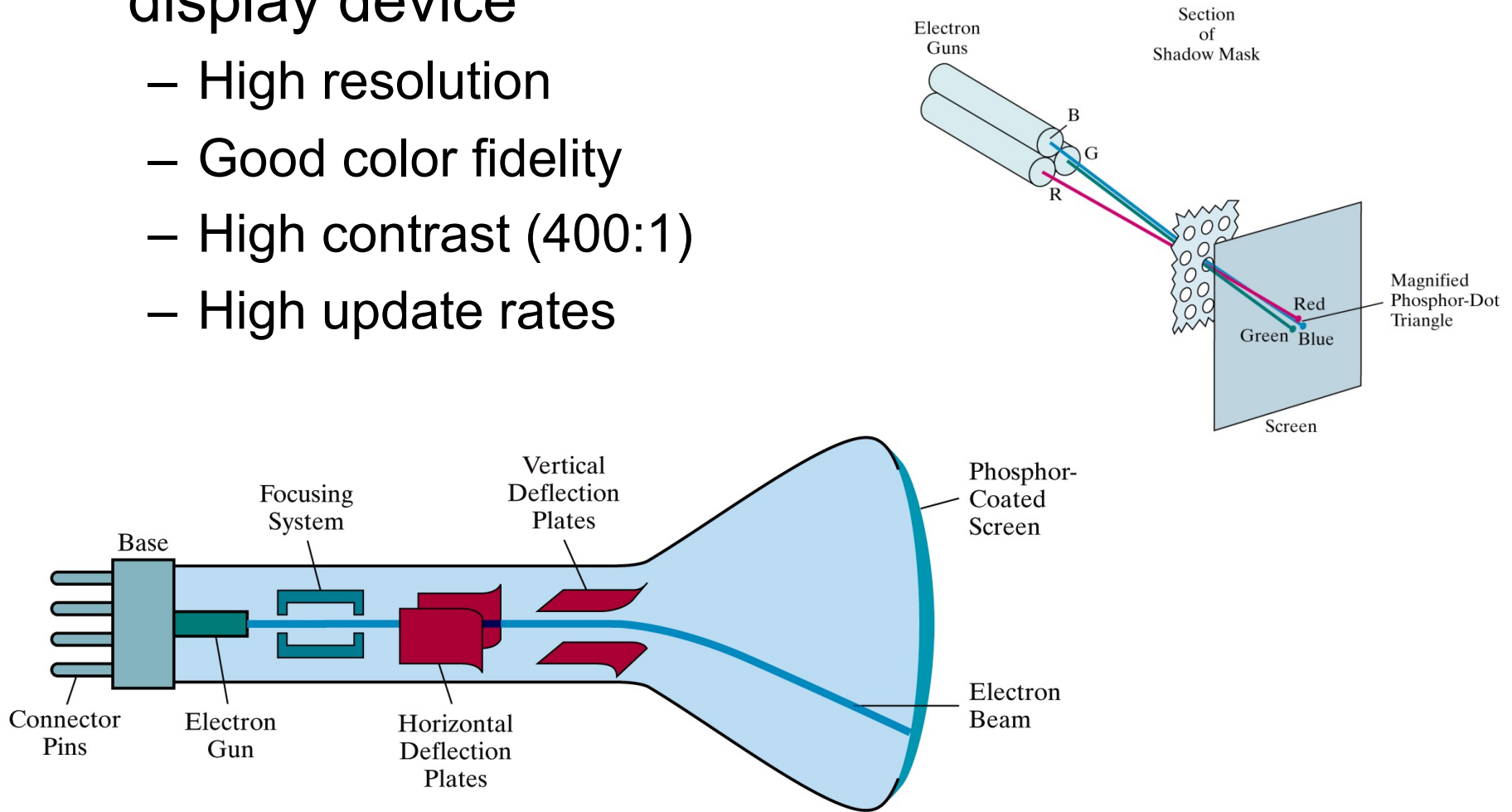# Graphics System Overview

**Jehee Lee**

Seoul National University

Video Display Devices

- Cathode Ray Tube(CRT) is the most common display device
  - High resolution
  - Good color fidelity
  - High contrast (400:1)
  - High update rates

Vector vs Raster CRT

- ***Vector* displays**: a list of line endpoints was used to move the electron beam along some random path, a so-called *vector scan.*

- ***Raster* displays** (TVs etc) drive the beam in a regular pattern called a *raster scan.*

- Vector displays are almost extinct.

