What is Computer Graphics?

- A set of tools to create, manipulate and interact with pictures.
- Data (synthetic or natural) is visualized through geometric shapes, colors, textures.
- Exploits the pattern recognition capabilities of the human visual system.
- Graphical User Interfaces (GUI) - means to interact with complex applications
- Scientific, Engineering, Business and Educational applications.

What can we do with Computer Graphics?

- A core technology and infrastructure for drawing programs.
- Pervasive across scientific, engineering, business and educational applications.

Applications: 2D/3D Plotting

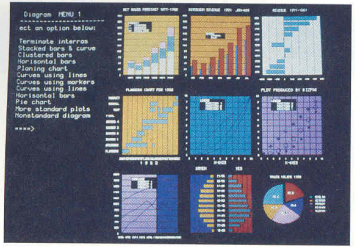
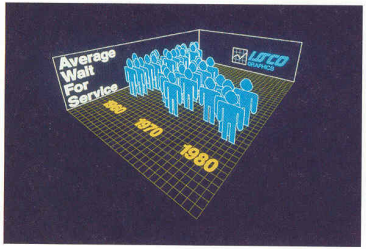
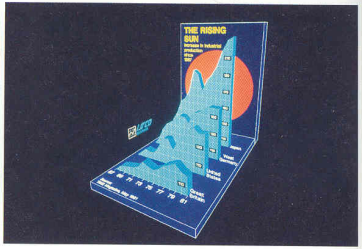


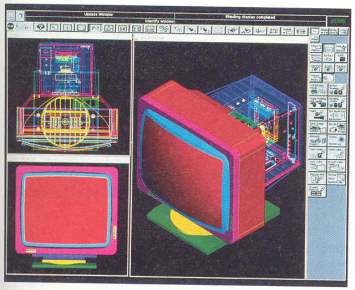
FIGURE 1–2 Two-dimensional line graphs, bar charts, and a pie chart. (*Courtesy of UNIRAS, Inc.*)

FIGURE 1–3 Two color-coded data sets displayed as a three-dimensional bar chart on the surface of a geographical region. (*Reprinted with permission from ISSCO Graphics, San Diego, California.*)

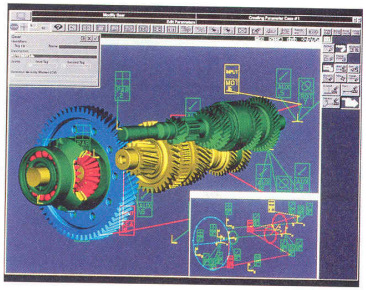




Applications: Computer-aided Drafting and Design (CAD)



(a)



(b)

FIGURE 1-9 Multiple-window, color-coded CAD workstation displays. (*Courtesy of Intergraph Corporation.*)

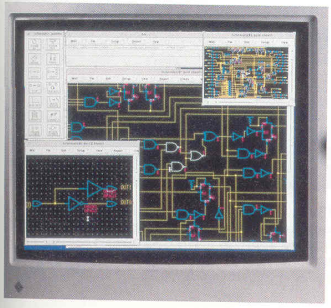


FIGURE 1-10 A circuit design application, using multiple windows and color-coded logic components. (*Courtesy of Sun Microsystems.*)

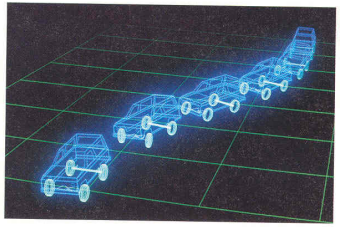
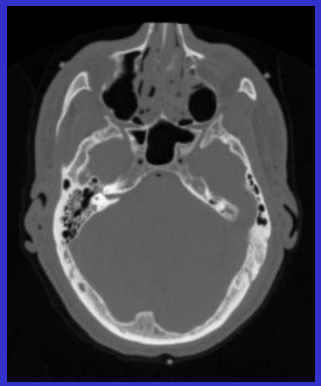
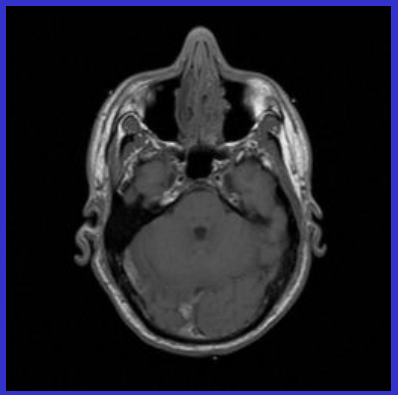
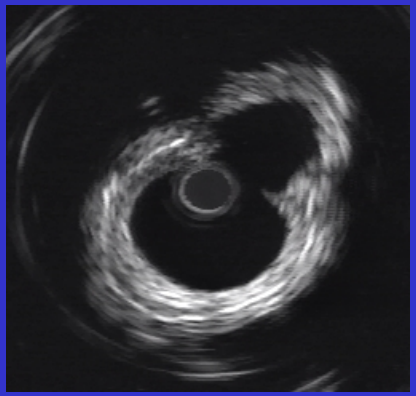


FIGURE 1-11 Simulation of vehicle performance during lane changes. (*Courtesy of Evans & Sutherland and Mechanical Dynamics, Inc.*)

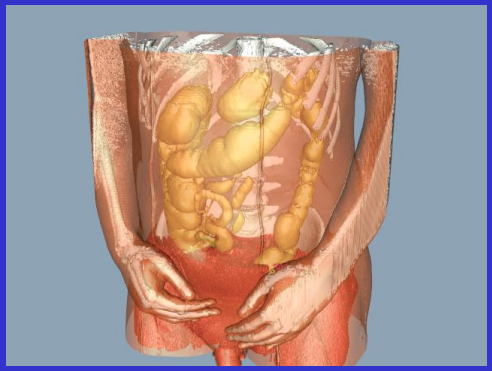
Applications:Scientific Data Visualization

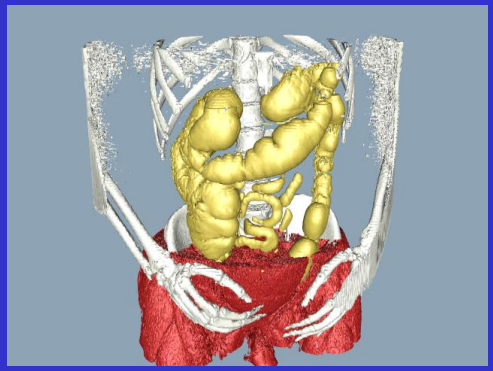
- Bio-Medicine (CAT Scan, MRI, PET), Biology.
- Biology (molecular structure/models),
- Bioinformatics (Gene sequences, proteins).
- Weather Data
- Environmental Data - pollution data..

