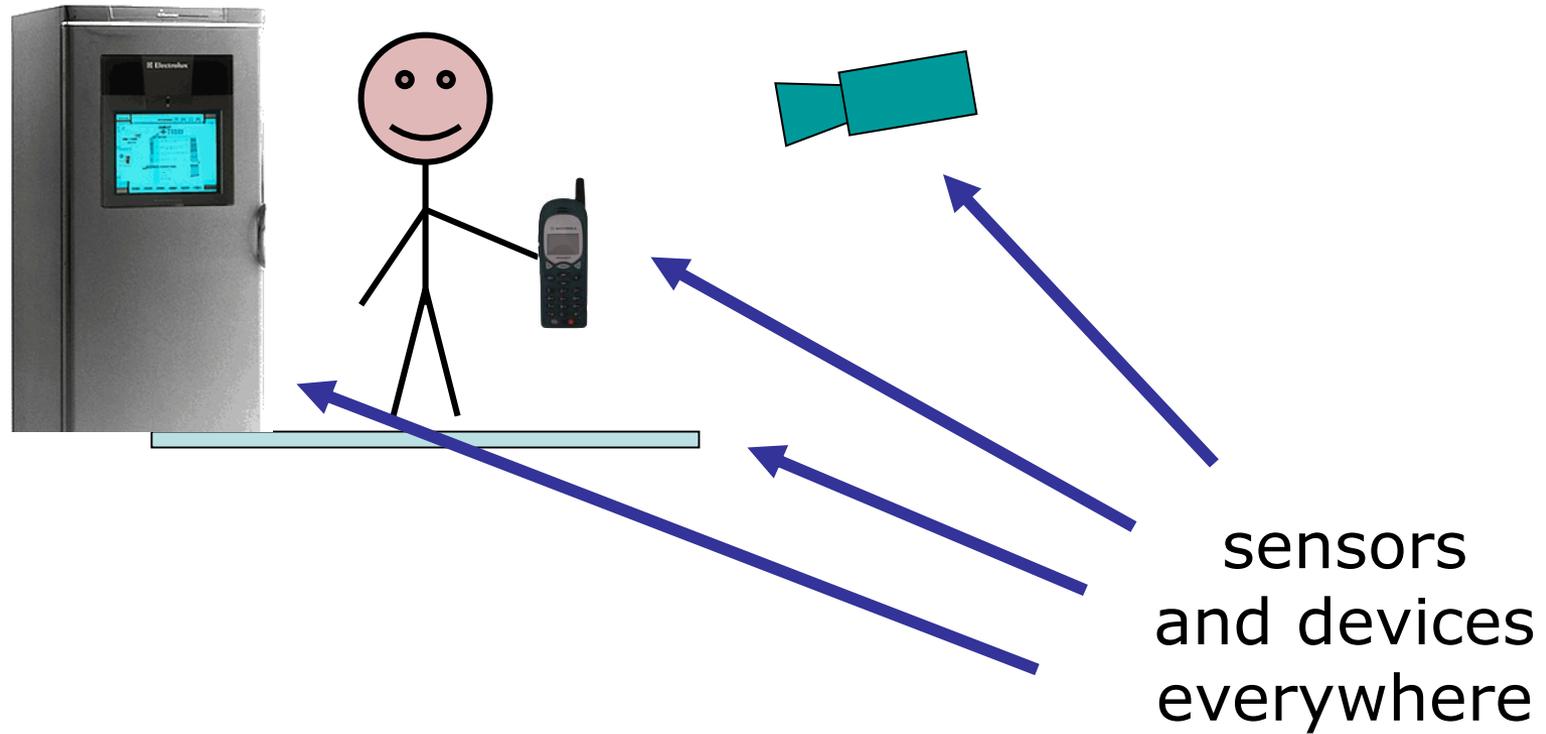
- punched card stacks or large data files prepared
 - long wait
 - line printer output
- ... and if it is not right ...