- **Scan conversion**: convert geometric primitives from *vector scan* descriptions (endpoints etc.) to *raster scan* descriptions (sets of pixels to turn on.)
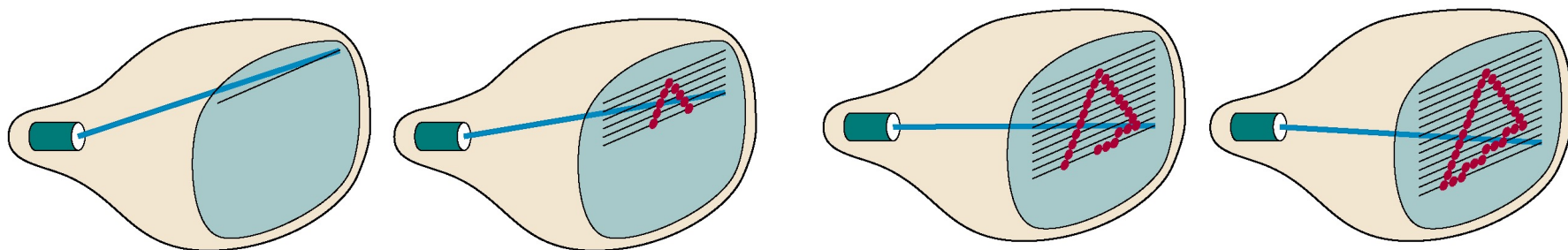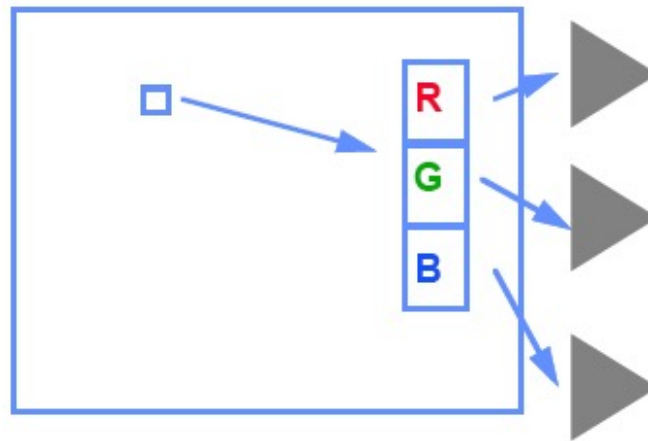
Frame Buffers

- The 2-D array of pixel values is called a *frame buffer*
  - Frame, refresh, raster buffers are used interchangeably
- Each row of pixels is called a *scan-line* or a raster line
- Frame buffer can be peripheral to the host or resident as part of the host computer's address space.
- The video hardware continuously scans the frame buffer.
- Types of display
  - B&W displays: 1 bit/pixel *(bitmap).*
  - Basic color displays: 8, 15, 16, or 24 bits.
 - High-end displays: 96 or more bits.

Full-Color (RGB) Displays

- For 24 bit color:
  - store 8 bits each of red, green, and blue per pixel.
  - E.g. (255,0,0) is pure red, and (255, 255, 255) is white.
  - 2^24 = 16 million colors.
- For 15 bit color: 5 bits red + 5 green + 5 blue
- The video hardware uses the values to drive the R,G, and B guns.

Color Lookup Table

- A single number (e.g. 8 bits) stored at each pixel.
  - Used as an *index* into an array of RGB triples.
  - With 8 bits per pixel, you can get the 256 colors of your choice
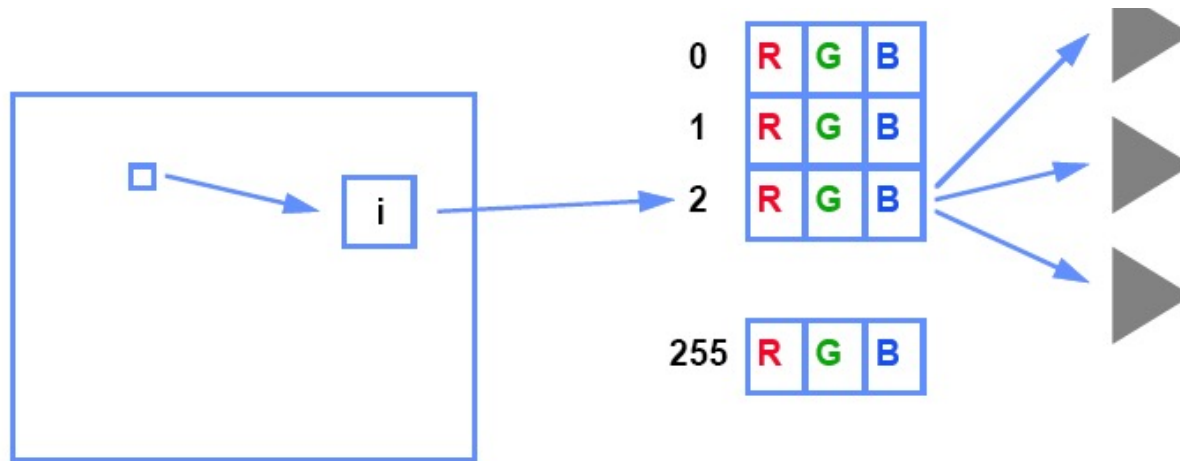
Deeper Frame Buffers