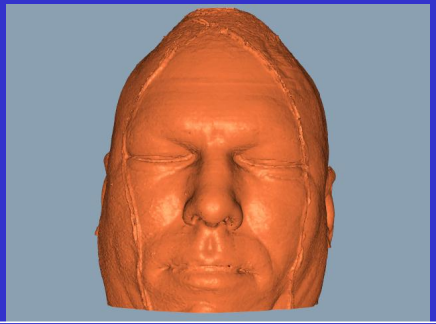
Applications:Medical Visualization: Visible Human Project

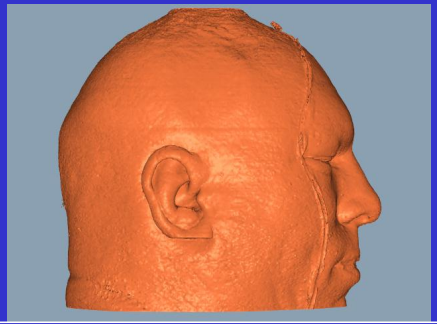
From CT



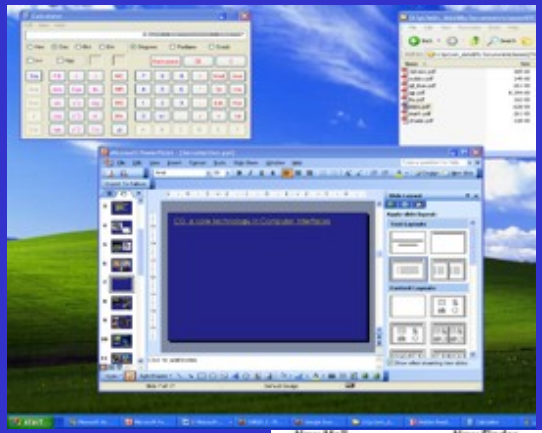


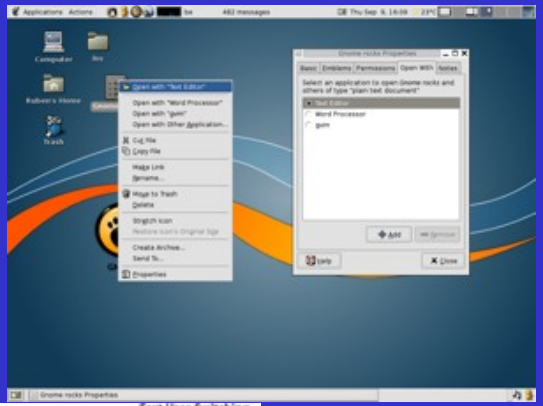
From the Physical Data





Applications:Computer Interfaces



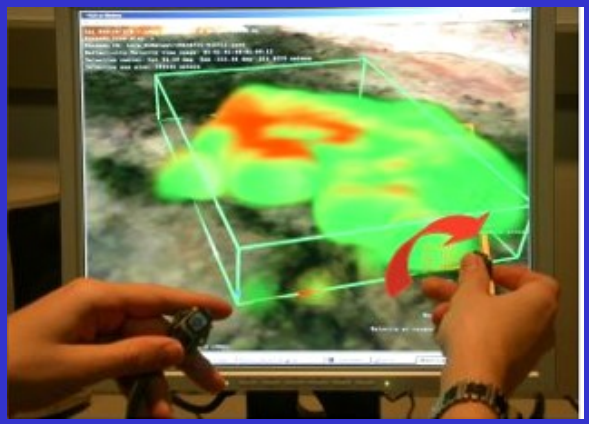


Applications:Computer/Video Games

Applications: Entertainment (movies, animation, advertising)

Virtual and Immersive Environments

Virtual and Immersive Environments



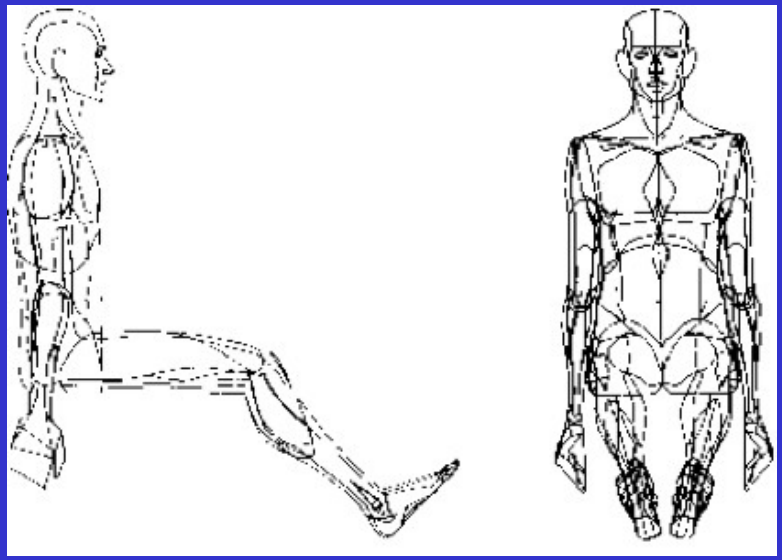
What Disciplines does CG draw on?

