

Computer Graphics

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Spring 2021–2022

Outline

- 1 Homework
- 2 Graphics Input Devices
 - Introduction
- 3 Graphics Output Devices
 - Introduction
 - Displays

To Do

- ➊ Go to Wikipedia <http://en.wikipedia.org/> and read the pages on Colour Spaces (http://en.wikipedia.org/wiki/Colour_spaces), Optical Illusions (http://en.wikipedia.org/wiki/Optical_illusion) and M. C. Escher (http://en.wikipedia.org/wiki/M._C._Escher)
- ➋ Buy Hearn, Baker and Carithers and read all of Chapters 1 and begin reading Chapter 2
- ➌ Sort out your Linux account / password

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Input Devices: Introduction

- Piece of hardware by which a user enters information into a computer system
 - mouse, trackball, joystick, voice systems, touch screens, others
- A major goal in designing graphics software libraries is device-independence – enhances portability of the application
- To provide a level of abstraction for graphics input or output, most graphics systems support logical devices
- These shield the application from the details of the physical devices available
 - Physical device: a piece of hardware that provides a **response** to a **stimulus**
 - Abstract this idea now to software components

Logical Devices – §20.2 of *HBC*

- Locator: to indicate a position or orientation; inputs a position (x, y) typically via mouse or crosshairs.
- Pick: to select a display entity (e.g. icon); identifies a displayed object and *not* just an (x, y)
- Valuator: to input a single “value” – maybe from a kbd or a dial
- String: to input text
- Choice: to select from a set of possible actions or choices e.g. integer value from buttons on a box or via a menu selection with lightpen, crosshair or digitiser

Locator Devices

- Absolute or Relative
 - Absolute: report position with regard to an origin e.g. data tablet, touch screen
 - Relative: report position w.r.t. their former position e.g. mouse, joystick, Wii remote controller
- Direct or Indirect
 - Direct: user points directly at screen using light-pen or finger on touch screen e.g. smartphone, ATM (cash machine)
 - Indirect: user moves cursor on screen with device not on screen e.g. mouse or joystick, Wii remote
- Discrete or Continuous
 - Continuous: smooth hand motion e.g. mouse, trackball
 - Discrete: define action e.g. cursor-control keys

Virtual Reality / Voice Recognition

- Virtual reality has generated a completely new set of input devices:
 - Dataglove
 - Pressure pads
 - Digitizing arm
 - Various other tactile and gesture input device
- Much research is currently in progress to devise better ways of interacting with the machine
- Voice recognition and natural language comprehension are also currently the focus of much research

Keyboard and Mouse

- Keyboard was original general input device
- Mouse was developed at SRI labs in 1963



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Graphics Tablet

- Artist's tool
- Very fine resolution, very precise measurements
- Popular in East Asia as device for entering CJK (Chinese, Japanese, Korean) characters
- Replacement for the computer mouse as a pointing device??



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Digital Camera

- Raster (line-by-line) Scan
- Matrix of charge-coupled device (CCD) or complementary metal-oxide semiconductor (CMOS) light sensors
- Sensors produce digital output proportional to light intensity of each of colour bands
- Good light sensitivity, resolution
- Monochrome, colour, smart (*framegrabber* for machine vision applications)

Digital Scanner

- Line sensor moves over the image
- Very high resolution
- Colour sensitive

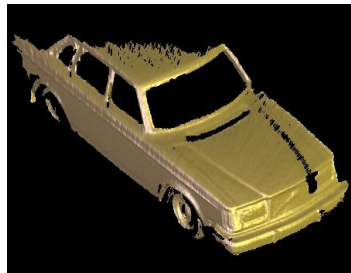
Laser Scanner

- Sweeps scene with laser beam
- Uses “radar” technology to detect distances
- Builds 3D surface representation of object from *point cloud*
- No colour!



