



## chapter 2

# the computer



# The Computer

a computer system is made up of various elements

each of these elements affects the interaction

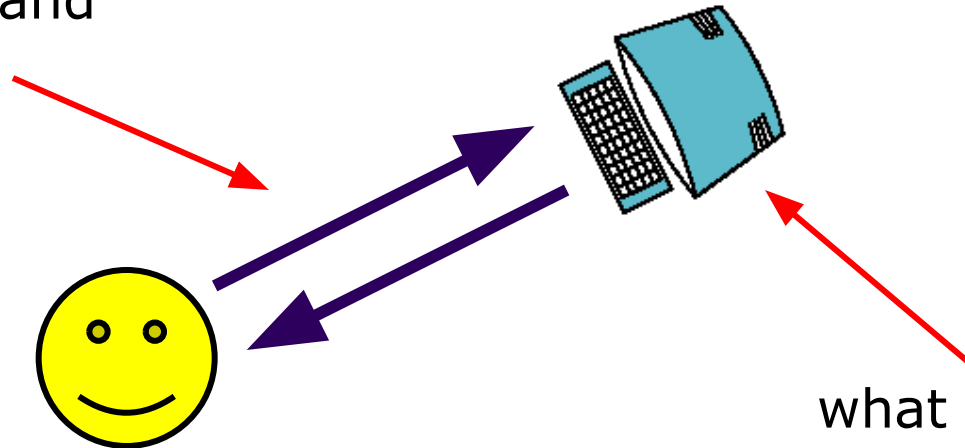
- input devices – text entry and pointing
- output devices – screen (small&large), digital paper
- virtual reality – special interaction and display devices
- physical interaction – e.g. sound, haptic, bio-sensing
- paper – as output (print) and input (scan)
- memory – RAM & permanent media, capacity & 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 ...

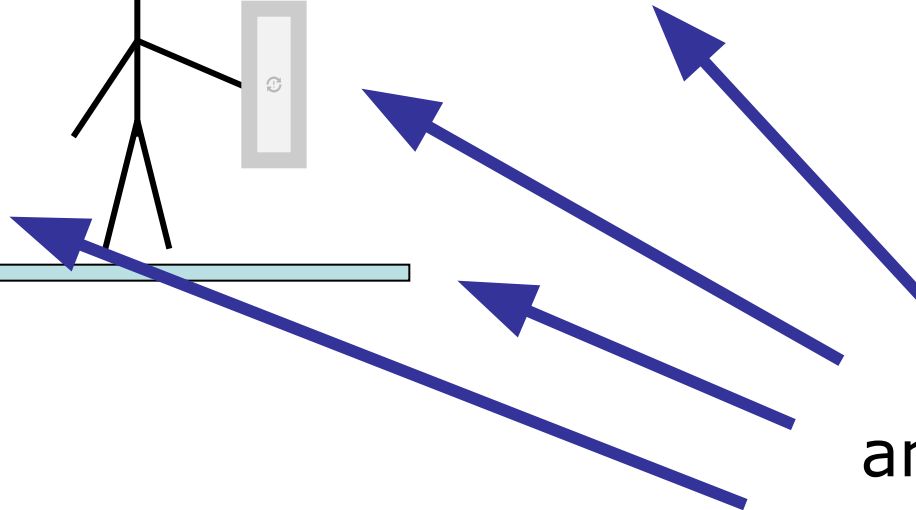
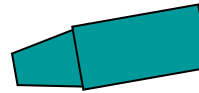
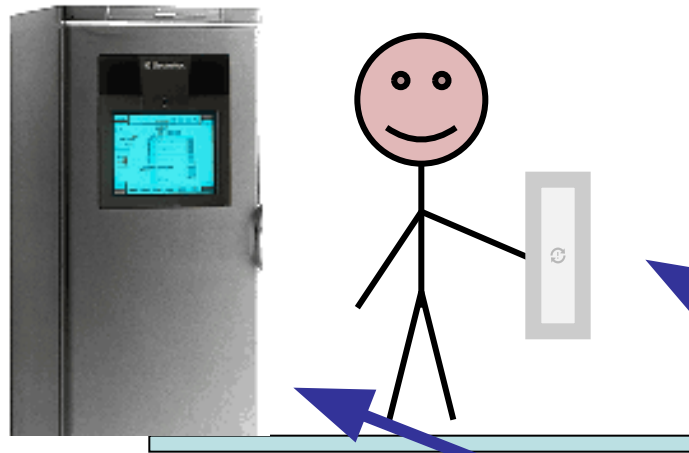
Now most computing is interactive

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

Is faster always better?