- Algorithms
- Mathematics
  - Basic : linear/vector algebra, geometry, trig.
  - Advanced: advanced calculus, comp/differential geometry, topology
- optics (very approximate in ITCS 4120)
- software engineering and programming
- hardware engineering
- psychophysics: human visual system
- industrial art & design

How long has CG been around? Some History

Ivan Sutherland, SketchPad, 1963, MIT
CRT, light-pen, direct-manipulation 2D graphics

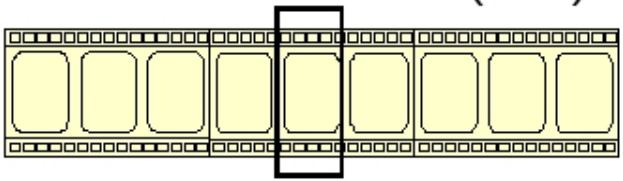
How long has CG been around?



William Fetter, 1960, Boeing Aircraft Co.
"Boeing Man, human figure simulation, credited with "computer graphics

CG Applications: Spectrum

- 2D versus 3D
- Speed – Frames Per Second (FPS)

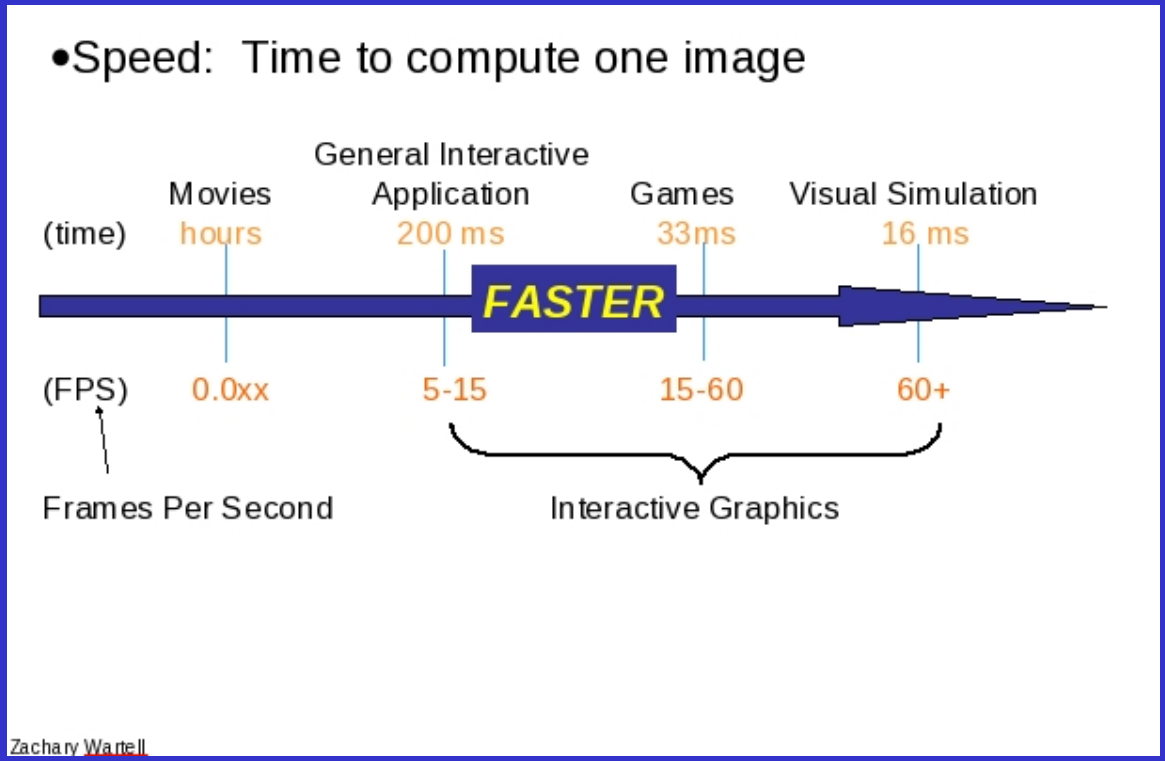


- Realism

vs


- $$$
  - 1950's, Whirlwind, $4.5M, 40K adds/s
  - today's PC: $1K, 2-3B ops/s
  - CG: 1995, $100K, SGI = 2004, $1K PC

CG Application Spectrum: Speed



CG Application Spectrum: Realism

- Realism
  - more math, more physics → more realism
    (real-time CG → ray-tracing → radiosity → "rendering equation")

  - display technology & human visual perception
    (image fidelity, stereopsis, motion parallax)

CG Application Spectrum: Speed vs. Realism

- Generally: more realism less speed
- But Moores Law continues to reign
  - price/performance improves 2x every 18 months
  - since 1995 gaming market driving graphics hardware (Nintendo GameCubeTM (ATI), Xbox (Nvidia inside), PC: nVidia Geforce 7900, ATI Radeon X1900)
- Display capability still lags human eyes precision (but there is substantial and continuing advances)