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

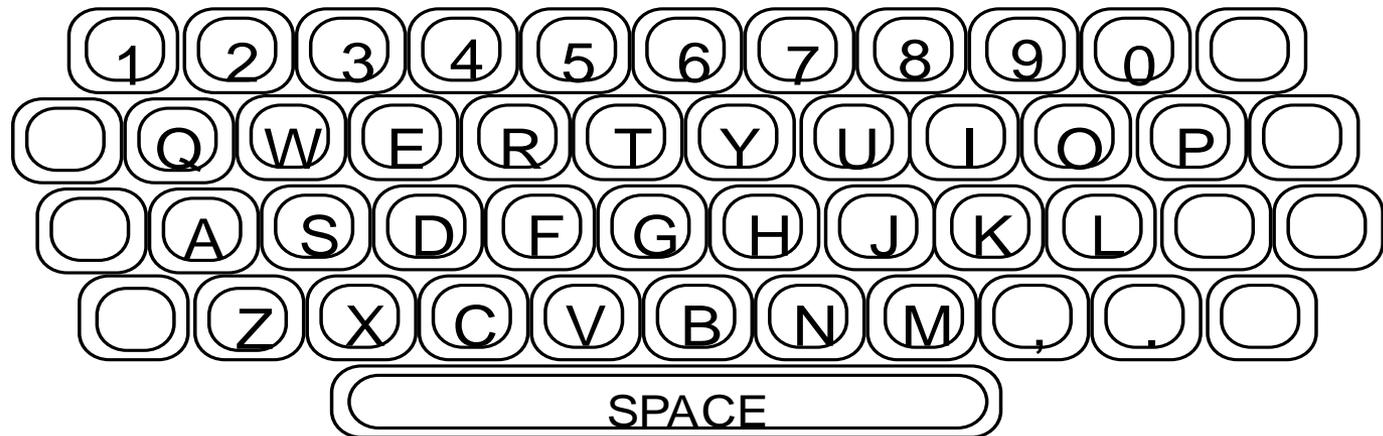
Keyboards

- 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

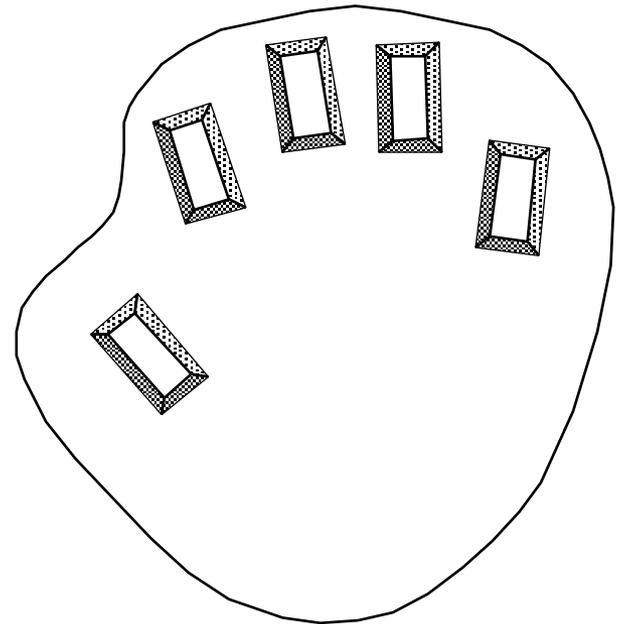
special keyboards

- 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 zhello = 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 digitizing 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