# Richer interaction



sensors  
and devices  
everywhere





# 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

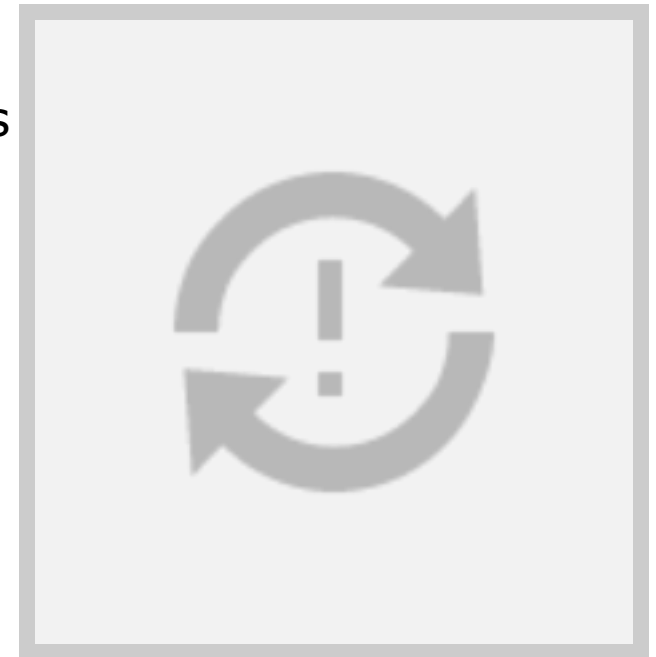
- ideal for portable applications

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

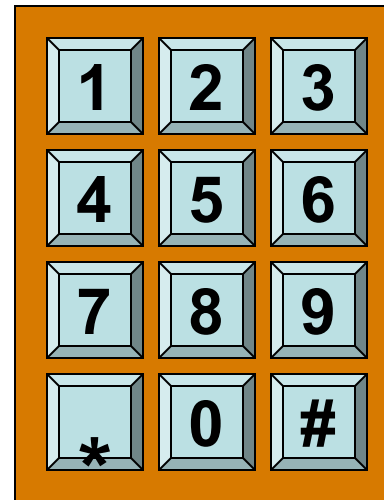


# Numeric keypads

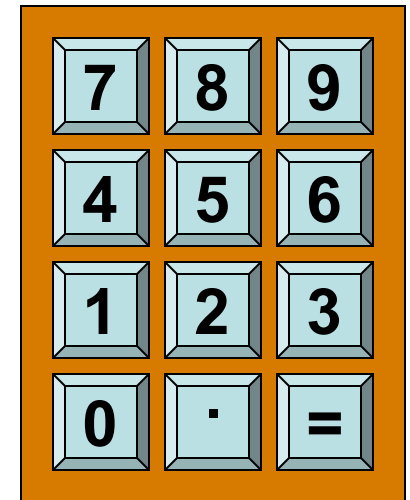
- for entering numbers quickly:
  - calculator, PC keyboard
- for telephones

not the same!!

ATM like phone



telephon  
e



calculato  
r



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)

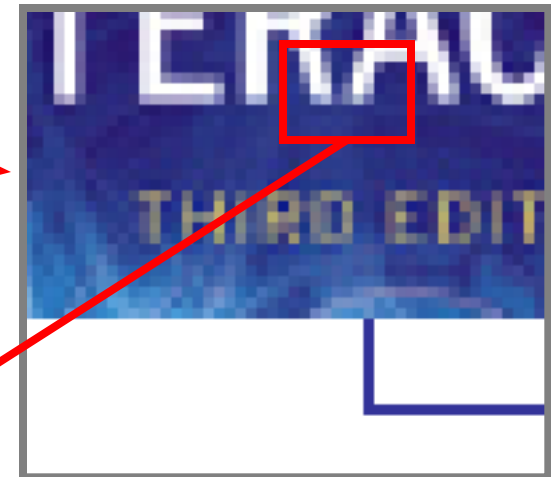
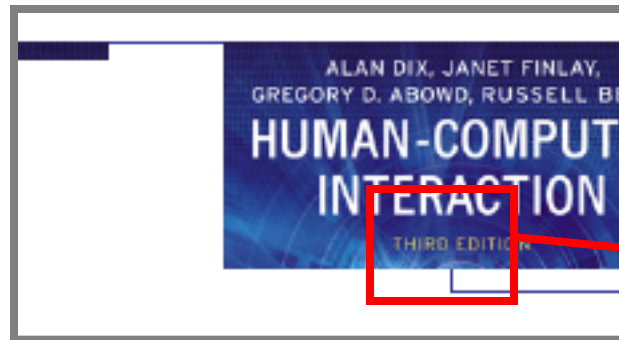
large & situated displays