CG Application Components

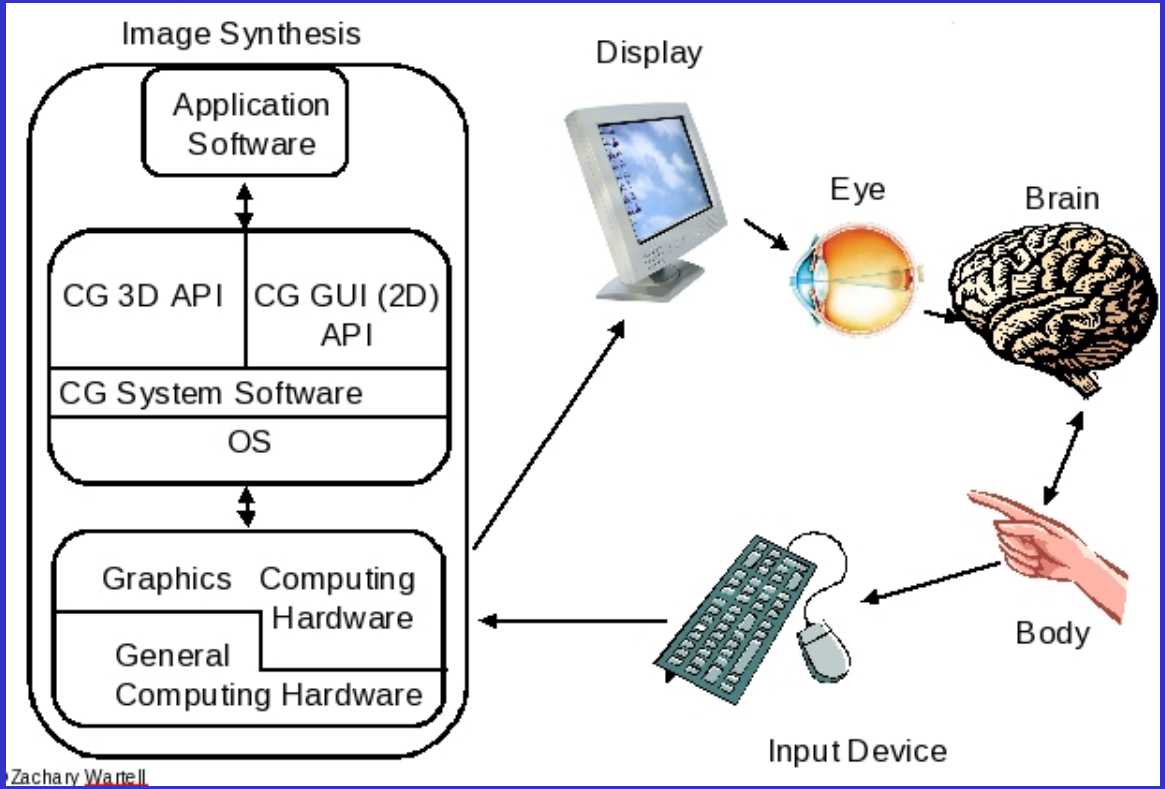
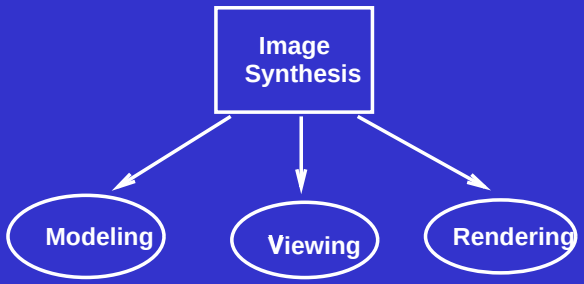
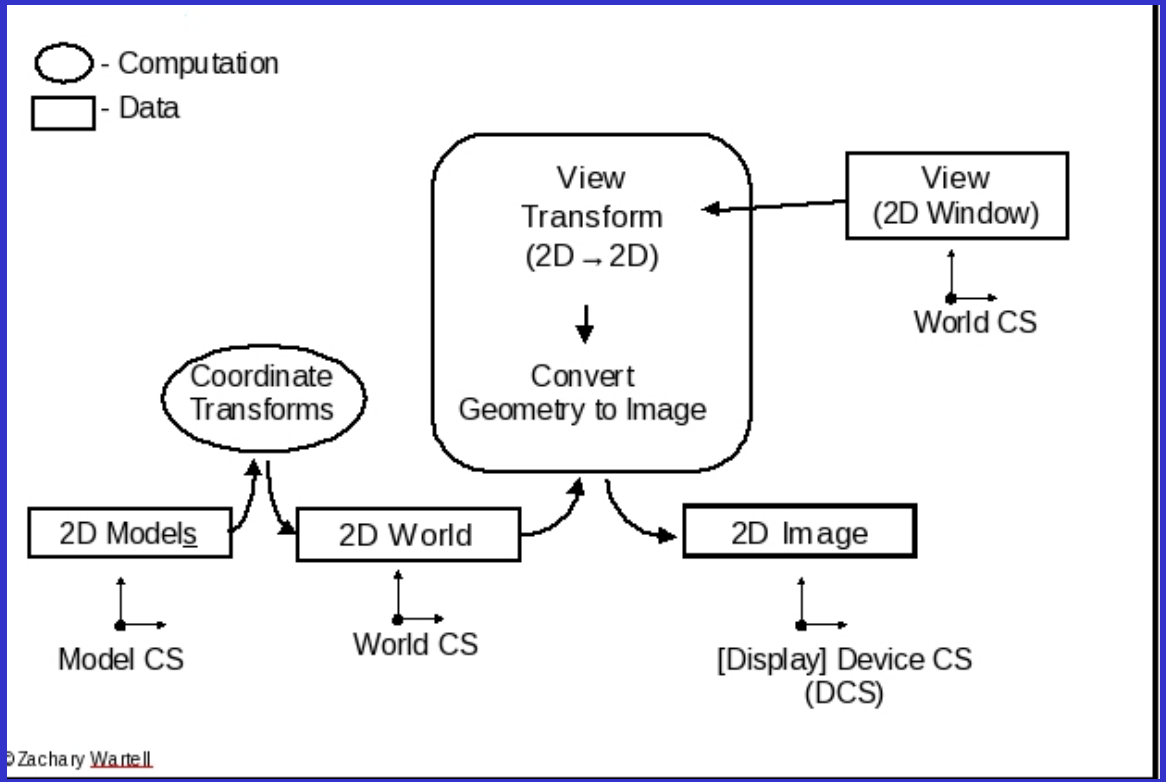