- Some frame buffers have 96 or more bits per pixel. What are they all for? We start with 24 bits for RGB.

- Alpha channel: an extra 8 bits per pixel, to represent "transparency." Used for digital compositing. That's 32 bits.

- A Z-buffer, used to hold a "depth" value for each pixel. Used for hidden surface 3-D drawing. 16 bits/pixel of "z" brings the total to 48 bits.

- Double buffering:
  - For clean-looking flicker-free real time animation.
  - Two full frame buffers (including alpha and z).
  - Only one at a time is visible—you can toggle instantly.
  - Draw into the "back buffer" (invisible), then swap.
  - Can be faked with off-screen bitmaps (slower.)
  - 2 x 48 = 96.

Raster CRT Display

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

- Refreshing should be the responsibility of the device:

  – buffer memory (frame buffer)

  – 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

Display Processor

- Raster graphics system with a dedicated display processor
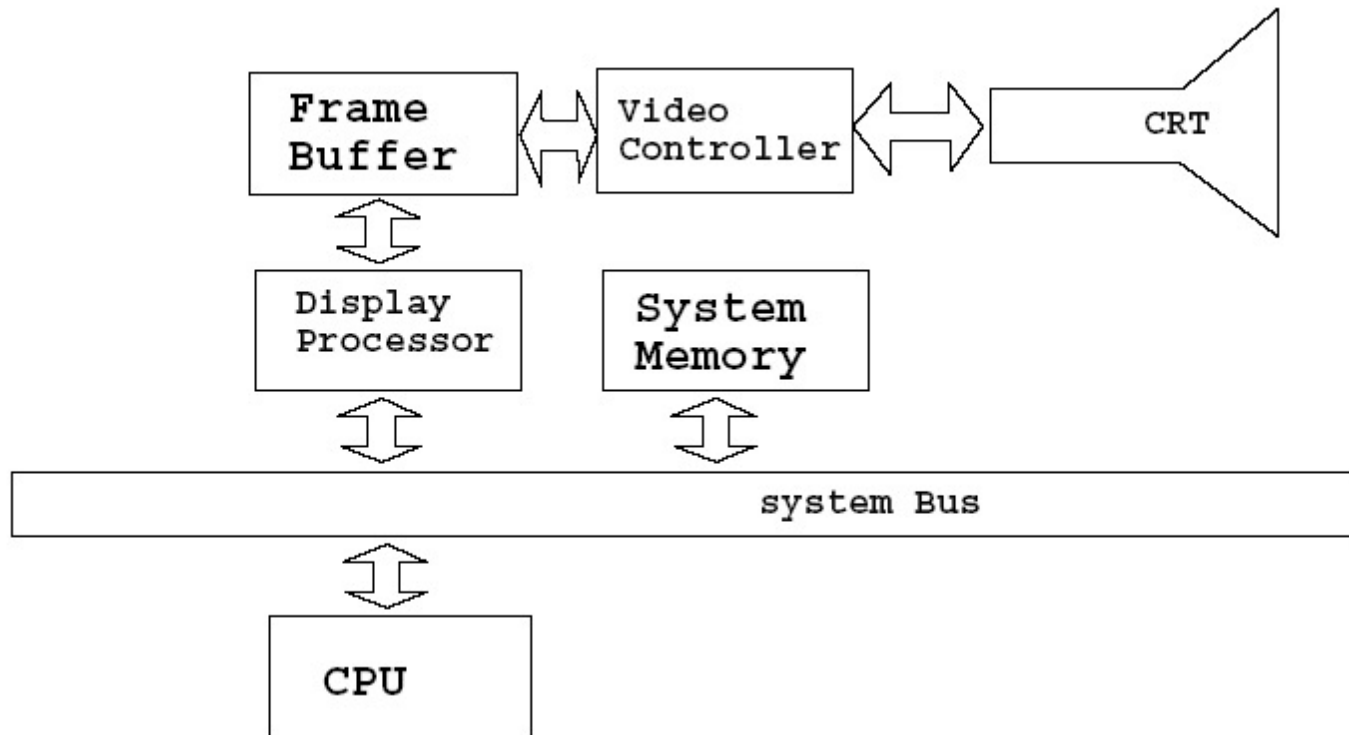
Interlacing

