

# 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

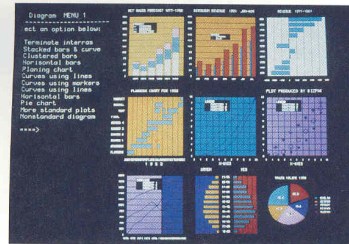


FIGURE 1-2 Two-dimensional line graphs, bar charts, and a pie chart. (Courtesy of UNIRAS, Inc.)

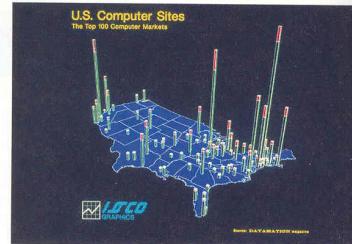
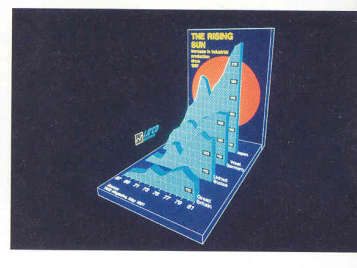
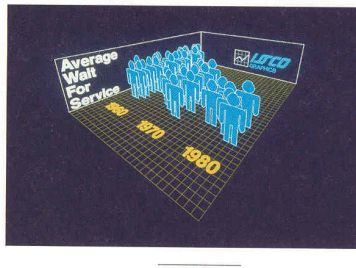
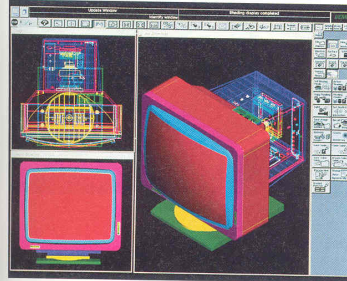


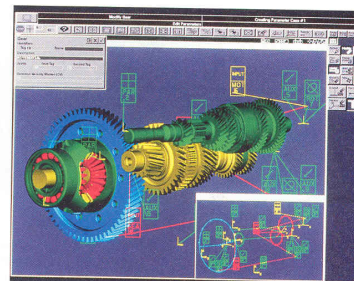
FIGURE 1-3 Two color-coded data sets displayed as a three-dimensional bar chart on the surface of a geographical region. (Reprinted with permission from ISSCO Graphics, San Diego, California.)



# Applications: Computer-aided Drafting and Design (CAD)



(a)



(b)

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

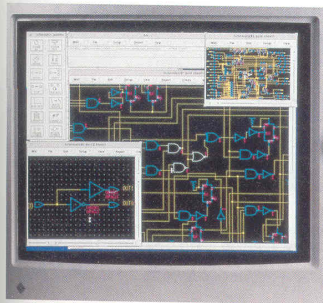


FIGURE 1-10 A circuit design application, using multiple windows and color-coded logic components. (Courtesy of Sun Microsystems.)

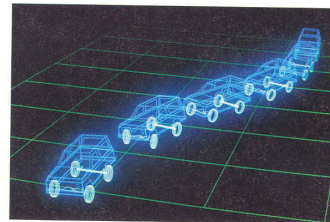
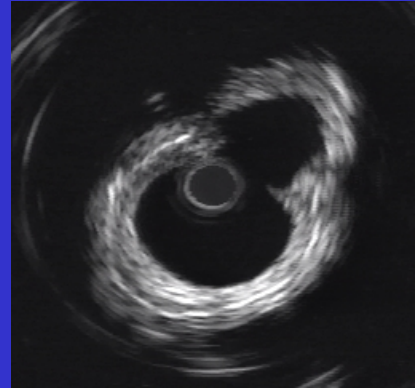
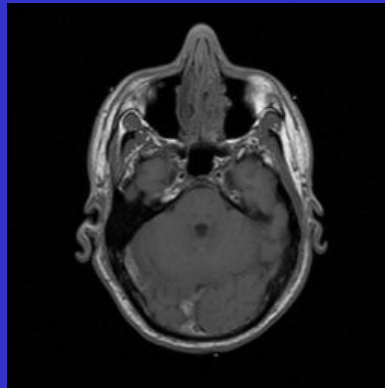
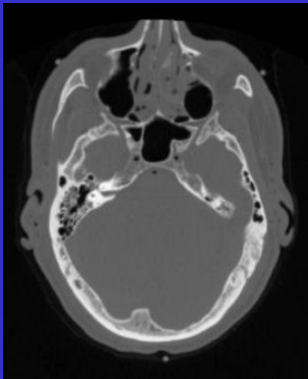


FIGURE 1-11 Simulation of vehicle performance during lane changes. (Courtesy of Evans & Sutherland and Mechanical Dynamics, Inc.)

