WHAT IS COMPUTER GRAPHICS?

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Disclaimer

- These slides can only be used as study material for the Computer Graphics at Sejong University
- The slides cannot be distributed or used for another purpose

Computer Graphics

- *Computer graphics* deals with all aspects of creating images with a computer
  - Hardware
  - Software
  - Applications
- Example from textbook

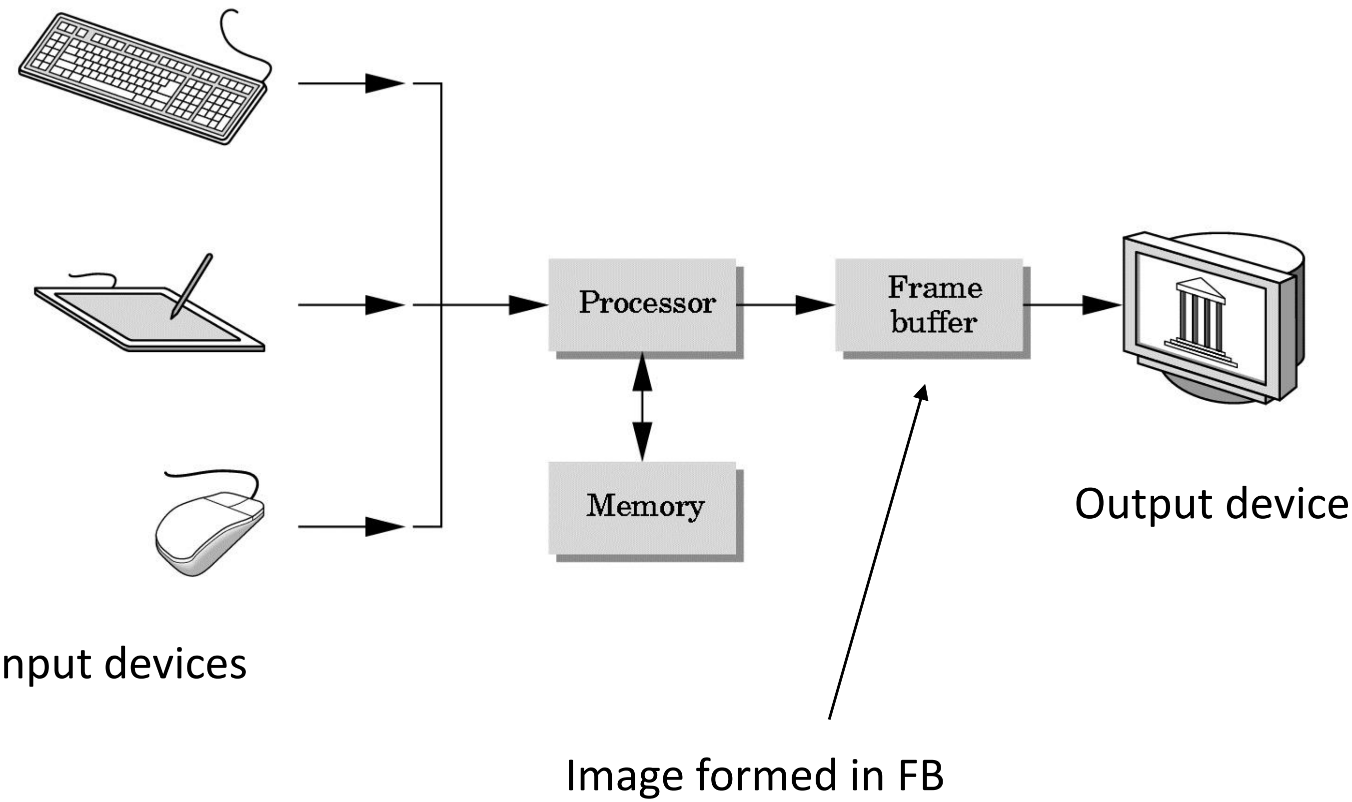
Example

- Where did this image come from?
- What hardware/software did we need to produce it?