- 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.
- Interlacing
  - a usual frame display rate : 60 Hz
  - divide a frame into even-numbered scan lines and odd-numbered scan-lines(each 1/60 sec)

    $\Rightarrow$ whole frame takes 1/60 + 1/60 = 1/30 sec
- Recently, progressive scan is becoming popular
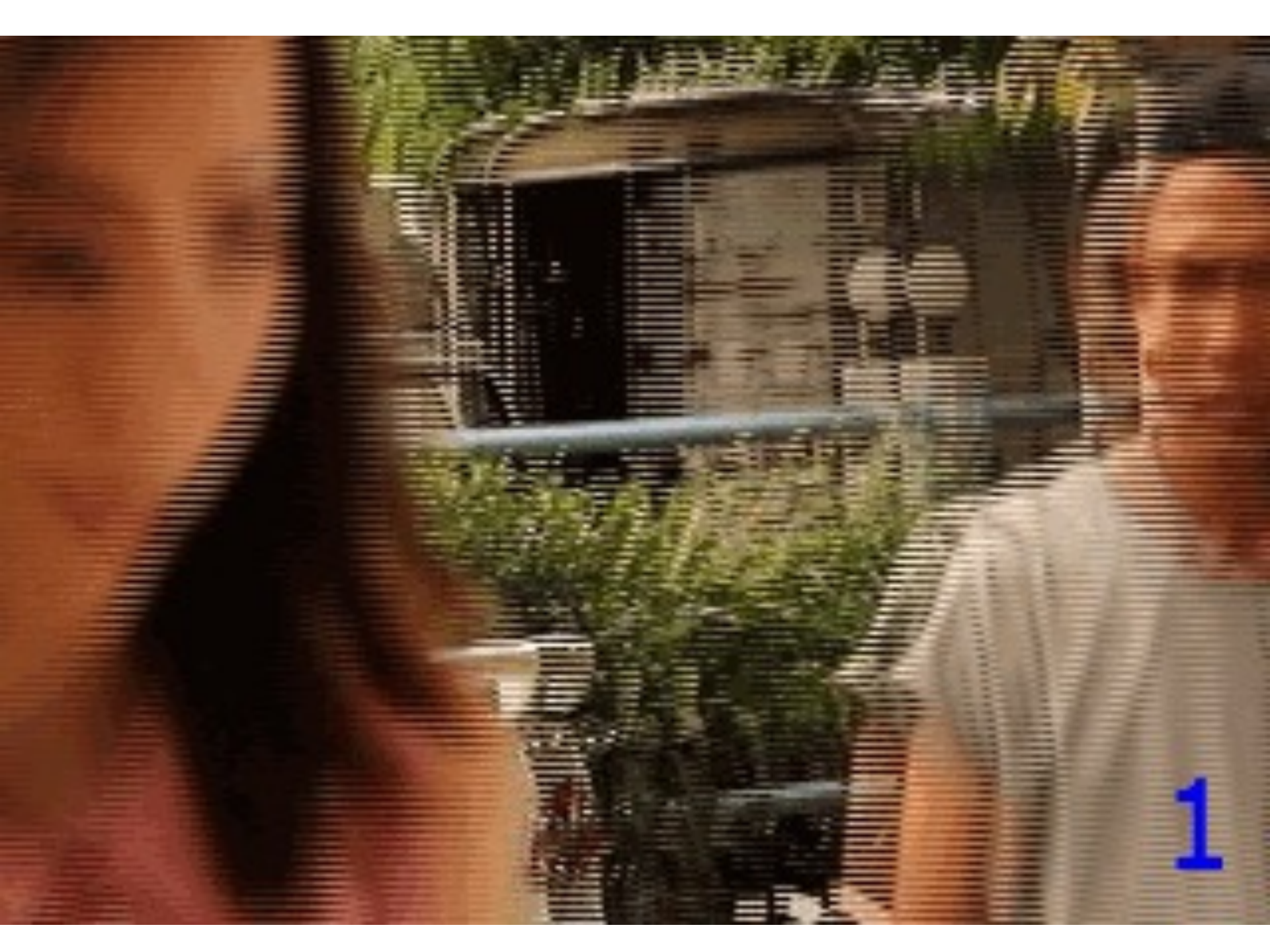
Flat Panel Displays