Image Synthesis

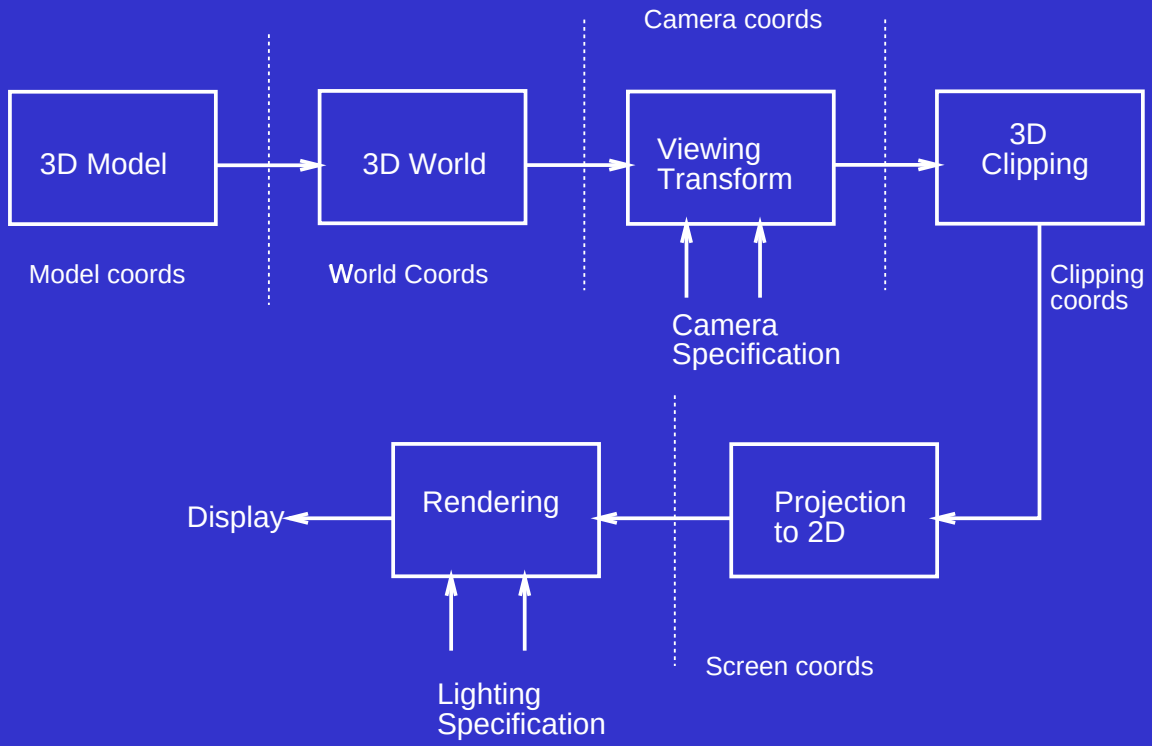


- **Modeling:**The process of creating objects of a scene that will be rendered by the graphics hardware.
- **Viewing:**Specification of camera and a viewing window (volume) that determines the part of the world (of objects) that will be included in the final image.
- **Rendering:** The process that creates an image of the objects within the current view, taking into account lighting parameters and material characteristics.

The Viewing Pipeline (2D)



The Viewing Pipeline(3D)



Graphics (Hardware) Pipeline

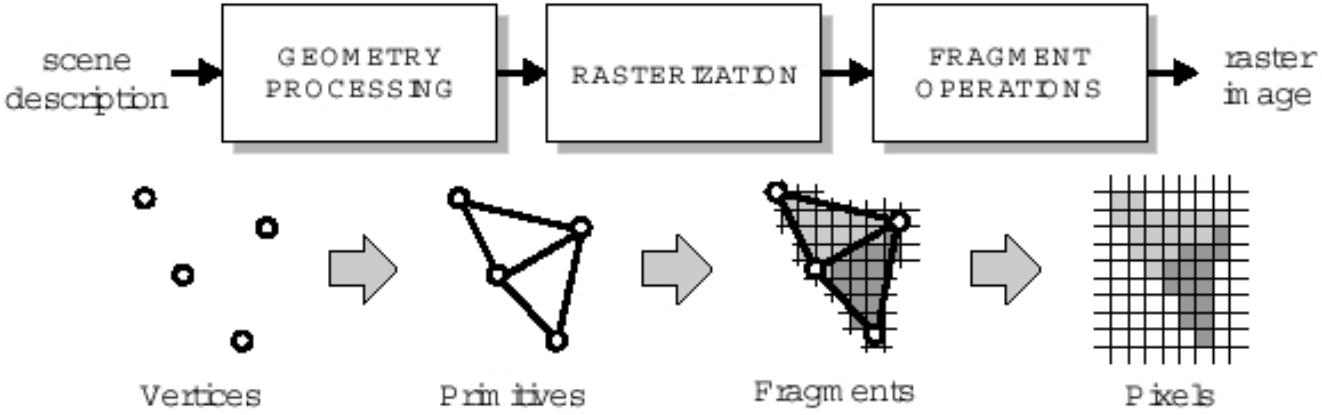
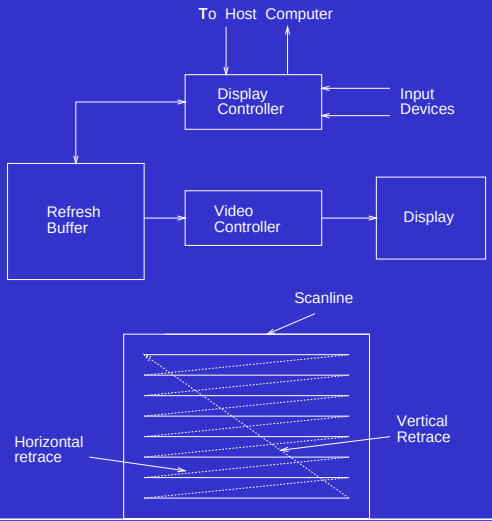


Figure 3.1: The graphics pipeline for display traversal.

Image Synthesis Hardware (Raster Technology)

