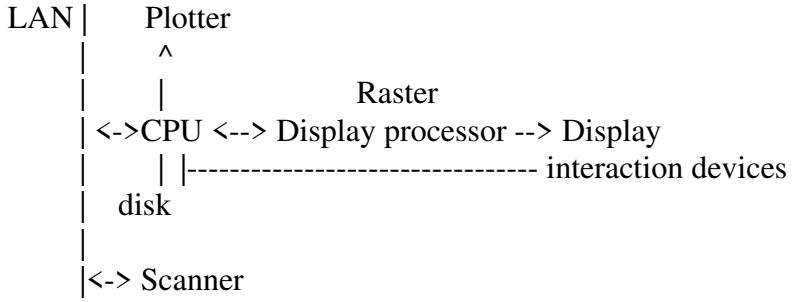
1996-10-30 Bo Nordin (bosse&cb.uu.se)

Lecture notes, computer graphics (F02) (Foley 4, Foley 8.1)

Agenda
Input
Output, screens
Hardcopy
Discussion & future trends

Overview of a interactive graphical system
(From Foley, p 130):



Harware for ICG:
screens (size, resolution, colour, 3D)
electronics (CPU, memories, buses)
interaction (mouse, ...)

Input

Input devices are of two kinds:
- (interactive) user tools (mouses, keyboards)
- conversion of scenes to digital images (scanners, cameras)

Interaction tools in turn are of two kinds:
- direct:
  - o light pen
  - o touch screen
- indirect (*echoes* (*visual feedback*) on the screen):
  - o mouse, relative
  - o arrow keys (relative)
  - o data tablet or digitizer, an area with detectors, absolute precision delivered to the software, high precision (CAD)

Data tablets, digitizers can be used to digitize existing line drawings manually - but slow and tedious, doesn't work for half-tone or colour images.
Conversion of scenes to a digital image may be done with:
- scanners
- video (TV camera and a digital frame grabber).

Both use CCD (charge-coupled-device) technique

Keyboard text input: ASCII code (coded vs. unencoded) *chording* for fast access!! PC/X code arrow keys for positioning: (Motif requires that all functions be accessible from the keyboard, too): *discrete,* all other *continuous.* QWERTY designed to slow down!

Mice: relative, differ in how motion is detected: mechanical (roller) or optical. Control-to-display (C/D <-> hand/display) ratio (need not be constant): rapid movement -> faster -> small ratio (same technique can be used for discrete devices)

Trackballs: up-side mouse

Joystick: often controls the *velocity* of cursor movement rather than absolute cursor movement

Data tablet: (absolute)
Movable *stylus* or *puck*, size from 15x15 cm's up to 200x200 cm's or event more. Electrical sensing mechanism for the position. Signal strength is used to determine pos. & roughly how far from the tablet the stylus is (*far*, *near*, *touching*). Pos. is echoed on the screen. Position, Button status, and nearness state are sent to computer when stylus tip is pressed against the tablet or when a button on the puck is pressed. IMPORTANT: a digitizer is NOT a mouse. Cross-hair cursor in puck. Relevant parameters: resolution, linearity, repeatability, accuracy, speed, and size. These parameters apply to mice as well but are less important when the used only to position a cursor on the screen (feedback!).

voice recognizers: still simple

3D interaction:
Polhemus 3SPACE 3D position and orientation sensor (digitizing 3D objects).

dataGlove (hand position and orientation as well as finger movements). Computer image of the hand.

head-mounted stereo display (VR) (Polhemus sensor on the head, DataGlove)

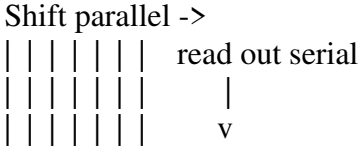
example of 2D->3D adaption: mice (with shift), joystick with twisting motion.

More about the *use* of intraction & the design of interfaces in later lectures about X/Morif.

Scanners:
The difficult part is the display (other than simple dump of the same image - mention pixel-based vs. geometry-based). If we want to be able to rotate, etc. *parts* of the image we must first extract it - this is the purpose of image analysis. Scanned images are usually in bitmaps (raster), i.e. suitable for display. But in order to use images in an interactive manner analysis and image understanding is needed. *vectorizing* (paradox).

An area of silicon elements accumulates a charge that differ with light intensity. Each element corresponds to one pixel. There are different sizes, for instance 2048x2048 (can be subsampled). You are free to select a wavelength band for the light.
Ex: colour scanners, b/w scanner, fax (vector), satellite (vector).

CCD:
A thin slice of silicon covered in electrodes that constrain the movement of charges within the device. Photons absorbed in the silicon generate single electrons that are held within a pixel by the voltage applied to the electrodes. The info is stored in an "array" that can be shifted out and converted to digital format:



Frame grabber (from video):
CCD (or electron tubes for higher precision).
Generates analog signals (TV format). In order to read this to permanent storage a frame grabber is required.
An image typically consists of 525 lines (northern Europe). The analog info for the TV set contains special pulses which defines the functions *new line* and *new frame*.
Ex: to get a 256*256 image sample 256 times along one line. When a new line pulse is received start sampling for the next line. Repeat 525 times. Convert the measured analog values to digital. Then resample to 256*256.
Relevant parameters: size, depth (# of bits),linearity. photometric/geometric resolution
high speed vs. high accuracy.