- Plasma-panel (gas-discharging) displays

- Liquid crystal displays

- Comparison to CRT
  - Thin, light
  - Flicker free
  - Narrower color gamut

Output Devices

- 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
- Printer
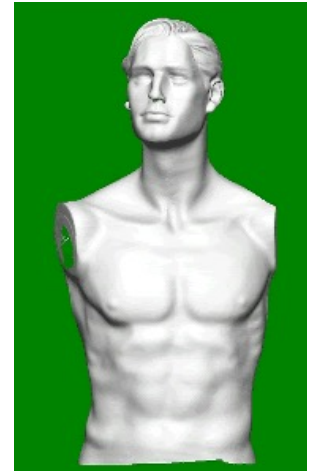
Output Devices

- Wide Screen

Input Devices

- **Keyboard**
- **Mouse**
- **Trackball**: a 2D input device, usually used on a mouse or a lap-top computer.
- **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.
- **Head Mounted Display**: Although it is primarily a display device, it can also track position and orientation
- **Joystick**: similar to the space ball. Can be movable and non-movable.

Input Devices

- **Data glove**: a glove with sensors. Used to control a virtual hand for grasping, dropping, and moving an object in a virtual environment.

- **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.
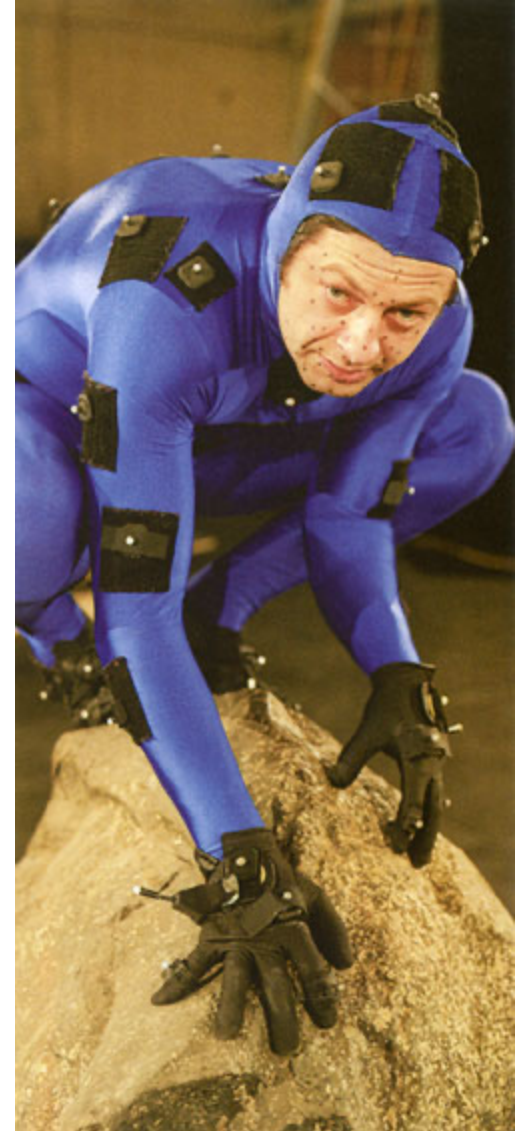
Input Devices

- **Motion Capture**: input full-body, facial, hand movements

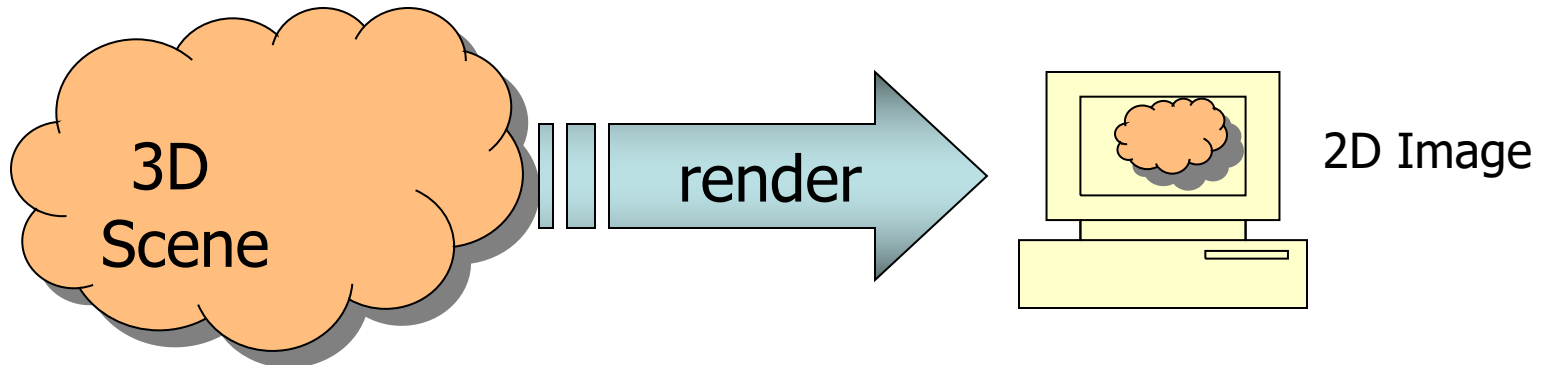[The Two Towers | New Line Productions]