Definitions

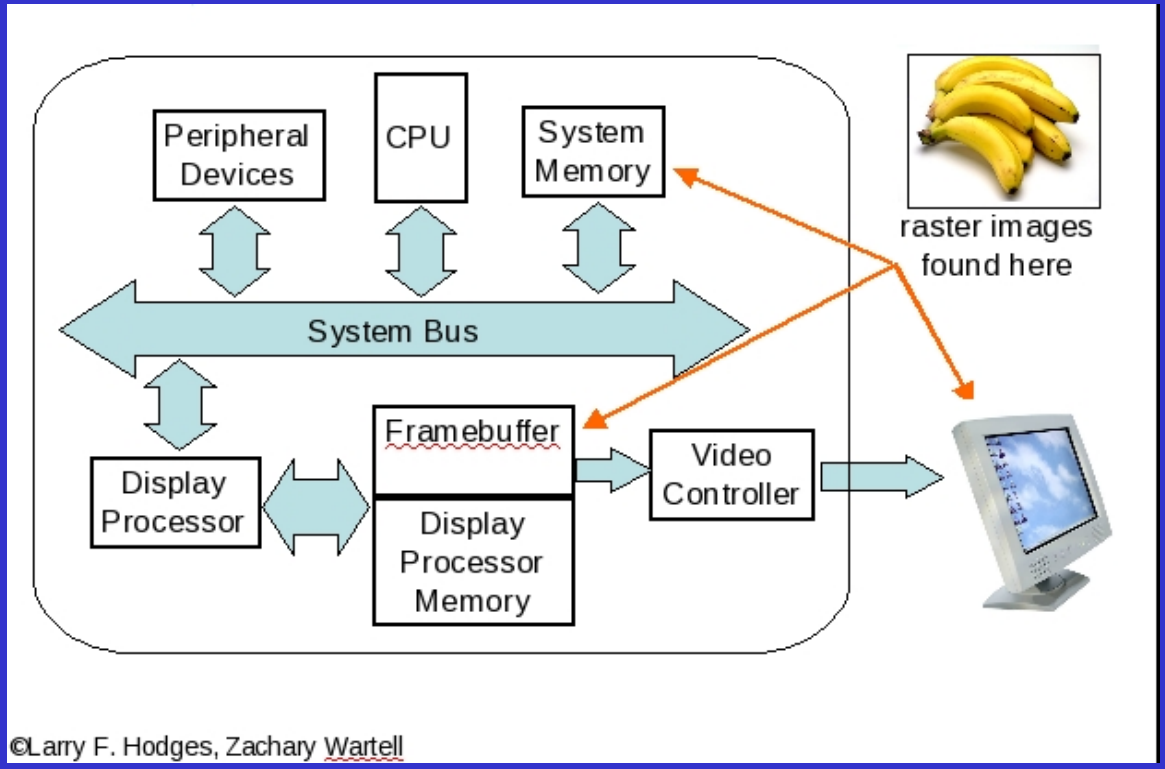
- **Raster:** A rectangular array of points or dots (either on physical display or a data structure in memory).
- **Pixel (Pel):** One dot or picture element of the raster
- **Scan Line:** A row of pixels



Definitions(contd)

- **Bitmap:** 1s and 0s representation of a rectangular array of points (1 bit/pixel).
- **Pixmap:** Same as bitmap, but multiple bits/pixel.
- **Vector, Stroke, Random Scan:** A type of display system where the electron gun can scan from one point to another on the screen.
- **Raster Scan:** A type of display system where the electron gun scans horizontally from left to right, top to bottom at a fixed rate (television technology).
- **Vertical/Horizontal Blanking:** Times the electron gun is turned off.
- **Refresh/Frame Buffer:** A portion of memory that contains the image.
- **Video controller:** The part of the display system that reads the frame buffer and produces the image.
- **scan-conversion:** Conversion of geometric primitives (lines, polygons) to a set of pixel values or intensities (required in raster scan systems).

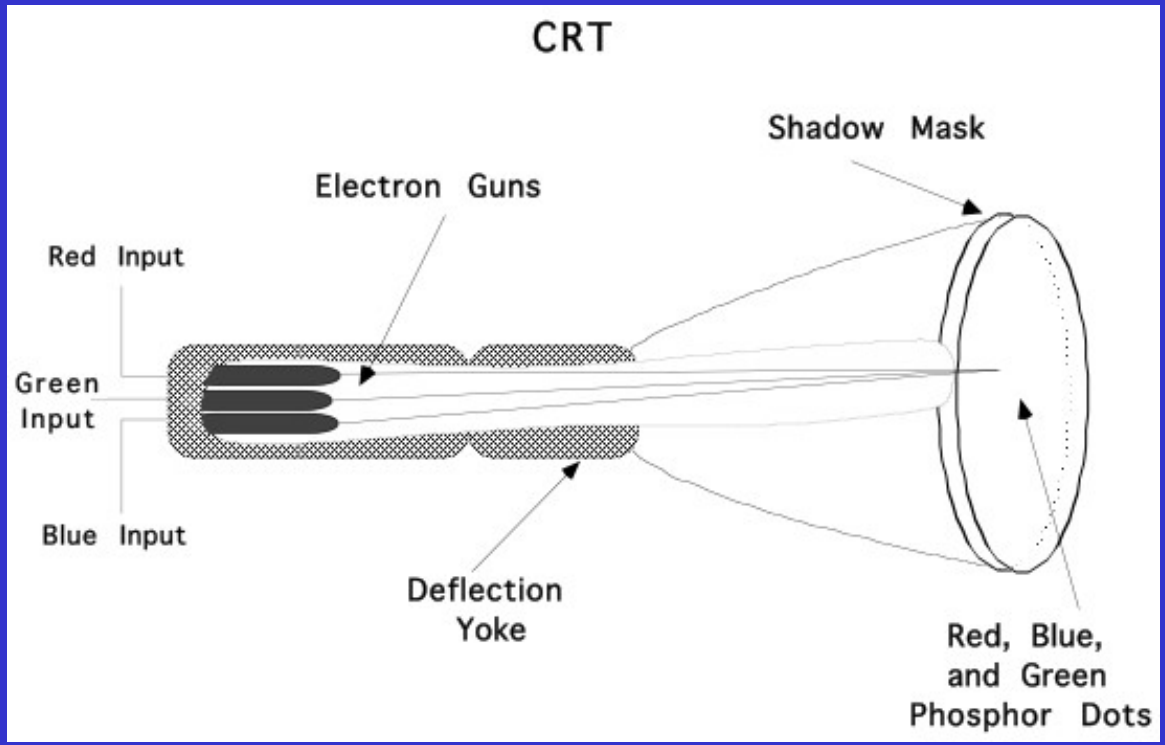
Image Synthesis Hardware (Raster Technology)



Raster-Bit Depth

- A raster image may be thought of as computer memory organized as a 2D array with each (x,y) addressable location corresponding to one pixel.
- Bit Planes or Bit Depth is the number of bits corresponding to each pixel.
- A typical framebuffer resolution might be
  - $1280 \times 1024 \times 8$
  - $1280 \times 1024 \times 24$
  - $1600 \times 1200 \times 24$