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



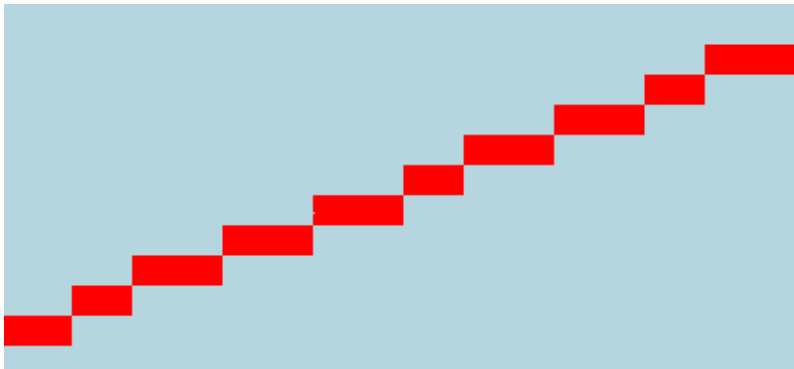
# anti-aliasing

## 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 ( $50\text{Hz}$ - $0.5\text{MHz}$ ). 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 dedicated 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



# Hermes a situated display

small displays  
beside  
office doors



handwritten  
notes left  
using stylus



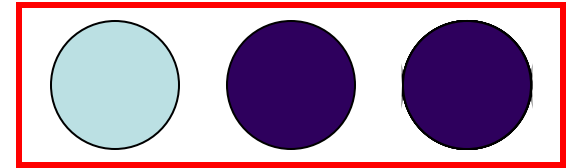
office owner  
reads notes  
using web  
interface



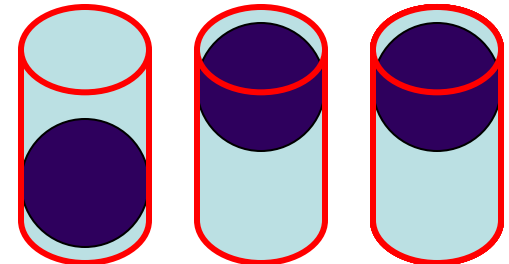
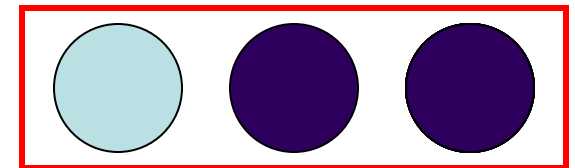
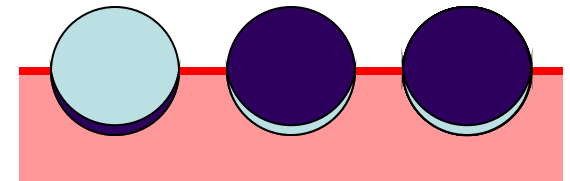
# Digital paper