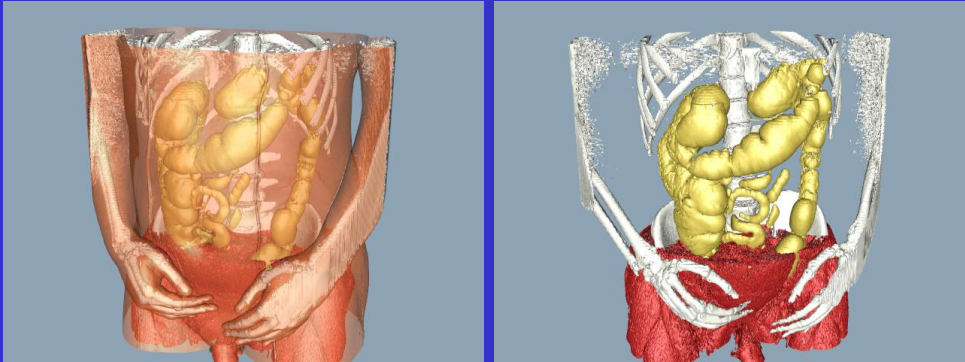
# Applications: Scientific Data Visualization

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

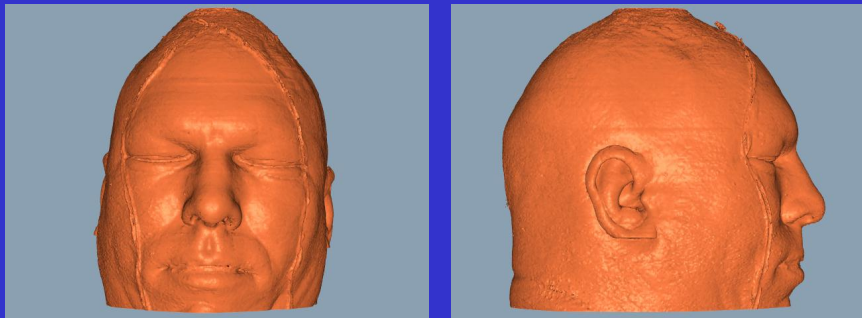


# Applications: Medical Visualization: Visible Human Project

From CT



From the Physical Data



# Applications: Computer Interfaces



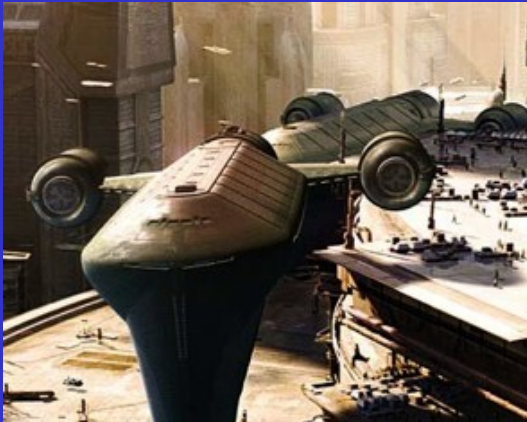


# Applications: Computer/Video Games

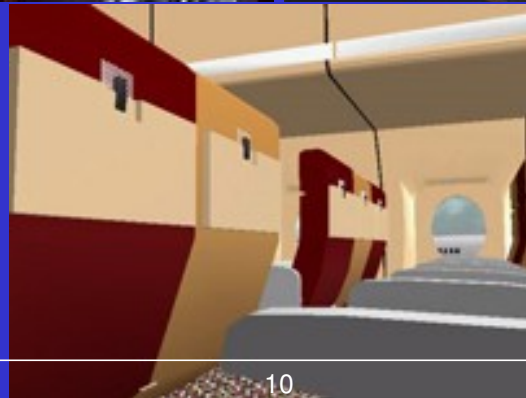




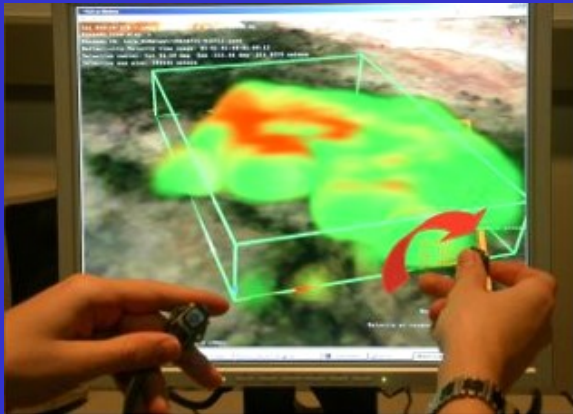
# Applications: Entertainment (movies, animation, advertising)



# Virtual and Immersive Environments



# Virtual and Immersive Environments



# What Disciplines does CG draw on?

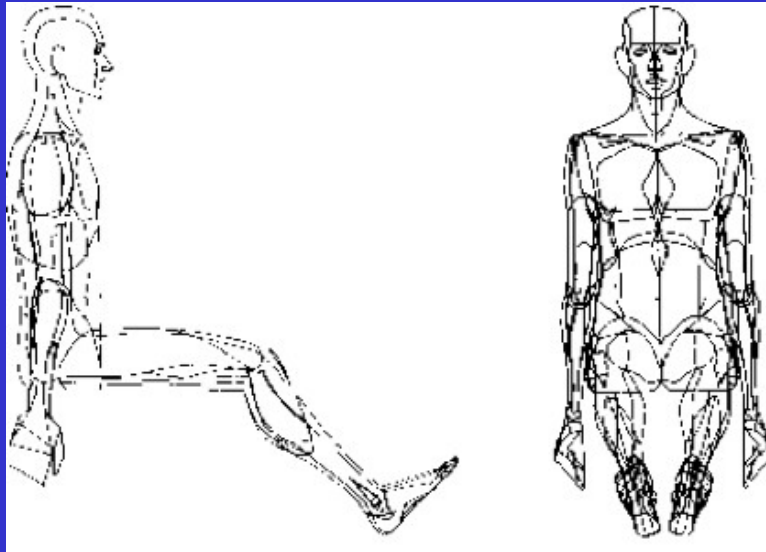
- Algorithms
- Mathematics
  - Basic : linear/vector algebra, geometry, trig.
  - Advanced: advanced calculus, comp/differential geometry, topology
- optics (very approximate in ITCS 4120)
- software engineering and programming
- hardware engineering
- psychophysics: human visual system
- industrial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