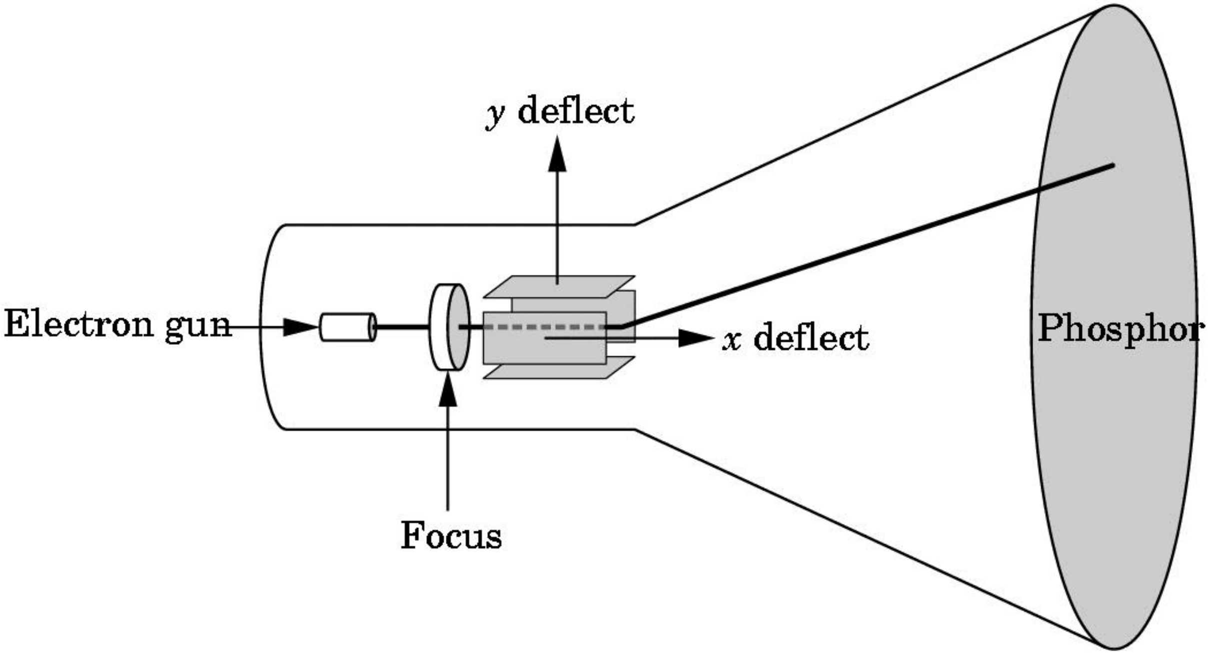
Preliminary Answer

- **Application**: The object is an artist's rendition of the sun for an animation to be shown in a domed environment (planetarium)
- **Software**: Maya for modeling and rendering but Maya is built on top of OpenGL
- **Hardware**: PC with graphics card for modeling and rendering