Motion Capture

- Reptile capture
- Breakdance
- Dynamic duo

Graphics Rendering Pipeline

- Rendering: the conversion of a scene into an image

3D Scene → render → 2D Image

- Scene is composed of "models" in 3D space.

- Models are composed of "primitives" supported by graphics packages such as OpenGL.

- Models entered by hand or created by a program

# Graphics Rendering Pipeline
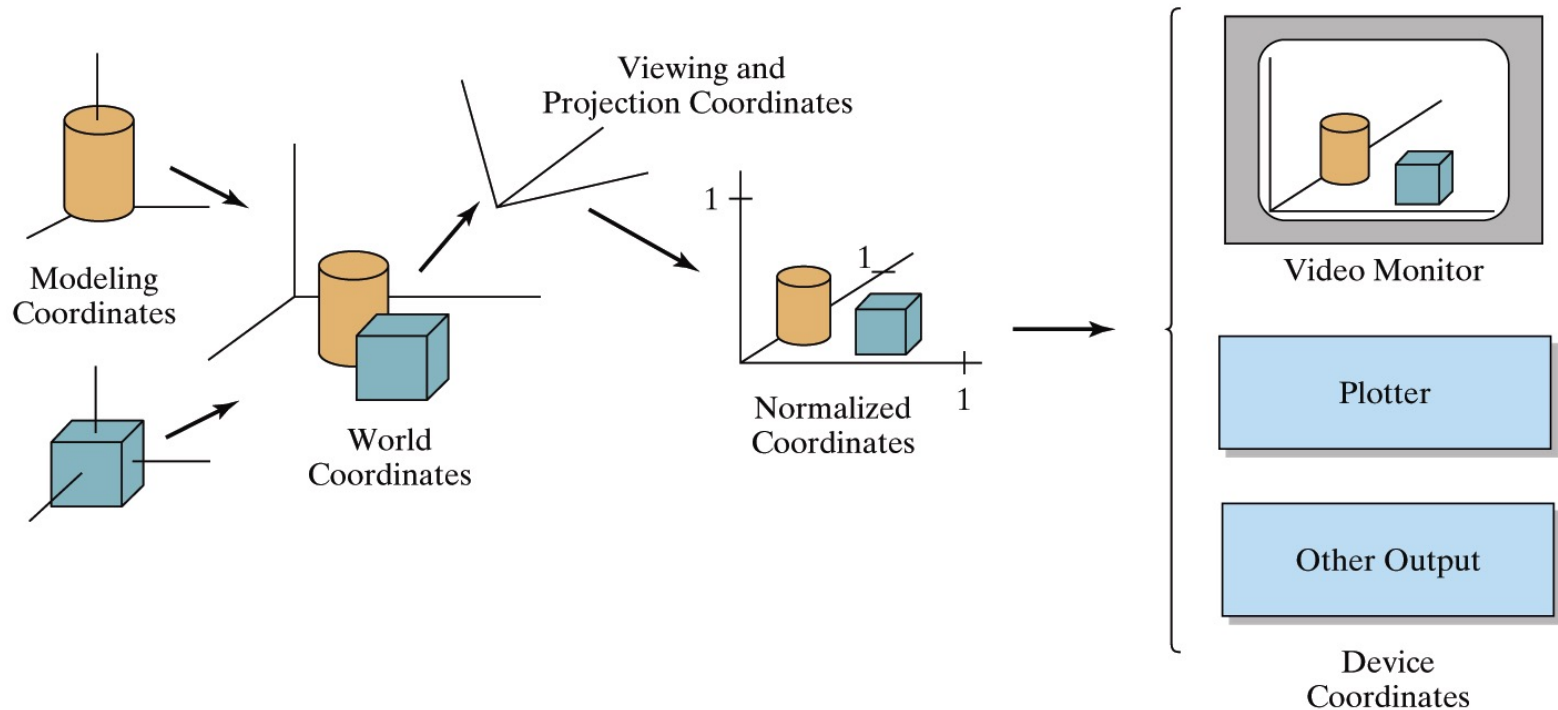
- Modeling (local) coordiantes
- World coordinates
- Normalized (device-independent) coordinates
- Device (screen) coordinate