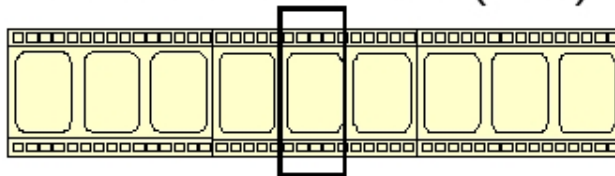


William Fetter, 1960, Boeing Aircraft Co.

“Boeing Man, human figure simulation, credited with “computer graphics

# CG Applications: Spectrum

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



- Realism



vs



- \$\$\$

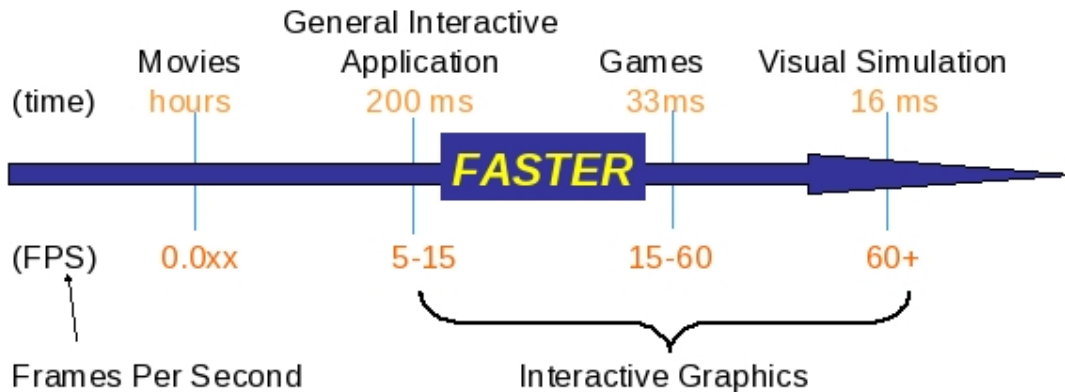
- 1950's, Whirlwind, \$4.5M, 40K adds/s
- today's PC: \$1K, 2-3B ops/s
- CG: 1995, \$100K, SGI = 2004, \$1K PC

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# CG Application Spectrum: Speed

- Speed: Time to compute one image



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# CG Application Spectrum: Realism

## •Realism

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

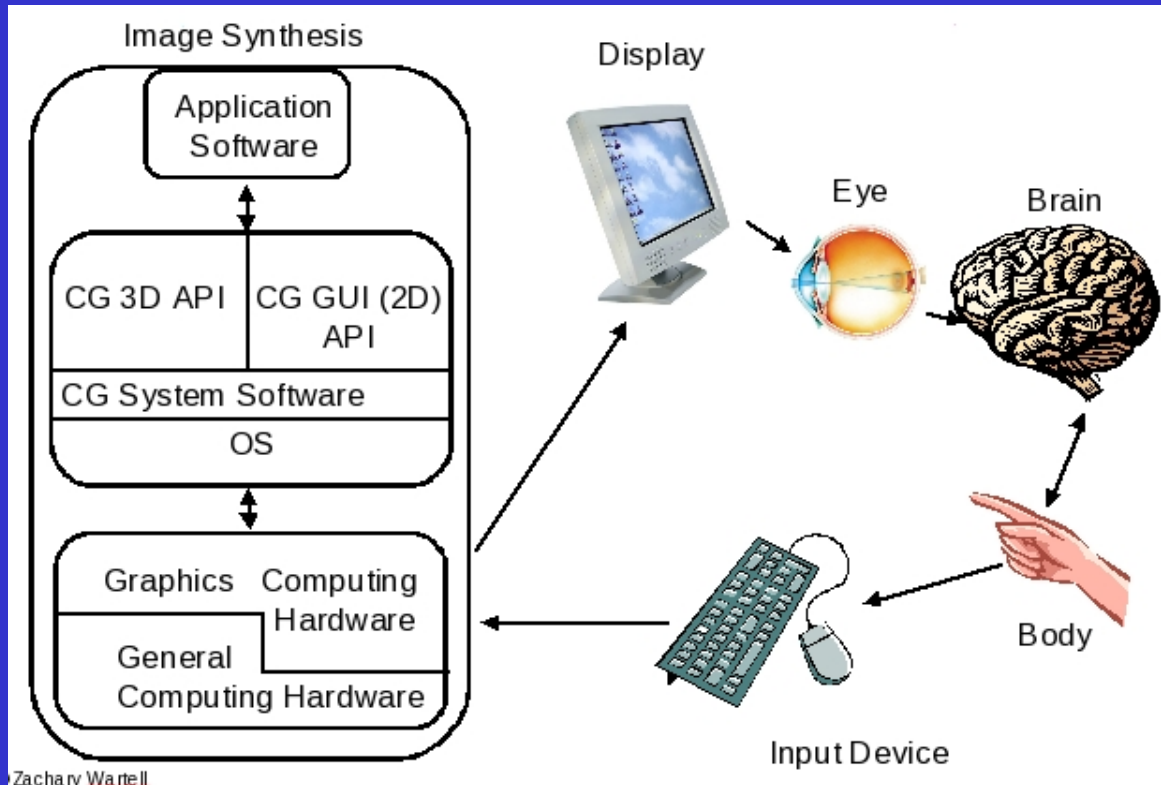


- display technology & human visual perception  
(image fidelity, stereopsis, motion parallax)