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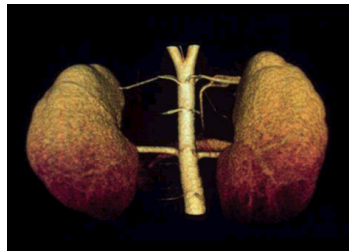
CT Scanner

- Computed tomography (prev. Computed Axial Tomography)
- Captures a series of 2D X-rays and is combined by computer into a 3D density matrix (volumetric rendering)



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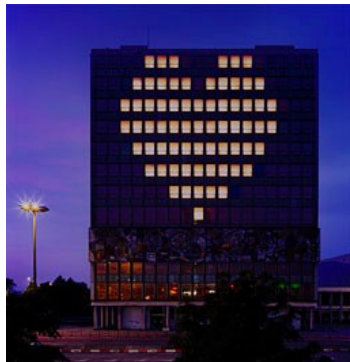
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Types of Output Device

- Cathode Ray Tube (CRT)
- TFT (Thin Film Transistor) Liquid Crystal Display
- Printer
- Projector
- Virtual Reality Headset e.g., Google Cardboard
- e-Paper
- Holographic Dome
- Virtual retinal display (VRD) (or, retinal scan display)
- Blinkenlights (below)

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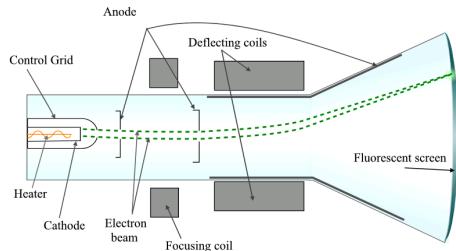


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Cathode Ray Tube

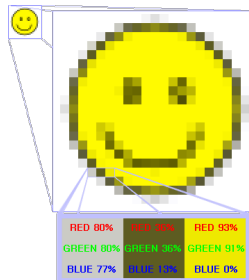
- Horizontal and vertical deflectors focus an electron beam emitted by an electron gun on any spot on a phosphor coated screen



- Maximum number of points, or pixels that can be displayed without overlap is called the resolution, e.g. 1280 x 1024 or 1024 x 768
- Three types of phospho(u)r on screen: RGB; three elec. guns needed, one for each colour
- Due to decay of light, need to refresh screen (60 - 120 Hz)
- Continuity lost at refresh rates below 24Hz (jerkiness)

Raster Scan Displays

- Treat screen as matrix of *pixels* and combine combinations of pixels to create characters, lines, shapes, etc.
 - Electron gun fires electrons at screen row by row
 - Interlacing trick when refresh rates are slow
 - Interlacing **demo** in context of `png` files
 - HD TV: 1920x1080 pixels;
UHD “4K” TV: 3,840x2,160 (=8M) pixels
- See also **How a Television works**¹



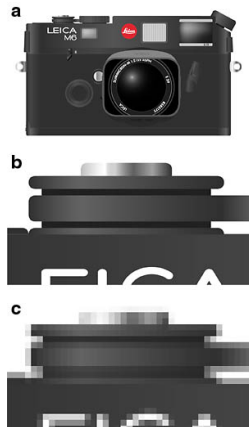
¹With thanks to Cathal Foley.

Raster Scan Displays (contd.)

- Screen is “controlled” by *frame buffer*, a matrix data structure of memory comprising information to be displayed
- Each pixel's colour, intensity are stored in frame buffer
- Using 24 bits for each pixel (8 bits for each colour)
→ $2^8 \times 2^8 \times 2^8 = 16,777,216$ colours in total
- 24 bits / pixel with a 1024 x 1024 display: $1024 \times 1024 \times 3$ bytes = 3 Mb (megabytes)

Random Scan (Vector) Displays

- Draws *exact* lines, rather than series of dots that approximate them
- Used quite a bit for plotters ($X - Y$ plotters)
- Random scan *displays* not used much any more
- Aside: pictures stored using vectors are more space efficient and scale much better; picture to left is detail of a camera; (b) is vector-based enlargement, (c) is raster-based enlargement



- [SVG example](#) [Euro Sign: SVG](#)

Flat Panel Displays

- Plasma panels (emissive) (see [wp:Plasma](#))
- TFT / LCD (nonemissive) (see [wp:TFT](#) and [TFT monitor](#))