Basic Graphics System



CRT



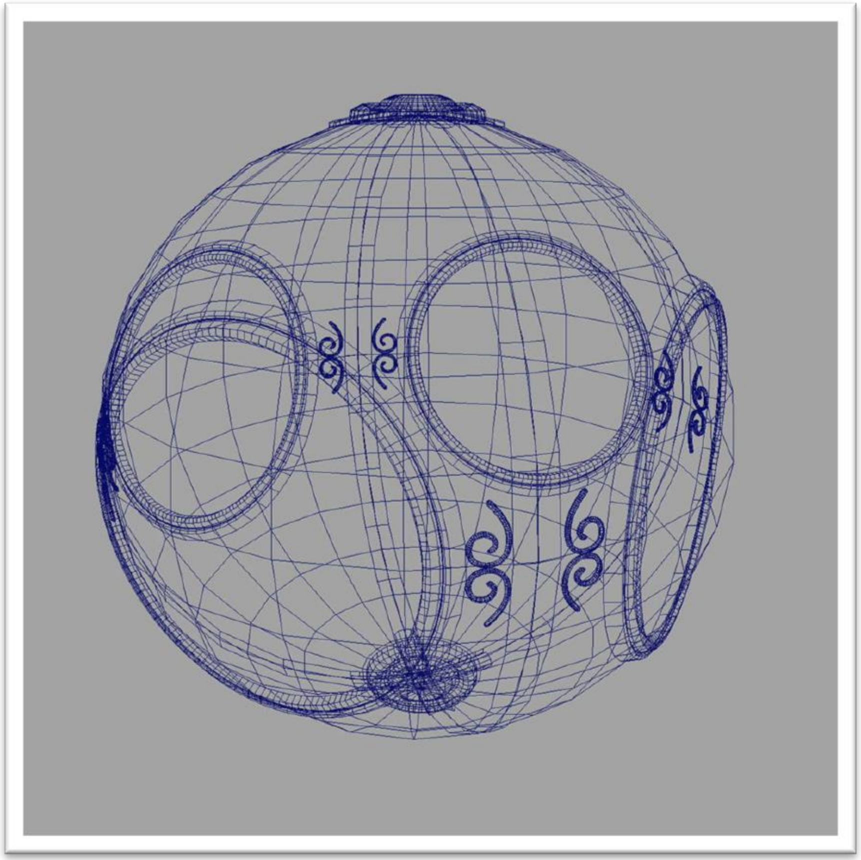
Can be used either as a line-drawing device (calligraphic) or to display contents of frame buffer (raster mode)

History: 1950-1960

- Computer graphics goes back to the earliest days of computing
  - Strip charts
  - Pen plotters
  - Simple displays using A/D converters to go from computer to calligraphic CRT
  - Like standard screens, but no refresh…
- Cost of refresh for CRT too high
  - Computers slow, expensive, unreliable

History: 1960-1970

- *Wireframe* graphics
  - Aka *vector graphics*
  - Draw only lines
- Sketchpad
- Display Processors
- Storage tube