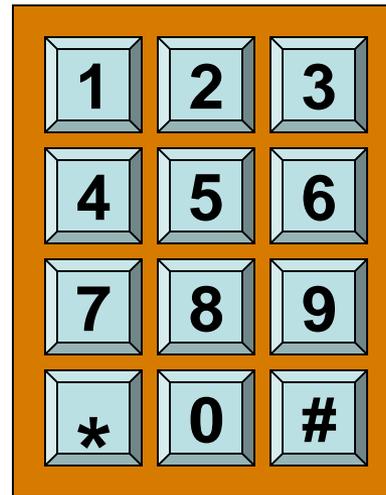


Numeric keypads

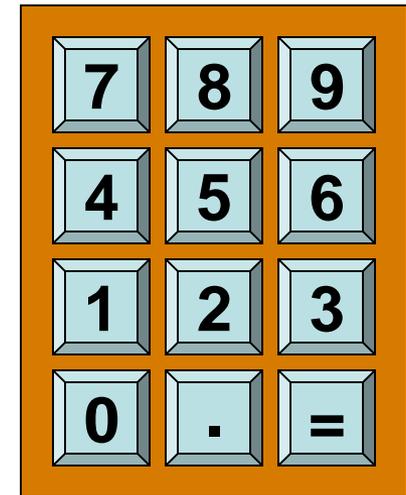
- for entering numbers quickly:
 - calculator, PC keyboard
- for telephones

not the same!!

ATM like phone



telephone



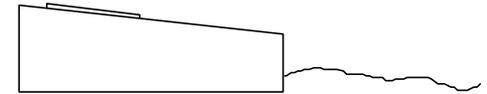
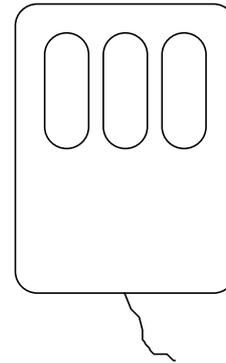
calculator

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.)

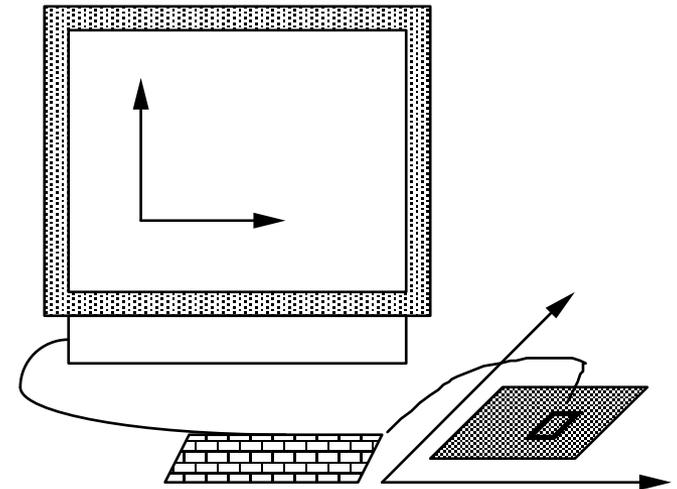
the mouse (ctd)

- 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 upside 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

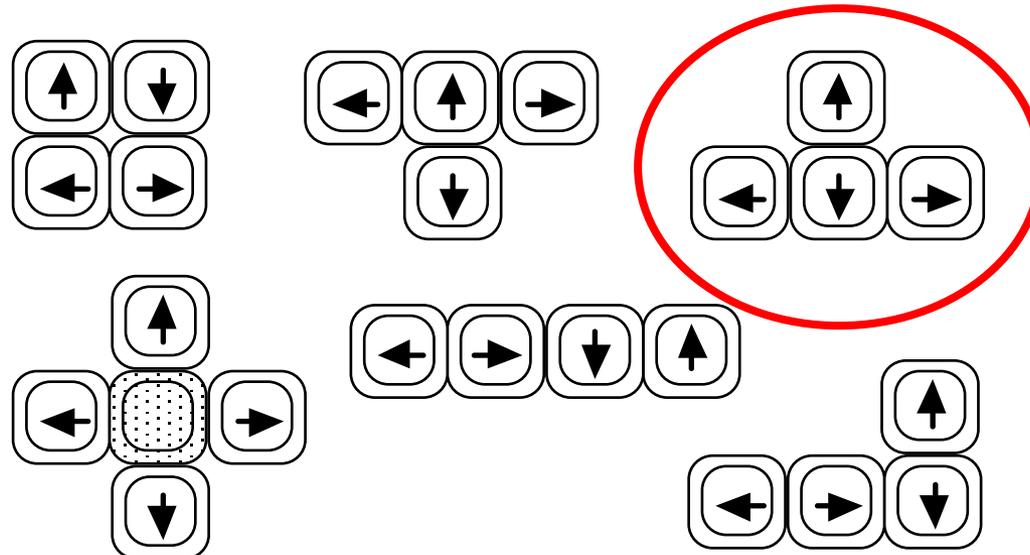
- Mouse like-device with cross hairs
- used on special surface
 - rather like stylus
- very accurate
 - used for digitizing maps