Functions of a Graphic Package

Graphics Library such as Core, OpenGL, DirectX

- Provide primitives for graphic description
- Build and maintain graphic representation models
- Provide primitives for viewing operations
- Support user interaction with application program
- Interact directly with users to allow them modify viewing parameters, if possible

Graphics System
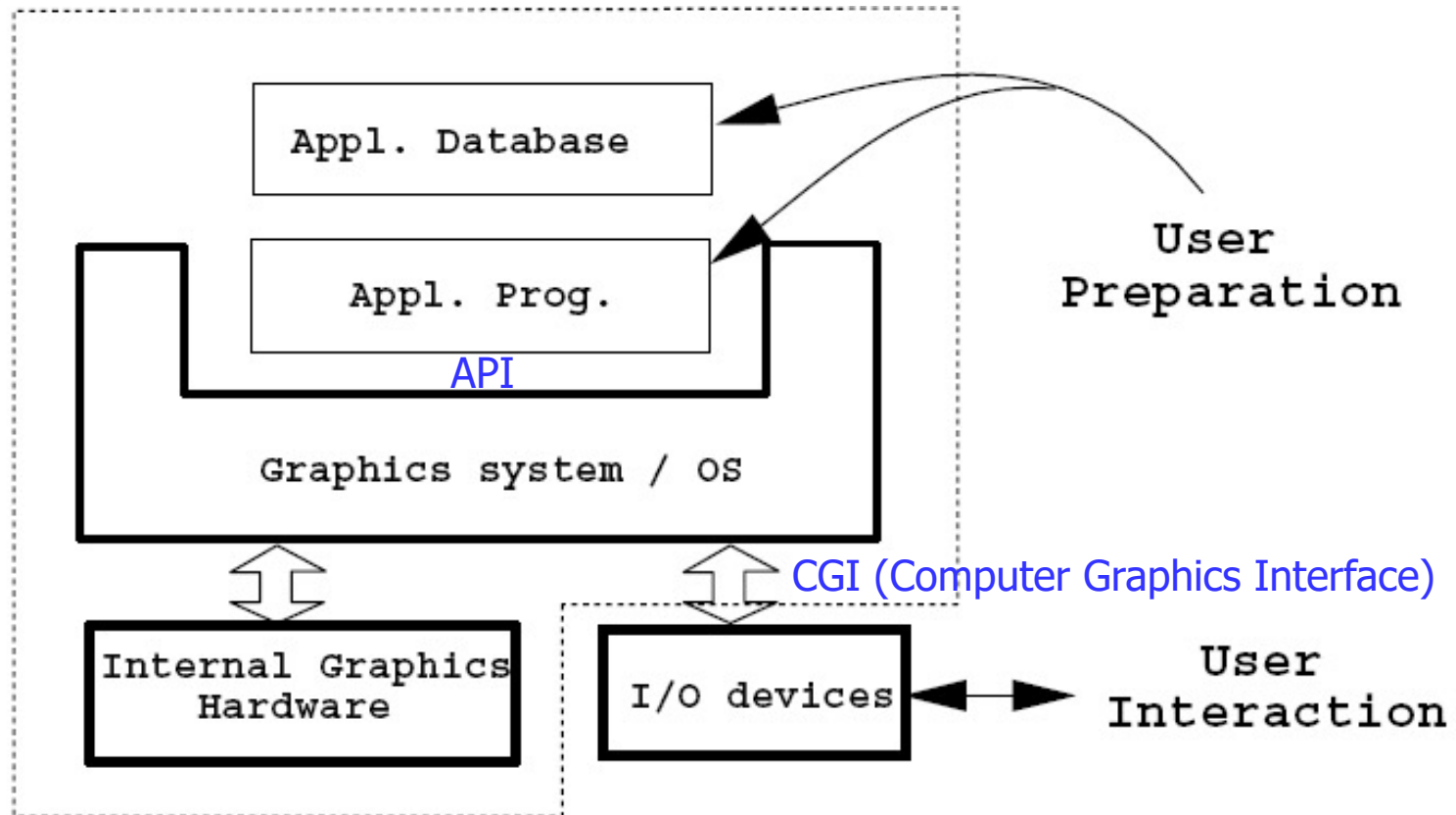
Graphics system: a library of graphics functions