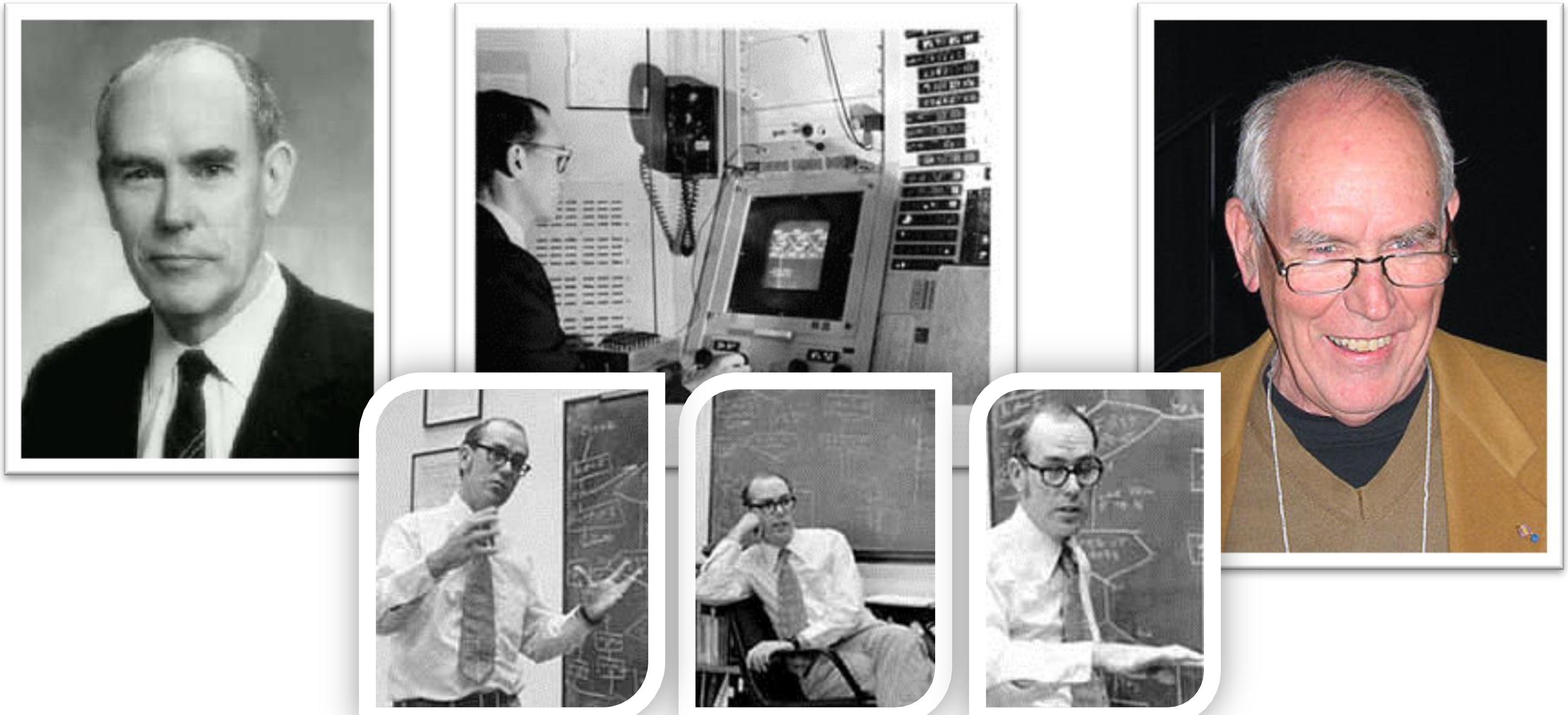


wireframe representation of sun object

Sketchpad

- Ivan Sutherland's Ph.D. thesis at MIT
  - Recognized the potential of man-machine interaction
  - Loop
    - Display something
    - User moves light pen
    - Computer generates new display
  - Sutherland also created many of the now common algorithms for computer graphics

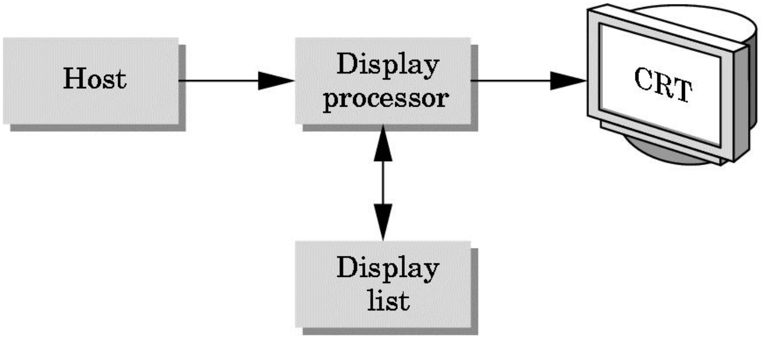
Ivan Sutherland (b. 1938-)



"A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland."