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

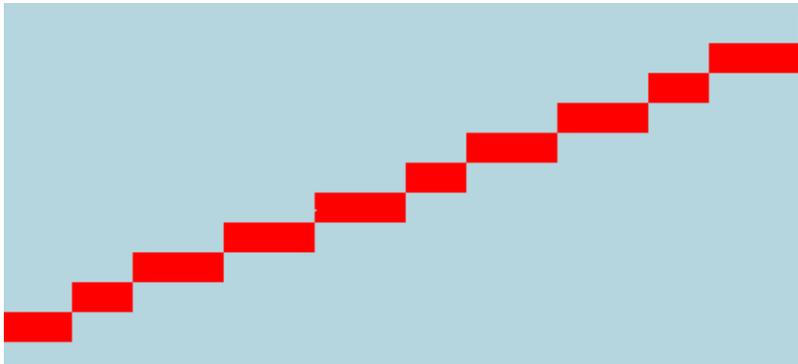
anti-aliasing

Jaggies

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

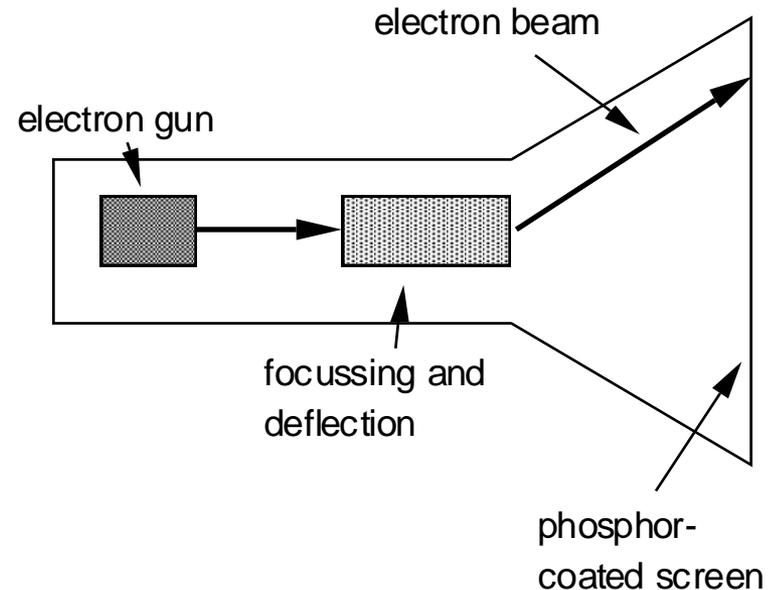
Anti-aliasing

- 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 ($\sim 16\text{kHz}$)
- 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

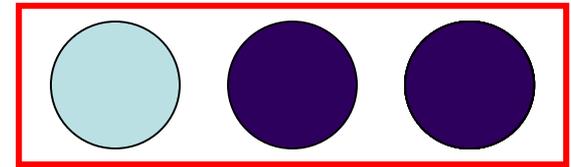
situated displays

- 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 screen
- in all cases ... the location matters
 - meaning of information or interaction is related to the location