# CG Application Spectrum: Speed vs. Realism

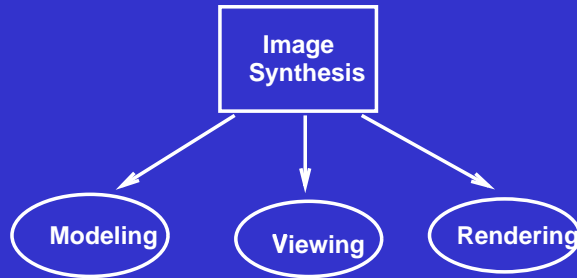
- Generally: more realism less speed
- But Moores Law continues to reign
  - price/performance improves 2x every 18 months
  - since 1995 gaming market driving graphics hardware (Nintendo GameCube™ (ATI), Xbox (Nvidia inside), PC: nVidia Geforce 7900, ATI Radeon X1900)
- Display capability still lags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

# CG Application Components



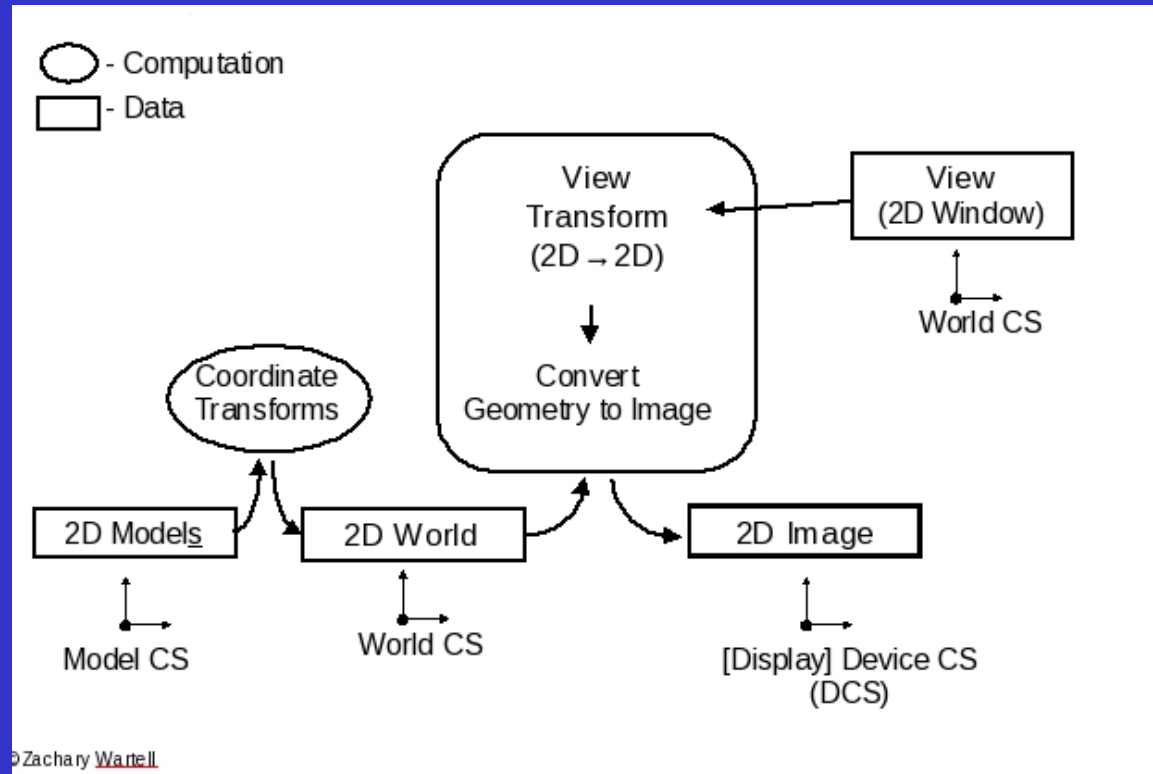
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# Image Synthesis



