

Computer Graphics studies the means to model, represent, manipulate, and display geometric objects with computers.

Raster Graphics

A raster display consists of a matrix of dots, called *pixels* (picture elements). A *pixel* is the smallest addressable unit on the display surface. Workstation screen normally consists of $1280 \times 1024 = 1.2\text{M}$ such pixels. Raster devices include the monitor of a computer, the laser-jet or ink-jet printer.

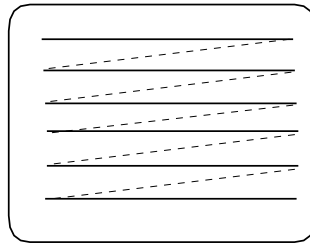
The color values of all pixels are stored in the *frame buffer* (*refresh buffer*). Each row of pixels is called a *scan-line* or a *raster line*. Another type of display devices are *vector* devices, such as the pen plotter and vector CRT. We are mainly interested in raster graphics with *dynamic* display.

Dynamic display means that the display needs to be refreshed in order to keep a pattern being displayed.

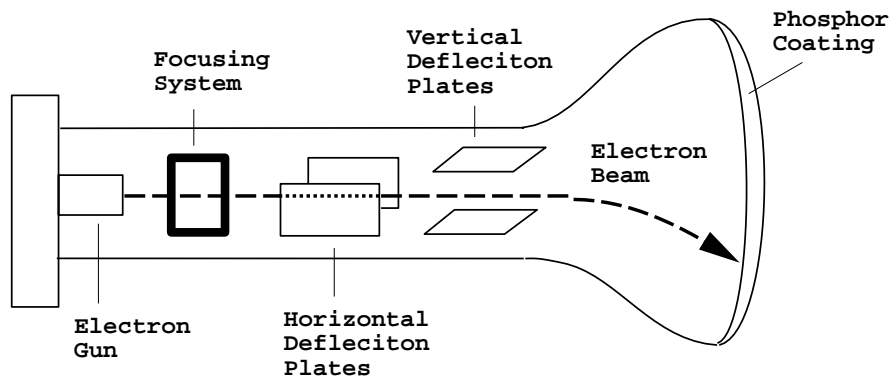
Graphics Hardware

Graphics hardware includes input devices, graphics output devices, and internal graphics processing units.

On a typical computer, input devices include keyboard and mouse; output device is the monitor.



A raster-scan system

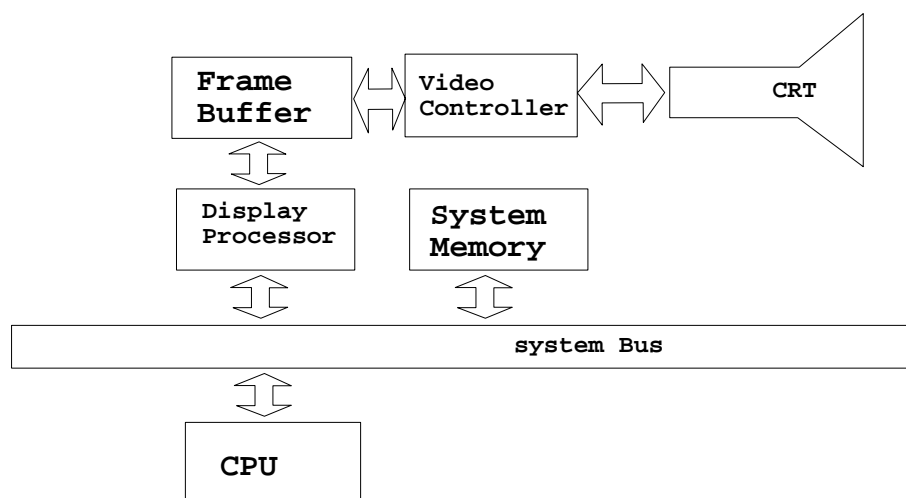


Control of Electron Beam
in Cathode Ray Tube

Internally, a dedicated processor, called *video controller*, constantly copies color intensity values from the frame buffer onto screen, scanline by scanline.

Such a process is called *refresh*.

Refresh rate = # of refreshes per second.



A raster graphics system with a display processor

Refresh rate of a PC or workstation monitor is about 60 to 70 *Hz*. Lower refresh rates result in *flickering*, which is the visually discernible disruption of light intensity on screen. An acceptable refresh rate is determined by the acuity of the human vision. Refresh rate must be matched with the *excitement persistence* of phosphor coating.

High performance graphics systems also have a display processor (VGA board on PC). Common functions of such internal graphics hardware include

- Z-buffer for visible surface determination;
- line drawing;
- clipping;
- texture mapping;
- ...

Output devices

CRT: used on most general-purpose computers.

Stereoscopic viewing glasses: the user wears them to perceive stereoscopic view of 3D scenes displayed on screen.

Used in screen-based Virtual Reality (VR).

Has high resolution.

Limited head-movement.

Head-mounted display (HMD): two small TV screens are embedded in a rack and placed in front of the two eyes. It allows full-freedom head movement, and gives the feel of immersion.

Widely used in Virtual Reality (VR). A tracking system is used to report the position of HMD in 3D space.

Plotter: used for producing drawings in CAD and other applications.