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

appearance



cross section





# virtual reality and 3D interaction

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



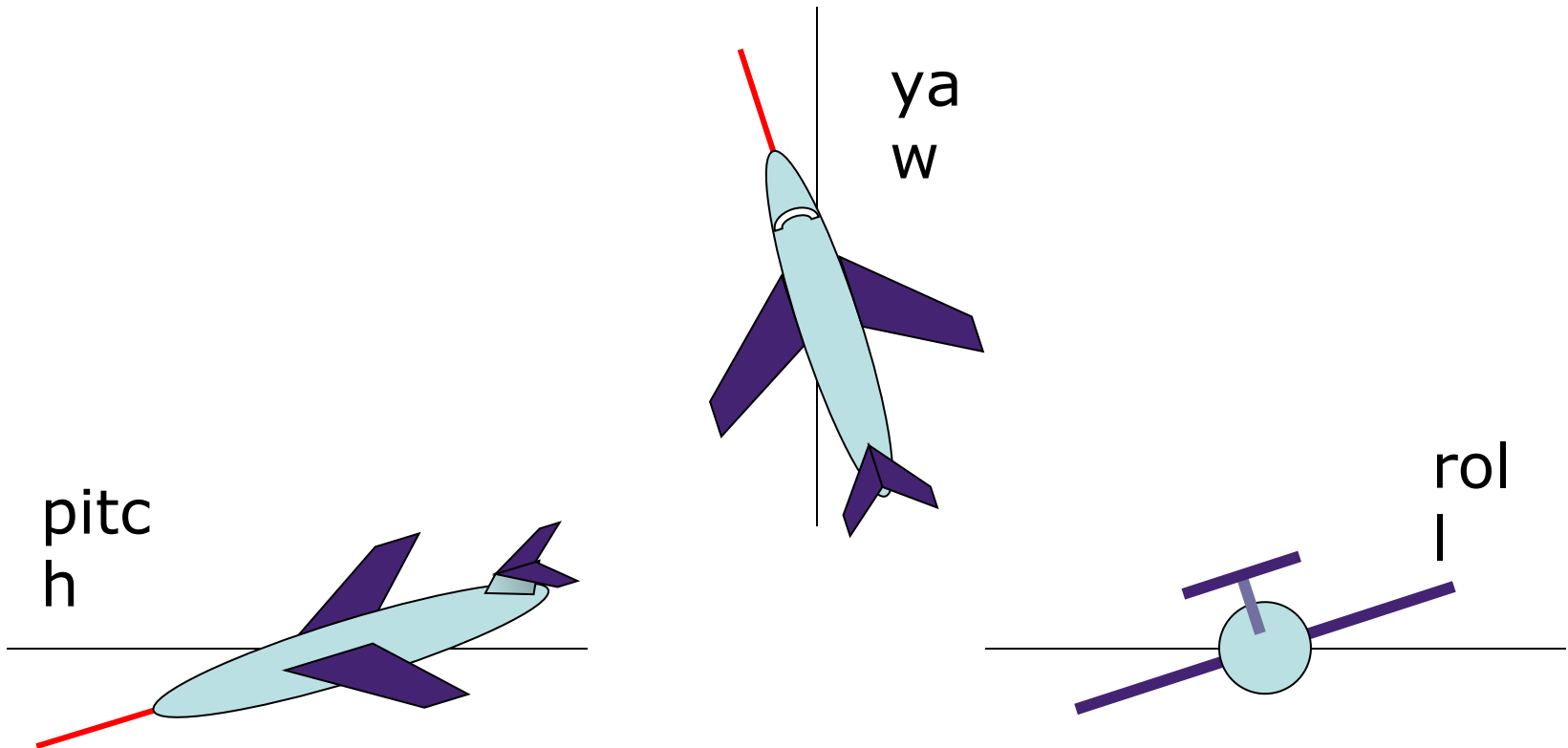
# positioning in 3D space

- 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





# pitch, yaw and roll





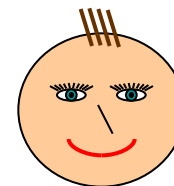
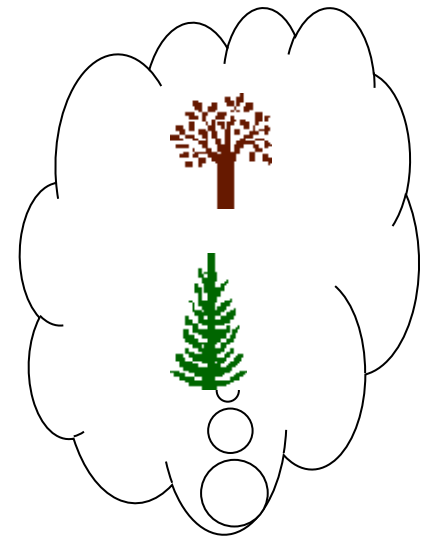
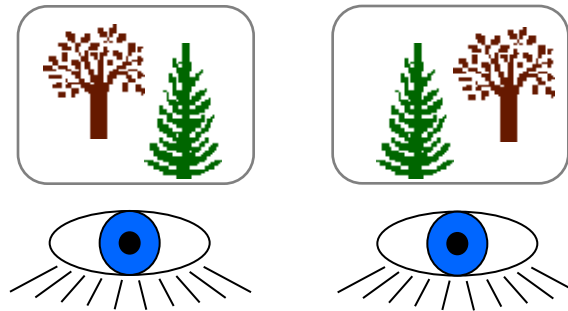
# 3D displays

- 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.