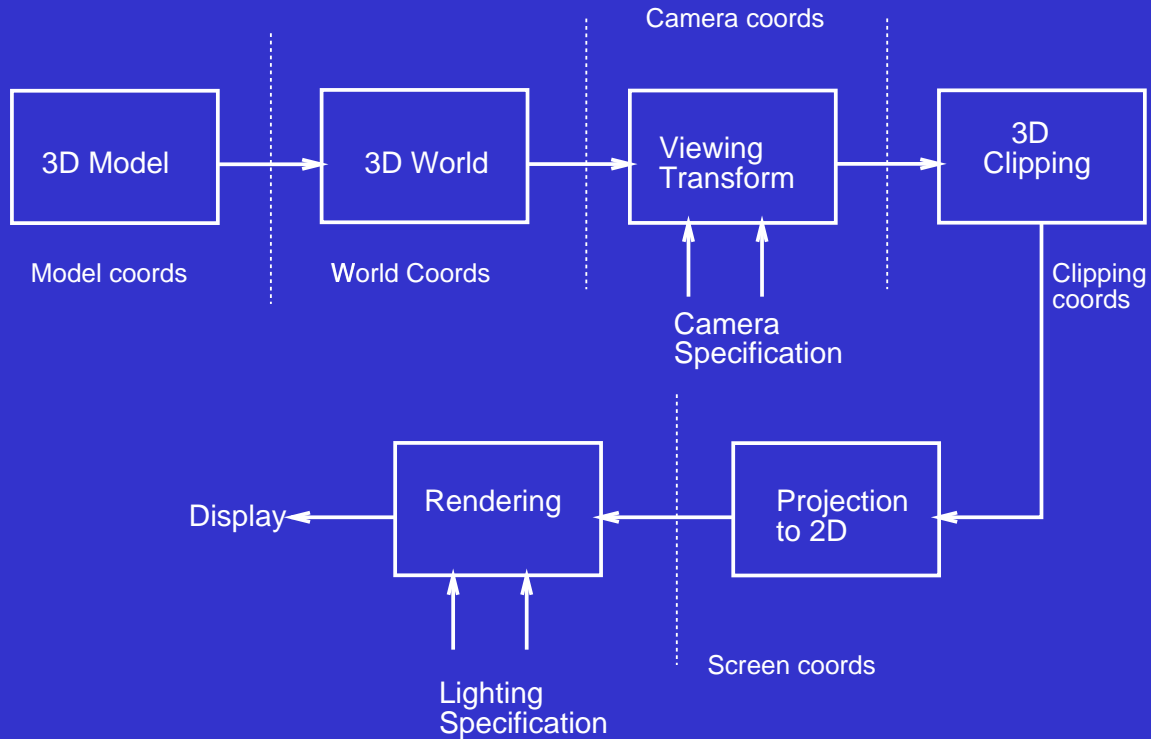
- **Modeling:** The process of creating objects of a scene that will be rendered by the graphics hardware.
- **Viewing:** Specification of camera and a viewing window (volume) that determines the part of the world (of objects) that will be included in the final image.
- **Rendering:** The process that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

# The Viewing Pipeline (2D)



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# The Viewing Pipeline(3D)





# Graphics (Hardware) Pipeline

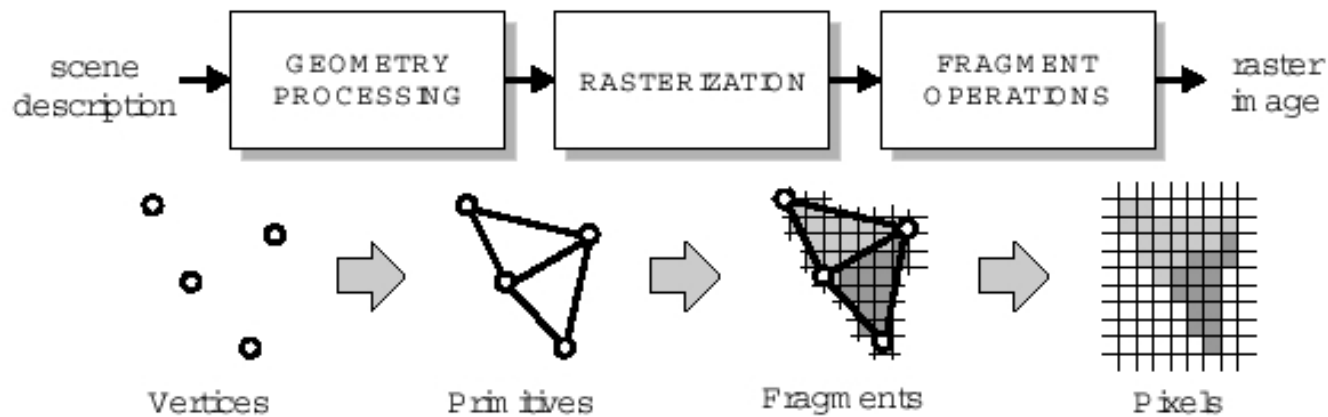
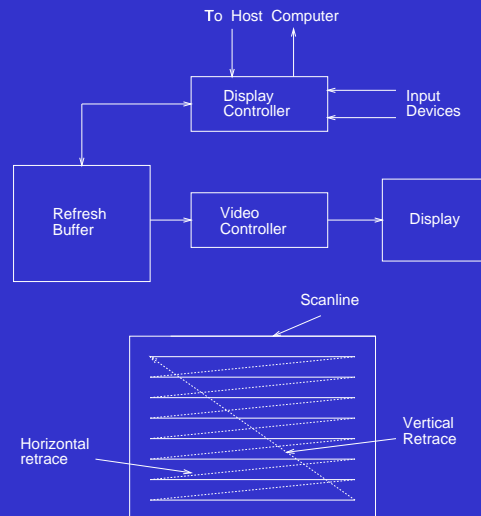


Figure 3.1: The graphics pipeline for display traversal.