Output
Output devices also of two kinds:
- displays (screens)
- hardcopy (paper)

Displays:
Vector vs. raster -> aliasing

Features (see Foley, page 141 for a summary):
# of addressable points (pixels)
resolution - distance between 2 dots that can be distinguished.
stability (flicker-free or not) - avoided (reduced) by increasing the refresh rate (to above what the eye can see).
b/w - colour (monochromatic vs. colour)
bit depth - 1, 8, 24
size (screens): 15-21 inches

CRT:
Monochromatic CRT's are essentially the same as those used in b/w television sets. Most screens today ar CRT (Cathode-ray tube). One or several electron guns emits a stream of electrons towards a phosphor-coated screen, accelerated by a high volage applied near the face of the tube. When they hit, the phosphor emits light. The electrons are directed towards a particular point on the screen by the magnetic fields produced by the deflection coils. Forced into a narrow bream by a focussing device. The phosphor's light decays -> refresh at least 30 t/s.
(When electrons hit some energy becomes heat, some transferred to the electrons of the phosphor atmos -> higher quantum levels When returning to lower light is emitted
fluorescence - light emtitted as very unstable electrons lose energy while hitting)
phosphorescence - light emitted by stable electrons after removing the beam).
)
refresh rate: # of times per second the image is redrawn (independent of image complexity)
persistence: time from removal of excitation until phosphorescense has decayed to 10%.
(10-60 microseconds)
critical fusion frequency (CFF): refresh rate above which the picture stops flickering
horizontal scan rate: # of scan lines / second that the CRT can display (ref rate * # scanlines)
bandwidth: # of times the gun can be turned off/on 1000x1000 often 100 MHz

RGB: uses shadow-mask CRT. Inside of the tube's viewing surface is covered with closely spaced groups (*triads*) of red, green, and blue phosphor dots. Perceived as a mixture. *shadow mask* (a metal plate with many small holes) is mounted close to the viewing surface.
delta-delta CRT
pitch: the distance between the centres of the triads (0.21 - 0.60 mm)
Problem: Bulky

Q: Why not use long-persistence phosphors (decrease the fusion frequency) routinely?

Plasma panel:
Flat screen (<10cm's) used in portable computers. Emits light created by discharges in inert gases. Three glass screens, 2 outermost transparent metal electrodes, middle one gas-filled holes. One glass vertical electrodes, one glass horizontal electrodes.Increasing voltage exits electrons in a gas and plasma is created. When electrons return energy in the form of photons is produced and the gas emits light. AC/DC variants exist.

LCD:
Liquid-crystal display. Probably the future of flat screens (watches, computer games, calculators). Unlike other monitors, an LCD monitor does not emit light but rather reflects it (cannot be used in the dark),
Made up of six layers: two polarizers (hor/ver) two grid wires (hor/ver electrodes), a reflective layer, and a liquid with crystals. Based on the polarization of light.
The direction of light passing through the lcd layer is rotated 90 degrees. When crystals are in an electric field, they have no polarizing effect, the light is stopped in the rear polarizer.

matrix-addressing scheme

Colour is achieved by colour filters (rgb).
+: low power consumption, flat, light, colour, low cost
-: poor contrast

Active matrix LCD panels have a transistor at each grid point.

Electroluminescent::
Similar to plasma panels Layer of EL material (ex. zinc sulfide doped with manganese => yellow) that emits light when in a high electric field. Outside the phosphor there are two dielectric layers
Colour EL screens are availabe (uses 3 different phosphors),
+: portable very bright, power consumption < plasma panel
-: power consumption > LCD, expensive

History, 1st graphical screen (&calligraphic) (~1965)
IBM 2250 >100000. Electron beam follows the shape of objects. Vector graphics.
refresh 30 Hz.

CRT, vector, must be refreshed, needs display buffer & controller. Display controller repeatedly cycles through the display buffer. Refresh rate depends on the complexity of the image.

History, storage tube (~1968):
No refresh. Memory in the tube (no phosphor). No flicker. Cannot erase selectively. Hard to

program (Trivia: Newman/Sproull: easy to program). Dynamic motion/animation impossible. Tektronix <$5000

History, Xerox:
early 70's, personal computer (Alto) based on the following assumptions:
- drastic decrease in price. All IT people will have a personal computer.
- networks to share expensive peripheral units
- the human-computer interface will be graphical
- raster technology.