# VR headsets

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





# VR motion sickness

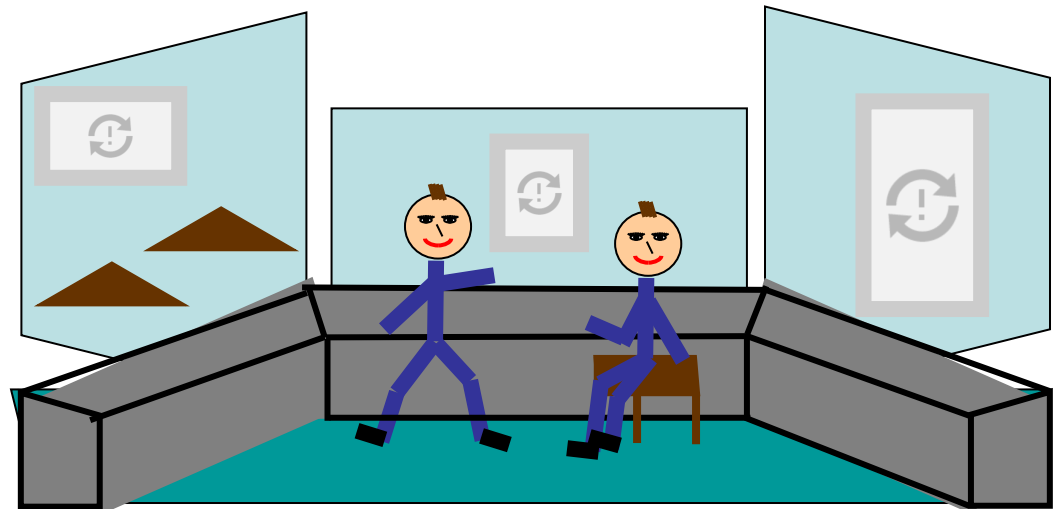
- time delay
  - move head ... lag ... display moves
  - *conflict*: head movement vs. eyes
- depth perception
  - headset gives different stereo distance
  - but all focused in same plane
  - *conflict*: eye angle vs. focus
- conflicting cues => sickness
  - helps motivate improvements in technology





# 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

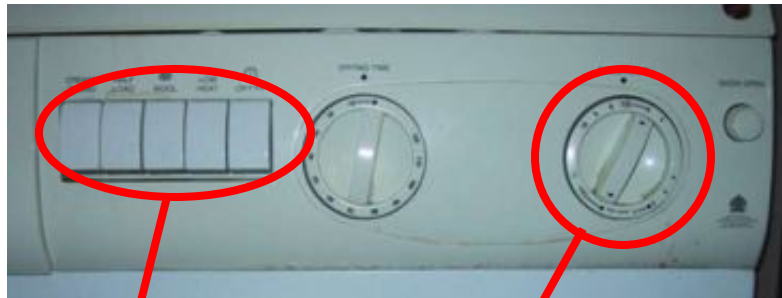
- for controlling menus
- feel small 'bumps' for each item
- makes it easier to select options by feel
- uses haptic technology from Immersion Corp.





# physical controls

- specialist controls needed ...
  - industrial controls, consumer products, etc.



large buttons

clear  
dials

tiny buttons



easy-clean  
smooth buttons

multi-  
function  
control





# 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

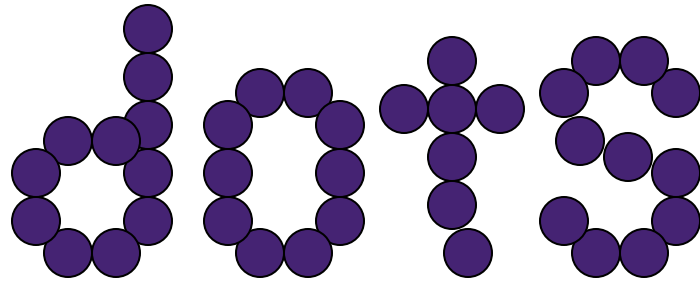
print technology

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

-  x α ≡ √ ∫ € ⊗ √ ~ € (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 /\\V/\\\\
  - 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,  $\sim 600$  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: AAAAAAAAAAABBBBBBCCCCCCCCC — 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: DARPA NET 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