# Image Synthesis Hardware (Raster Technology)

## Definitions

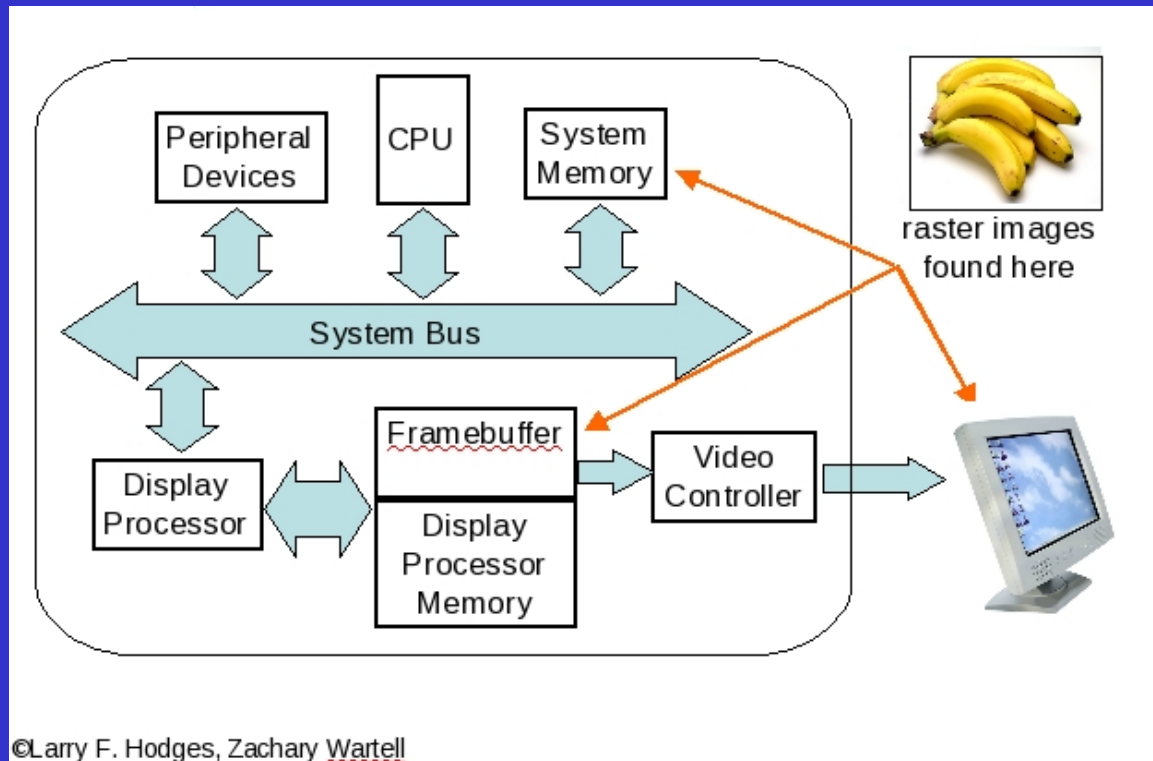
- **Raster:** A rectangular array of points or dots (either on physical display or a data structure in memory).
- **Pixel (Pel):** One dot or picture element of the raster
- **Scan Line:** A row of pixels



## 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).

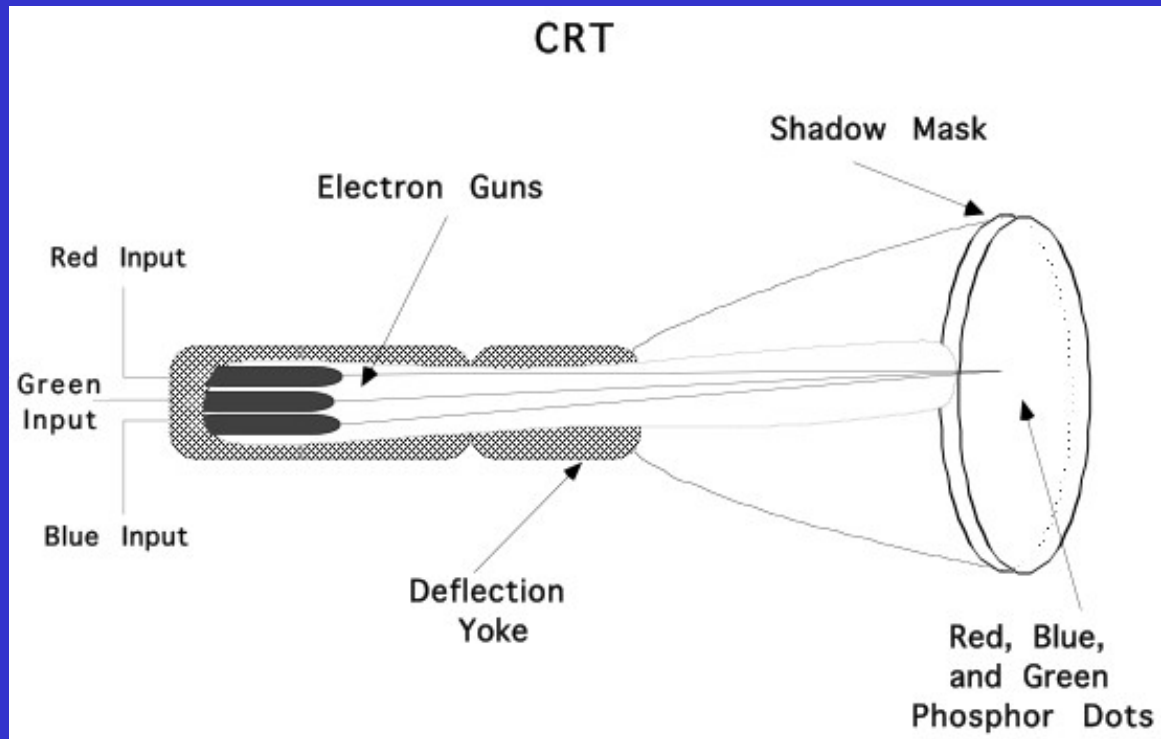
# Image Synthesis Hardware (Raster Technology)