Display Technology - Cathode Ray Tube(CRT)



CRT: Electron Gun

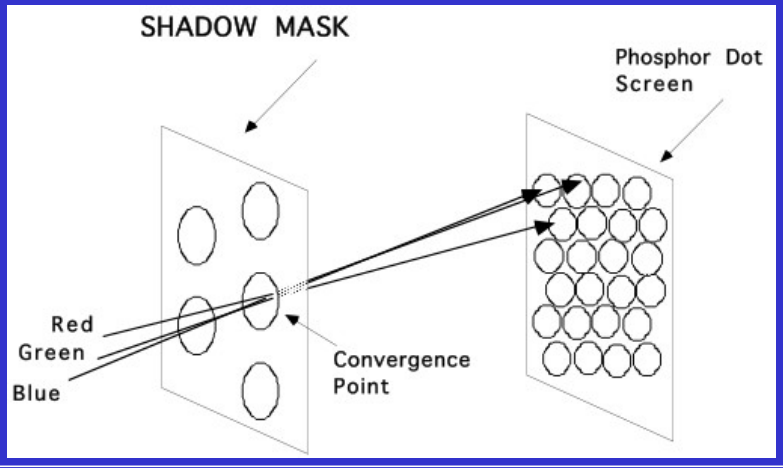
- Contains a filament that, when heated, emits a stream of electrons.
- Electrons are focused with an electromagnet into a sharp beam and directed to a specific point of the face of the picture tube.
- The front surface of the picture tube is coated with small phosphor dots.
- When the beam hits a phosphor dot it glows with a brightness proportional to the strength of the beam and how often it is excited by the beam.

Color CRT

- Red, Green and Blue electron guns.
- Screen coated with phosphor triads.
- Each triad is composed of a red, blue and green phosphor dot.
- Typically 2.3 to 2.5 triads per pixel.
- **FLUORESCENCE:** Light emitted while the phosphor is being struck by electrons.
- **PHOSPHORESCENCE:** Light given off once the electron beam is removed.
- **PERSISTENCE:** Is the time from the removal of excitation to the moment when phosphorescence has decayed to 10

Color CRT: Shadow Mask

- Shadow mask has one small hole for each phosphor triad.
- Holes are precisely aligned with respect to both the triads and the electron guns, so that each dot is exposed to electrons from only one gun.
- The number of electrons in each beam controls the amount of red, blue and green light generated by the triad.



Raster Scan Rate

- Some minimum number of frames must be displayed each second to eliminate flicker in the image.
- **Critical Fusion Frequency:** Typically 60-85 times per second for raster displays.
- Varies with intensity, individuals, phosphor persistence, room lighting.

Interlaced Scanning

- Display frame rate 30 times per second.
- To reduce flicker at lesser bandwidths (Bits/sec.), divide frame into two fieldsone consisting of the even scan lines and the other of the odd scan lines.
- Even and odd fields are scanned out alternately to produce an interlaced image.
- non-interlaced also called progressive

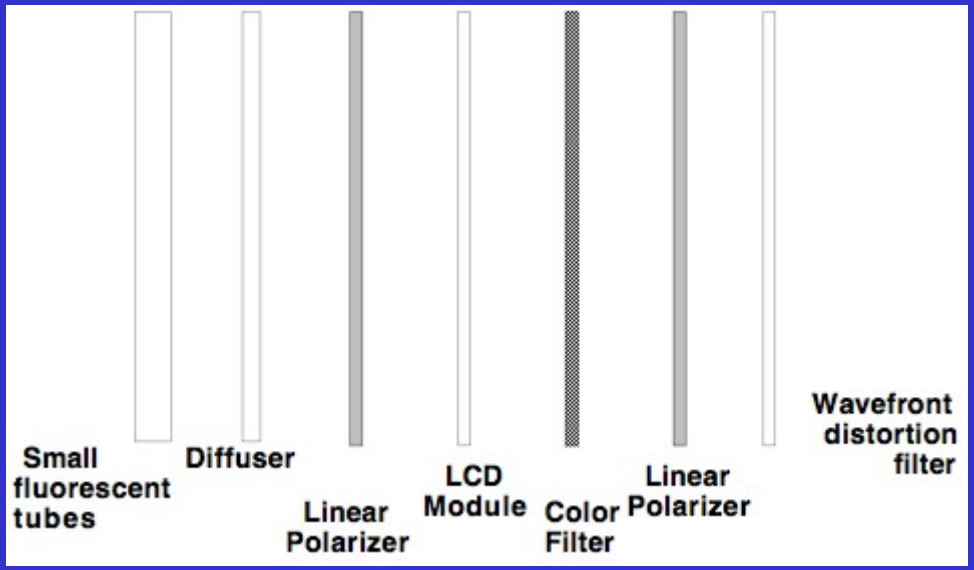
Example Video Formats

- NTSC 525 lines, 30f/s, interlaced (60 fld/s)
- PAL 625 lines, 25f/s, interlaced (50 fld/s)
- HDTV 1920 x 1080i, 1280 x 720p
- XVGA 1024x768, 60+ f/s, non-interlaced
- generic RGB(component) 3 independent video signals and synchronization signal, vary in resolution and refresh rate
- generic time-multiplexed color R,G,B one after another on a single signal, vary in resolution and refresh rate