Printer: widely used hardcopy device. A standard part of a computer. For textual, as well as graphics, output.

Input devices

Keyboard: standard input device, used for text string input, as well as selection, function control, and cursor movement.

Mouse: used to position screen cursor. The buttons on the top of a mouse are used for function selection.

Trackball: a 2D input device, usually used on a mouse or a lap-top computer, rolled by a finger to position screen cursor.

Space ball: hand held, non-movable. It uses a strain gauge to detect pull, push, and twist applied to the ball, and translate them into 3D locations. Used for navigation in virtual environments, CAD, etc.

3D tracker (bat): used to locate a 3D position and orientation, has 6 degrees of freedom. Put on the head or hand of a VR participant.

Joystick: similar to the space ball. Can be movable and non-movable. Measurement is by displacement for movable joystick, and by strain for the non-movable.

Data glove: a glove with sensors (18 – 22) embedded at finger joints to measure the bending of the fingers. Used to control a virtual hand for grasping, dropping, and moving an object in a virtual environment. Used for function selections by different hand gestures.

Image scanner: input still picture, photo, or slides as images into computer.

Touch panel: highly transparent and embedded over a display surface.

Digital camera: directly stores photo shots as images on a diskette.

Digital video recorder: input a video clip in digital form; often used for tele-conferencing.

Laser range scanner: input discrete and scattered points on a 3D surface

model from which a digital one can be built.

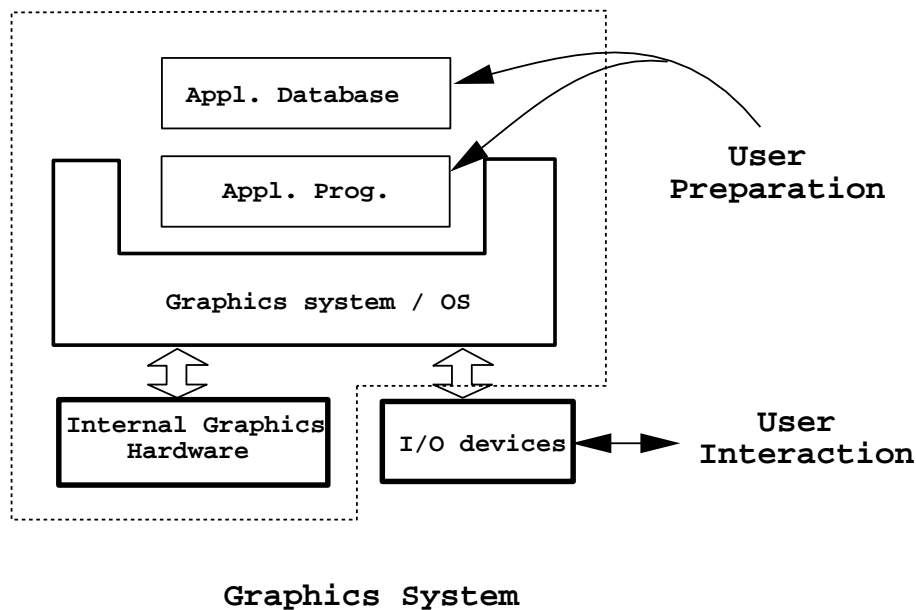
Graphics Packages

Graphics software consists of three parts.

Application model: geometric models and data used for an application.

Application program: programs developed to handle a specific task or application

Graphics system: a library of graphics functions, supported by operating systems.



These functions are invoked by high level application programs to control low level graphics hardware.

Images

An image is represented by a 2D array of pixels with color coding.

The spatial resolution of an image is

of pixels per rows \times # of pixels per column.

The color of each pixel is coded as a binary number (gray-level) or a set of binary numbers (RGB).

In the case of bitmap (B/W) images the color is represented by 1 bit.

On typical graphics workstations, images with *true color* (3 bytes or 24 bits color coding) are supported.

The total amount of memory used to store a 24 bit images of 640×480 pixels (VGA) is

$$24 \times 680 \times 480 \text{ bits} = 921600 \text{ bytes.}$$

Usually, on a VGA (Video Graphics Array) card of a PC, the memory size is fixed. Thus, the larger is the image processed, the fewer colors are available.

Classification of input devices

Five logical devices, classified according to their functions

- *locator (and stroke)*: for specifying a position (x, y)
- *string*: for inputting a text string
- *valuator*: for inputting a real value
- *choice*: for selecting a menu item or a function
- *pick*: for selecting a displayed object

Each logical device can be realized by several different actual physical

devices. For instance, a mouse and a keyboard can both be used to control the cursor position.

On the other hand, a physical device can serve as different logical devices. For instance, the keyboard can be used to input text strings as well as select a function.

Graphics User Interface (GUI)

The principle of user interface design is to hide the complexity of interface implementation from the user, and prevent the user from being overwhelmed by the details of a system.

- *Accommodate users with different skill levels:* Use both menus and control keys. Short prompts vs. tutorial-like help facilities.
- *Easy to understand and remember:* facilitate the learning process.
- *Backup and error handling:* give the user confidence to explore and make it easy to understand errors and recover from them.
- *Feedback:* Keep the user informed of the status of ongoing tasks. Acknowledge the receipt of an input value, etc.