# 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.

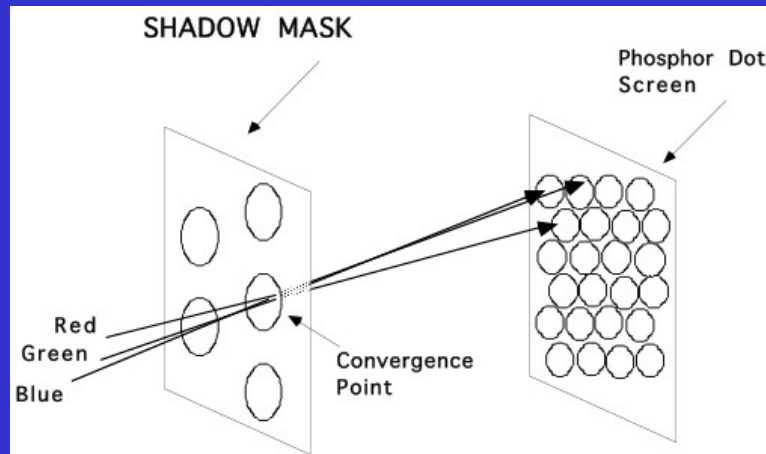


# Color CRT

- 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

1/30 SEC		1/30 SEC	
1/60 SEC	1/60 SEC	1/60 SEC	1/60 SEC
FIELD 1	FIELD 2	FIELD 1	FIELD 2
FRAME		FRAME	

- Display frame rate 30 times per second.
- To reduce flicker at lesser bandwidths (Bits/sec.), divide frame into two fields one 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

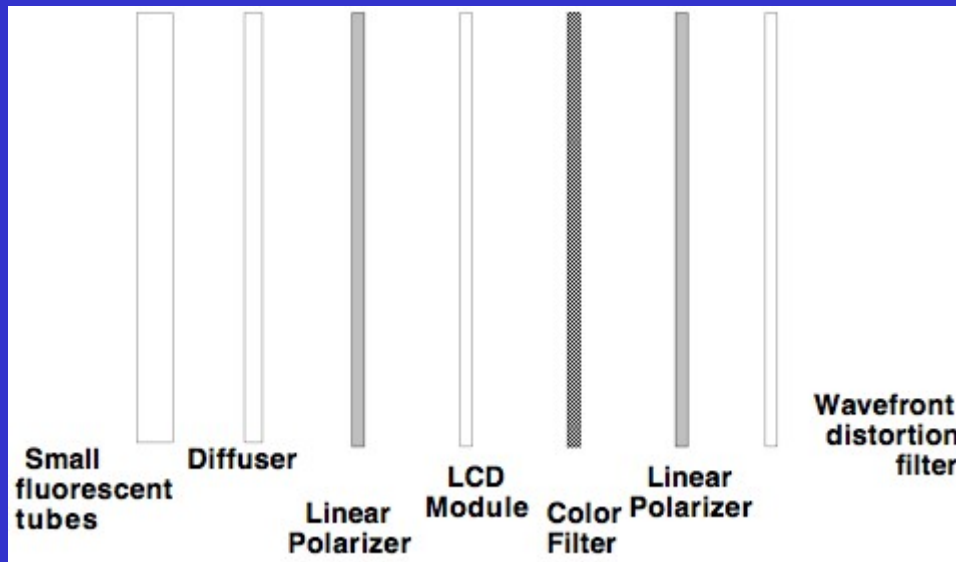
## Example Video Formats

- 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
- X VGA 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