Display Processor

- Rather than have the host computer try to refresh display use a special purpose computer called a *display processor* (DPU)



- Graphics stored in display list (display file) on display processor
- Host *compiles* display list and sends to DPU

Direct View Storage Tube

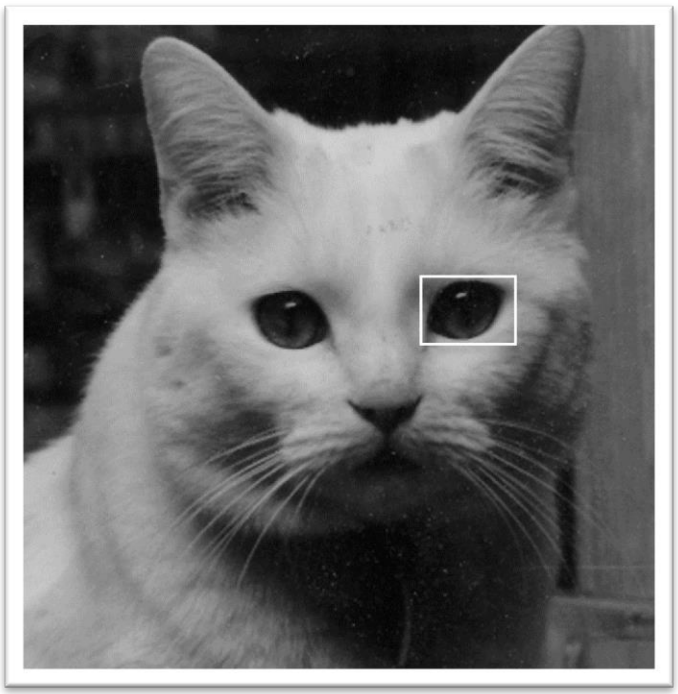
- Created by Tektronix
  - Did not require constant refresh
  - Standard interface to computers
    - Allowed for standard software
    - Plot3D in Fortran
  - Relatively inexpensive
    - Opened door to use of computer graphics for CAD community

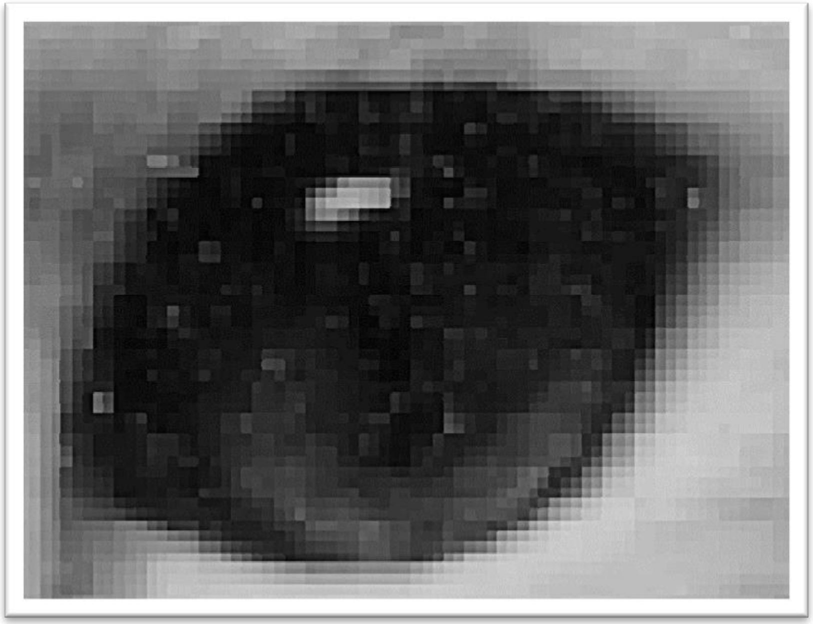
History: 1970-1980

- Raster Graphics
- Beginning of graphics standards
  - IFIPS
    - GKS: European effort
      - Low-level 2D vector graphics suitable for charting
      - Becomes ISO 2D standard
    - Core: North American effort
      - 3D but fails to become ISO standard
- Workstations and PCs