General Graphics Packages

- Graphics packages are device-independent
- Official Standards
  - Core: ACM SIGGRAPH 1977, U.S.
  - GKS : ANSI85, 2D, Europe
  - GKS-3D : ANSI88
  - PHIGS : ANSI88 - Hierarchical structures
  - PHIGS+ : ISO 92
- Non-official Standards
  - X Window System, PEX
  - Silicon Graphics OpenGL (1992)
  - Microsoft DirectX
  - Sun Mircorsystems VRML
  - Vulkan, Apple Metal, etc

Bit-Mapped vs. Object-Based

- Painting programs
  - bit-mapped representation
  - e.g., Adobe Photoshop, bit-map fonts

- Drawing programs
  - object-based representation
  - e.g., Powerpoint, outline fonts
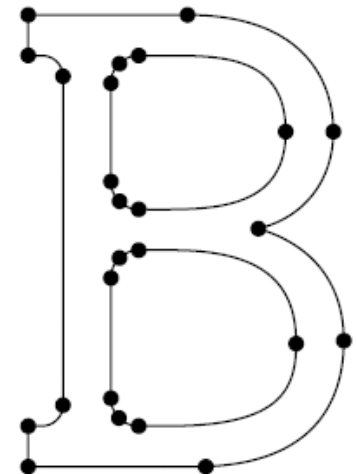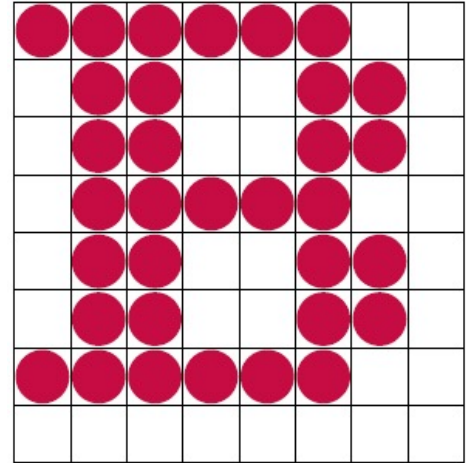
Bit-Mapped Graphics

- Bit-mapped memory - represent graphical images and patterns by assigning a block of memory for the direct storage of the intensity patterns

- Objectiveness of a line, polygon, or brush stroke is lost

- Limitations
  - pixel democracy - all pixels are created equal once, they are set in a bit-mapped image
  - no support of images requiring precision or numerical dimensioning device dependency

Object-Based Graphics

- Mathematical representation of lines, rectangles, ovals, polynomial curves, and so on.

- Objectiveness is maintained
  - Objects designed may have a hierarchical structure
  - Easily editable

- Difficulties
  - the representation is more complex

Image File Formats

- GIF (Graphics Interchange Format)
  - the CompuServe Information Service and F&R Block Company
  - copyrighted bitmap format
  - uses compression
  - can store only 256-color images, any size

Image File Formats

- TIFF (Tag-based Image File Format)
  - Aldus Corp. and Microsoft to support digital scanner manufacturers and desktop publishing systems to describe and store raster image data
  - run-length encoding with compression.
  - independent of OS, processors, compilers, and filing systems
  - become a standard for image storage and communication

Image File Formats

- ## JPEG
  - international compression standard (1992)
  - high compression rate can be acquired by removing the following redundancy in an image:
    - spatial (between neighboring pixels),
    - spectral (between color planes),
    - temporal (between adjacent frames in a sequence)
  - highly lossy compression

    But, objectionable blocking artifacts may occur.
  - poor lossless compression efficiency (less than 3)
  - lossy compression method is limited to input images with maximum bit depth of 8bits/pixel.
  - lossless support 2 to 16 bits/pixel.
  - no support for true-color

Image File Formats

- JPEG 2000
  - new international compression standard (2002.1)
  - significantly higher compression efficiency than JPEG
  - new functionalities:
    - integrated lossy/lossless compression
    - region-of-interest(ROI) encoding
    - Multi-resolution capability
    - progressive decoding

Image File Formats

- EPS (Encapsulated PostScript)
  - Adobe Systems Incorporated
  - importing and exporting PostScript language files
  - grayscale or color
  - usually ASCII
  - No compression
  - can be mix of raster and geometric data

Image File Formats Comparison

	BITS PER PIXEL	FILE SIZE	COMMENTS
JPEG	24	small	lossy, good for archives
TIFF	8,24	medium	good
GIF	1,4,8	medium	no good for colorful images
EPSF	1,2,4,8,24	huge	good for printing