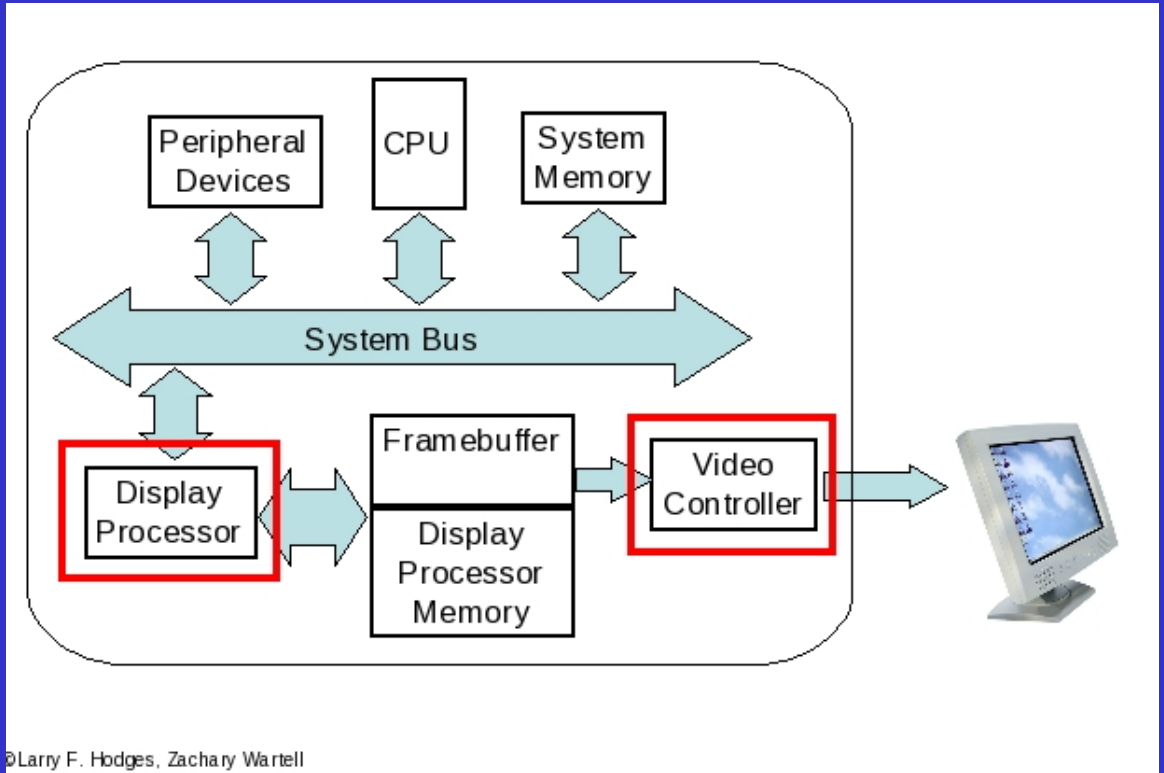
LCD Displays

- Liquid crystal displays use small flat chips which change their transparency properties when a voltage is applied.
- LCD elements are arranged in an n x m array call the LCD matrix
- Level of voltage controls gray levels.
- LCDs elements do not emit light, use backlights behind the LCD matrix
- Can use transistors at each pixel, resulting in **active matrix** displays.

LCD Displays

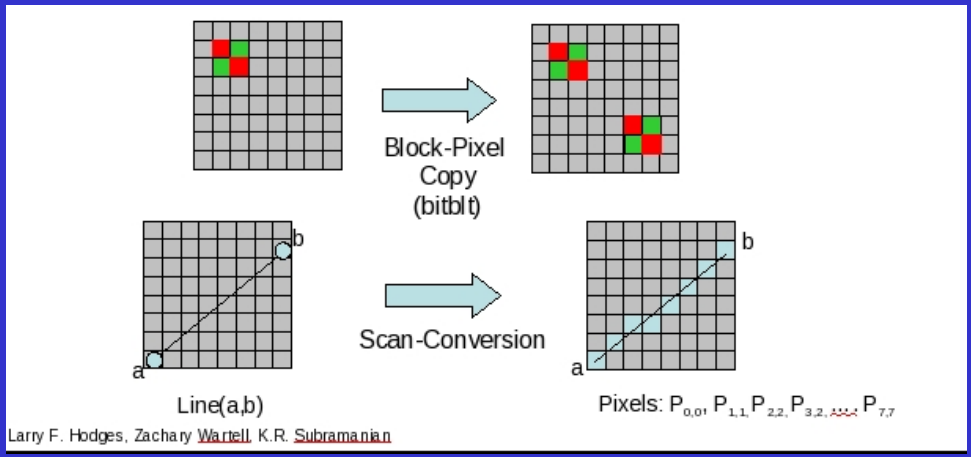


Display Architecture



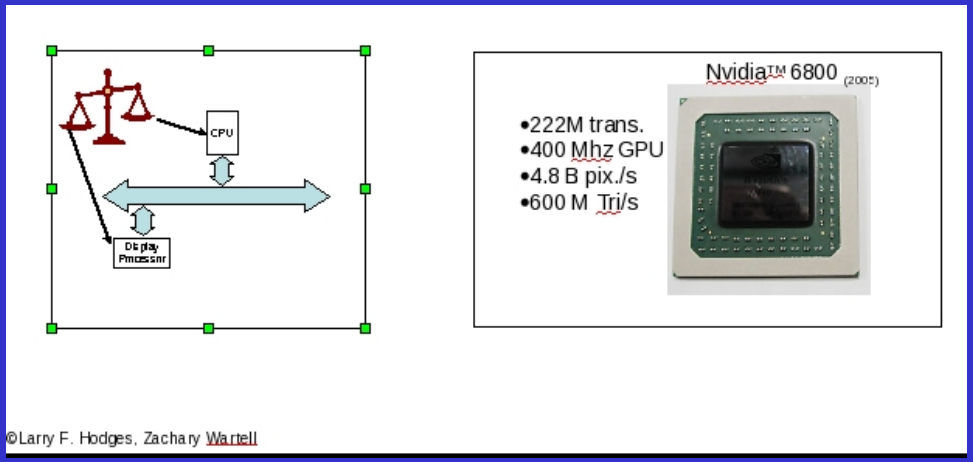
Display Processor

- Synonyms: Graphics Controller, Display Co-Processor, Graphics Accelerator, or GPU
- Specialized hardware for rendering graphics primitives into the frame buffer.



Display Processor

- Fundamental difference among display systems is how much the display processor does versus how much must be done by the graphics subroutine package executing on the general-purpose CPU.



Video Controller

- Cycles through the frame buffer, one scan line at a time.
- Contents of the memory are used the control the CRT's beam intensity or color.