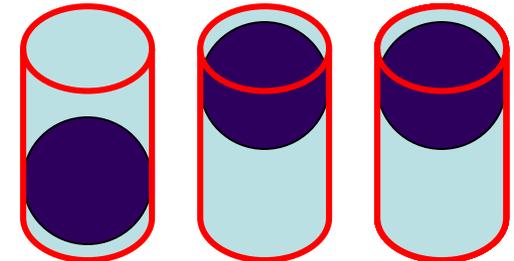
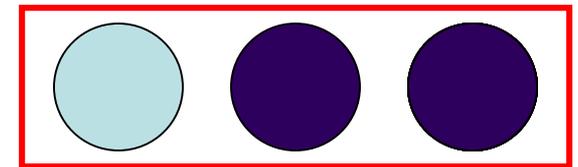
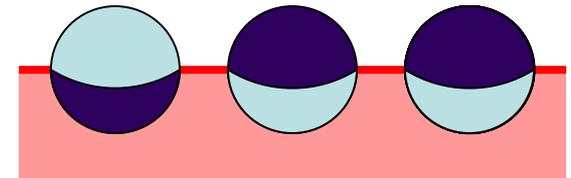
Digital paper

- what?
 - thin flexible sheets
 - updated electronically
 - but retain display
- how?
 - small spheres turned
 - or channels with coloured liquid and contrasting spheres
 - rapidly developing area

appearance



cross
section



virtual reality and 3D interaction

positioning in 3D space
moving and grasping
seeing 3D (helmets and caves)

positioning in 3D space

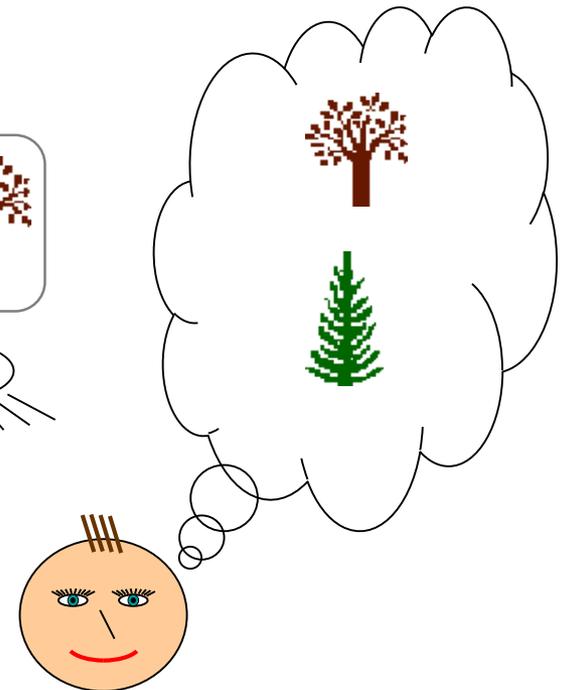
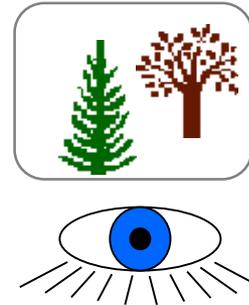
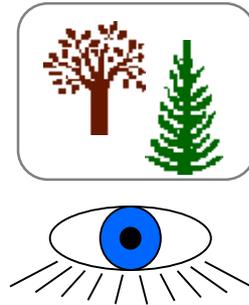
- cockpit and virtual controls
 - steering wheels, knobs and dials ... just like real!
- the 3D mouse
 - six-degrees of movement: x, y, z + roll, pitch, yaw
- data glove
 - fibre optics used to detect finger position
- VR helmets
 - detect head motion and possibly eye gaze
- whole body tracking
 - accelerometers strapped to limbs or reflective dots and video processing

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.