Raster Graphics

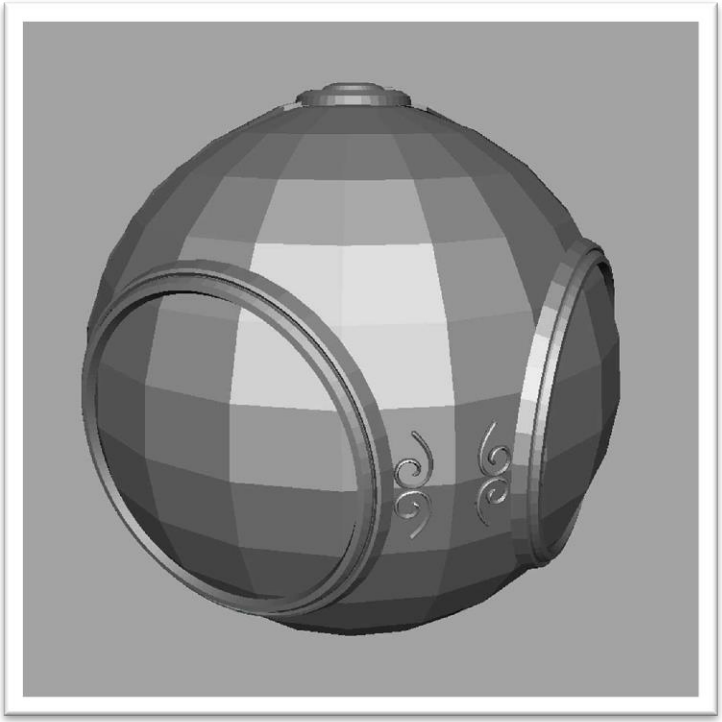
- Image produced as an array (the *raster*) of picture elements (*pixels*) in the *frame buffer*





Raster Graphics

- Allows us to go from lines and wire frame images to filled polygons

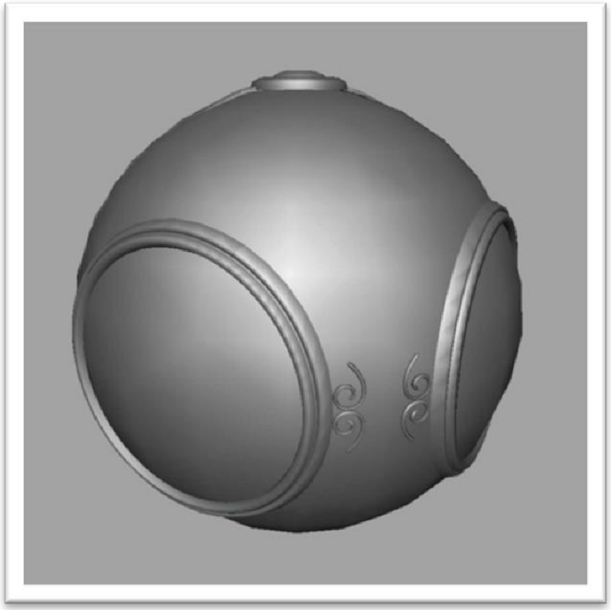


PCs and Workstations

- Although we no longer make the distinction between workstations and PCs, historically they evolved from different roots
  - Early workstations characterized by
    - Networked connection: client-server model
    - High-level of interactivity
  - Early PCs included frame buffer as part of user memory
    - Easy to change contents and create images