Hardcopy:
Features (see Foley, p 134 for a summary):
Dot size - diameter of a dot
Addressability - # of dots per inch (DPI)
Resolution - # of lines that can be distinguished per inch
Grey-level resolution (Contrast??) often only 2 levels. Eye is deceived (dithering)

Graphics on a printer is not easy. Rasterization -> bitmap!! Languages like PostScript. Standardization is a problem.

Before sending a file to a printer it must be converted to the language of the printer. After this the file is sent to the printer. The printer has a processor which converts from the language to a bitmap. If there is no such processor you write one yourself (or buy a new writer).

Dot-matrix printers (raster):
Use a print head with from 7 to 24 pins.
Sets dots on the paper. Scan conversion doesn't exist.
- slow, bad resolution + cheap

Pen plotters (vector)
Flatbad, desktop, drum
Draws lines, large sheets -slow
History: Calcomp 1961 (dum plotter) $5000

(
Electrostatic plotters:
Move the paper over a row of dots. Cole is attached to the paper with electric fields. Must do scan conversion yourself. ~200 DPI (2048 / A4)
)

Ink-jet plotters:
Uses yellow, cyan, magenta, (and black) -> all colours
-slow, expensive +good colour
~300 DPI, sorted graphics.
History: origin in an idea in Lund 1965. world's first in Lund 1972.

Laser:
either monochrome or eight-color device. Postscript
scan a laser beam across a positively-charged rotating drum coated with selenium. Areas hit by the beam lose their charge. (remains only where the copy is to be black).A negatively charged powdered toner adheres to the pos. charged areas of the drum and is transferred to the paper. In colour this is repeared 3 times.
Micro-processor for scan conversion. RAM (1.1 Mb for A4).

Camera:

Discussion: only film & ink-jet can capture a wide range of colours, the others are on/off for the 3 or 4 colours. *Control of colour* across devices is very tricky.

History, character graphics:
60's

Raster-scan display systems (Foley 4.3)
graphics display processor (scan conversion, moving, copying, etc.) - how much of the work is done in this and in a graphics package (software?).
also called graphics controller or display co-processor

RAMsize ex: 1280x1024x 8 = 1.25 Mb / 1280x1024*32 = 5 Mb

no graphics controller (4.3.1):

Simple system: slow scan conversion

A specialized display processor (Foley p. 146 -> possibly lecture 3 about software)

video controller (also 4.4)

0 - Xmax och 0 - Ymax: ex 1280x1024, 60 Hz 12 ns => multiple pixels
+ horizontal/vertical retrace times!!
24 bits per pixel for RGB (never needed on the screen simultaneously, though, since the screen is at most $\sim 2^{20}$ pixels).
often wanted feature is to be able to change the visual appearance without changing the image itself (dynamically changing contrast).
LUT (VLUT) - index in a table (several tables)

interlaced vs. *non-interlaced*
monochrome, RGB, NTSC
composite video; sync with the green

High-end system:
# of bitplanes
1 b/w
8 grey / colour without LUT (8x8x4, bad) / colour with LUT (ok after optimization)
24 full colour
X 24 double buffer (draws one image while another is being displayed - simple animation)
X 24 Z buffer (For 3D)
X 8 alpha-buffer (transparency)
X 2+2 menus, pointers, bgr
X 2 control (windows, etc.)
This sums up to 86 bitplanes or 20-30 MB)

How do we measure the performance of graphics systems:
# of vectors / second
bitBlt (moving blocks of bits)
# of polygons of a certain size / sec
3d volume that can be updated / sec
But what to measure changes as the field as a whole changes

Specialized graphics hardware:
WHY?
the "wheel of reincarnation" (Myers, Sutherland 1968):
tradeoff specialpurpose <-> generalpurpose (RISC)

Must program at low-level (micro-code) in order to fully exploit special hardware.
But in order to program quickly/effeciently highlevel languages with standard libraries are needed...
Standard can be built into hardware
But both HW and SW is constantly developing (very dynamic area)...

Discussion

The computing requirements for interactive graphics is *extremely high*.
Out demands increase faster than computer power increase.
This means that special hardware is still meaningful

The term *real-time* i CG means 1 sec at most to update the screen
(true animation 25 images per second).

Hardware performance development

General: 30% / year
Increase in memory capacity 100 times in 10 years

The future - trends

Demands (volume vizualization):
Data volume 512x512x512x3. classification/gradients 30 op/voxel,
screen update 20 times/sec (ca 10000 000 000 op /sec)
100-1000 times today's computers
Parallel solutions
Pipelined

Cheap chips for PC (home market) big: 160 000 Gouraud shaded polyogons/sec 4000kr
Extreme high performance (&high cost) parallel architectures.

We no longer have to worry about memory (cheap, cf. Epsilon).

Flatscreen (4 types): prompted by the HDTV requirements (home market!!)
1 - plasma (Fujitsu) 42" HDTV 2000 000 pixels (1998) (Mitsubishi, NEC)
2- micro tubes or beams move parallel and turned 90 degrees
3 - tilting mirrors (Texas Instruments)
4 - LCD / TFT (expensive though)