VR headsets

- small TV screen for each eye
- slightly different angles
- 3D effect



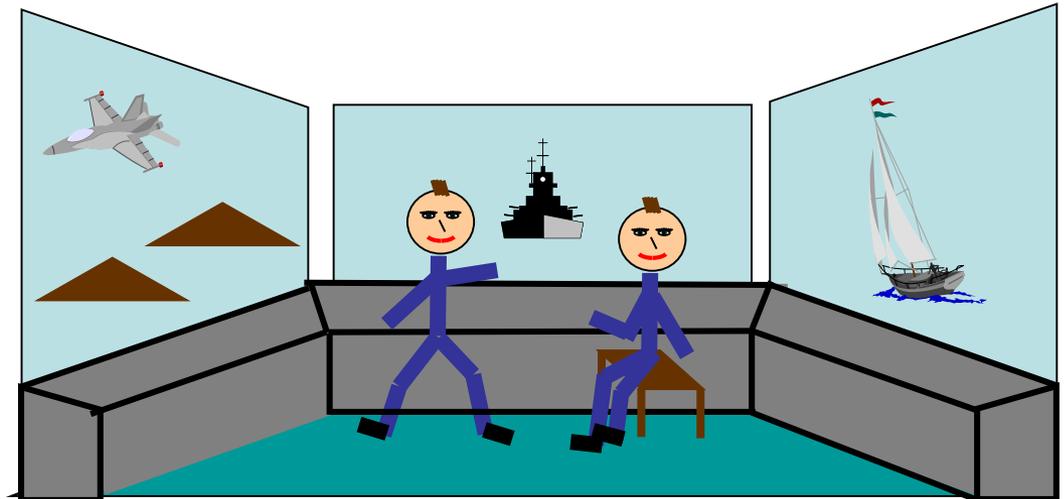
VR motion sickness

- 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



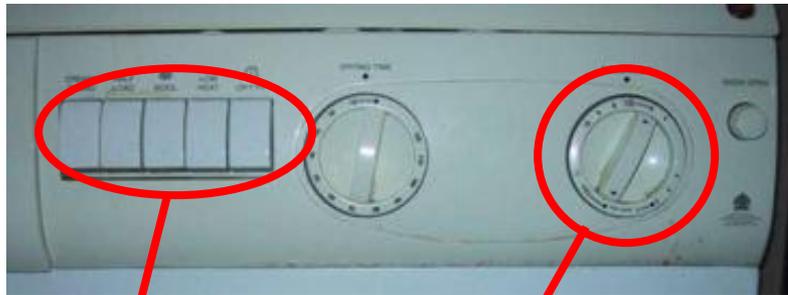
BMW iDrive

- 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

easy-clean
smooth buttons

multi-function
control

tiny buttons



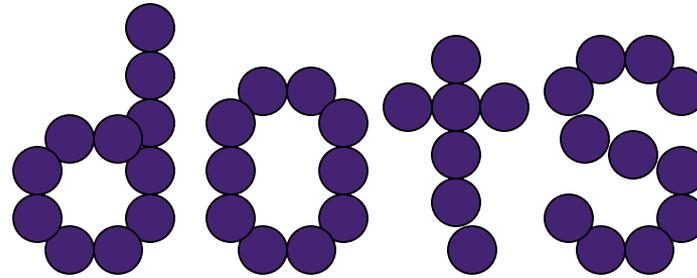
Environment and bio-sensing

- 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

□ §'∞≡↵℞ ⊗↵~ (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

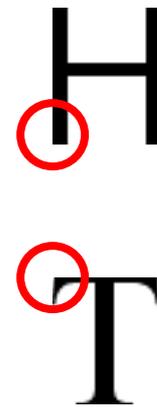
Fonts (ctd)

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 $\backslash\backslash\backslash\backslash$
 - used to identify forms etc.
 - used with scanner and fax to control applications
- more recently
 - papers micro printed - like watermarks
 - 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 $\sim 10\text{ms}$, transfer rate 100kbytes/s
- optical disks
 - use lasers to read and sometimes write
 - more robust than 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: AAAAAAAAAAABBBBBBCCCCCCCC → 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!



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 design

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: ARPANET 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