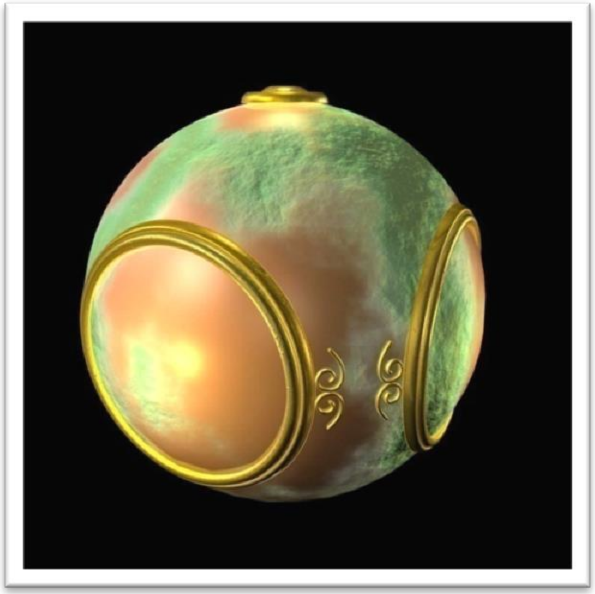
History: 1980-1990

Realism comes to computer graphics



smooth shading

environment mapping



bump mapping

History: 1980-1990

- Special purpose hardware
  - Silicon Graphics geometry engine
    - VLSI implementation of graphics pipeline
- Industry-based standards
  - PHIGS – descendant of GKS
    - 3D graphics standard for the 90s
    - Scene graph hierarchy part of standard
  - RenderMan
    - Pixar
- Networked graphics: X Window System
- Human-Computer Interaction (HCI)

History: 1990-2000

- OpenGL API
- Completely computer-generated feature-length movies (**Toy Story**) are successful
- New hardware capabilities
  - Texture mapping
  - Blending
  - Accumulation, stencil buffers
- Non-photorealistic rendering (NPR)

RenderMan

- 3D scene specification
  - Off-line rendering (cf. real-time for OpenGL)
  - Interface protocol for different 3D apps
  - Developed by Pixar Animation Studios
  - Like PostScript for 3D
- Components
  - High-level geometric primitives
    - Quadrics, bicubic patches, etc
  - Shading language (RSL)
    - C-like syntax, compare to GLSL (later lectures)


Disney
Disney · PIXAR
TOY STORY
em Disney DVD vídeo
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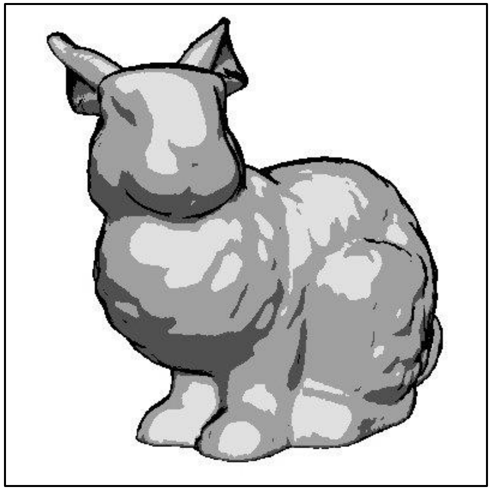
NPR



History: 2000-

- Photorealism
- Graphics cards for PCs dominate market
  - NVidia, ATI
- Game boxes and game players determine direction of market
- Computer graphics routine in movie industry: Maya, Lightwave
- Programmable pipelines

Questions?

- Ask now or e-mail later
- Acknowledgements
  - Previous instructors at Purdue
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  - Previous instructors at Arizona state university
    - Ross Maciejewski
  - Textbook (Ed Angel)
  - Google Image Search
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IMAGE FORMATION

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Objectives

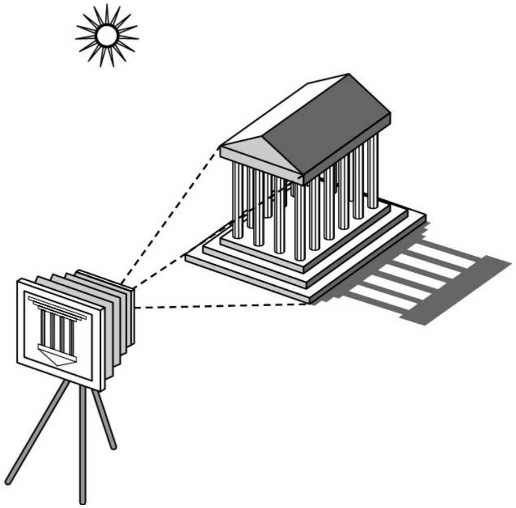
- Fundamental imaging notions
- Physical basis for image formation
  - Light
  - Color
  - Perception
- Synthetic camera model
- Other models