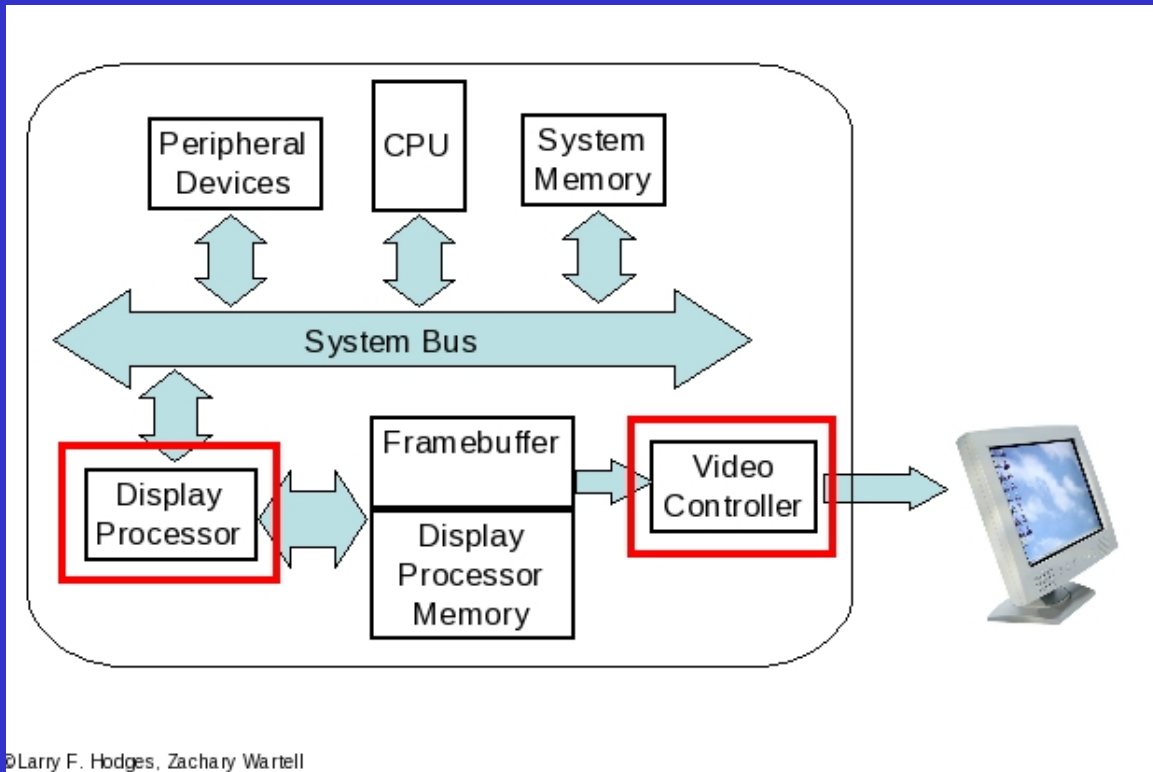
- Liquid crystal displays use small flat chips which change their transparency properties when a voltage is applied.
- LCD elements are arranged in an  $n \times m$  array call the LCD matrix
- Level of voltage controls gray levels.
- LCDs elements do not emit light, use backlights behind the LCD matrix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

# LCD Displays



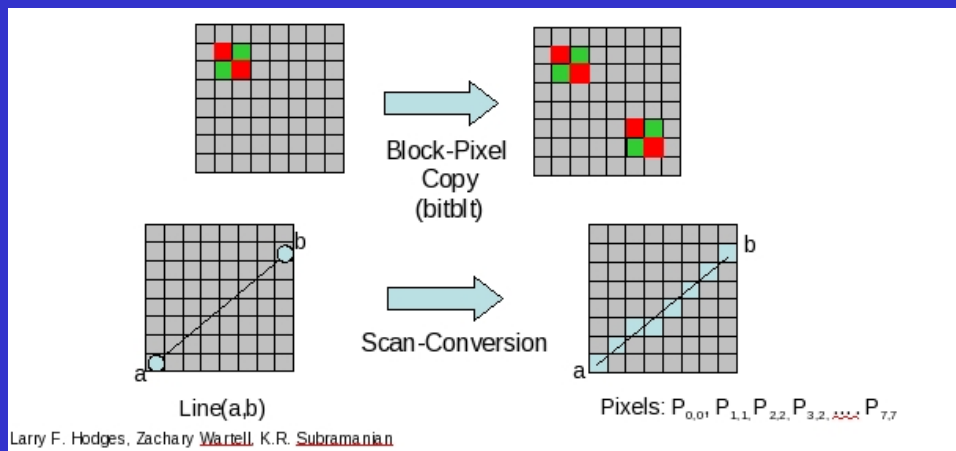


# Display Architecture



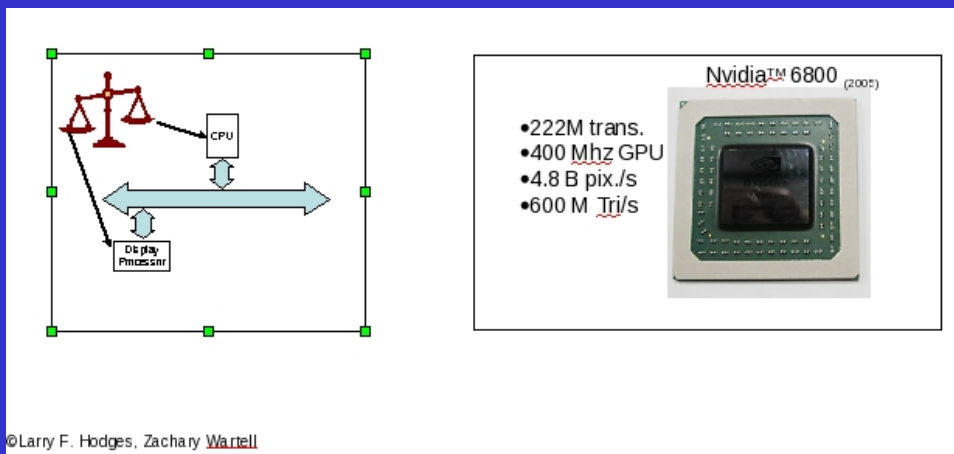
# Display Processor

- 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 to control the CRT's beam intensity or color.