Image Formation

- In computer graphics, we form images which are generally two dimensional using a process analogous to how images are formed by physical imaging systems
  - Cameras
  - Microscopes
  - Telescopes
  - Human visual system

Elements of Image Formation

- Objects
- Viewer
- Light source(s)

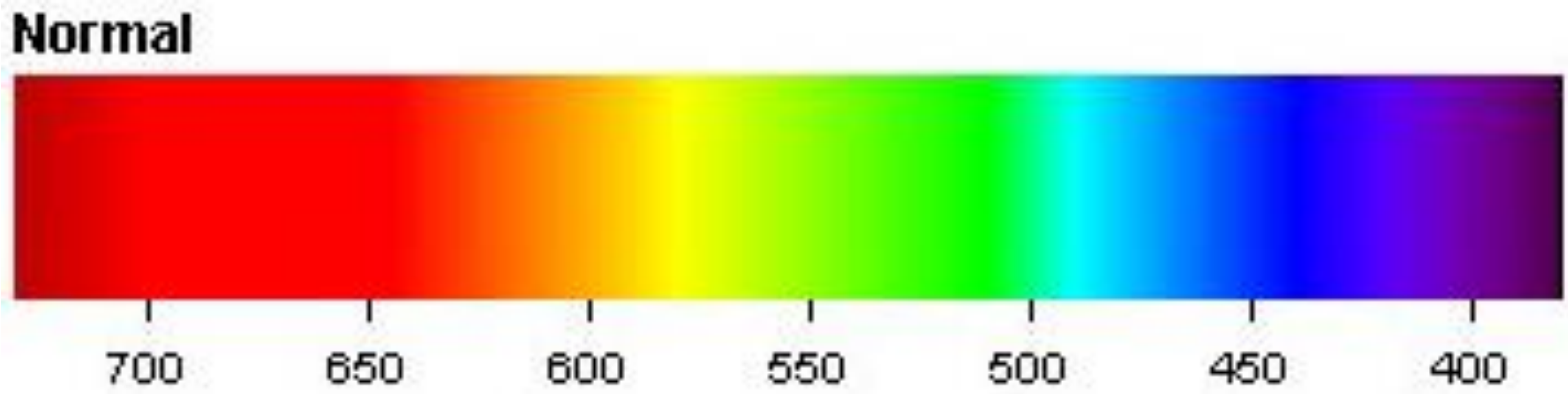


- Attributes that govern how light interacts with the materials in the scene
- Note the independence of the objects, the viewer, and the light source(s)

Light

- *Light* is the part of the electromagnetic spectrum that causes a reaction in our visual systems
- Generally these are wavelengths in the range of about 350-750 nm (nanometers)
- Long wavelengths appear as reds and short wavelengths as blues

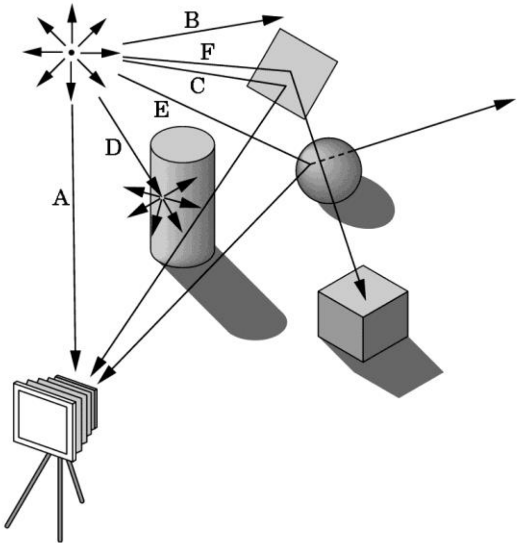
Visible Spectrum

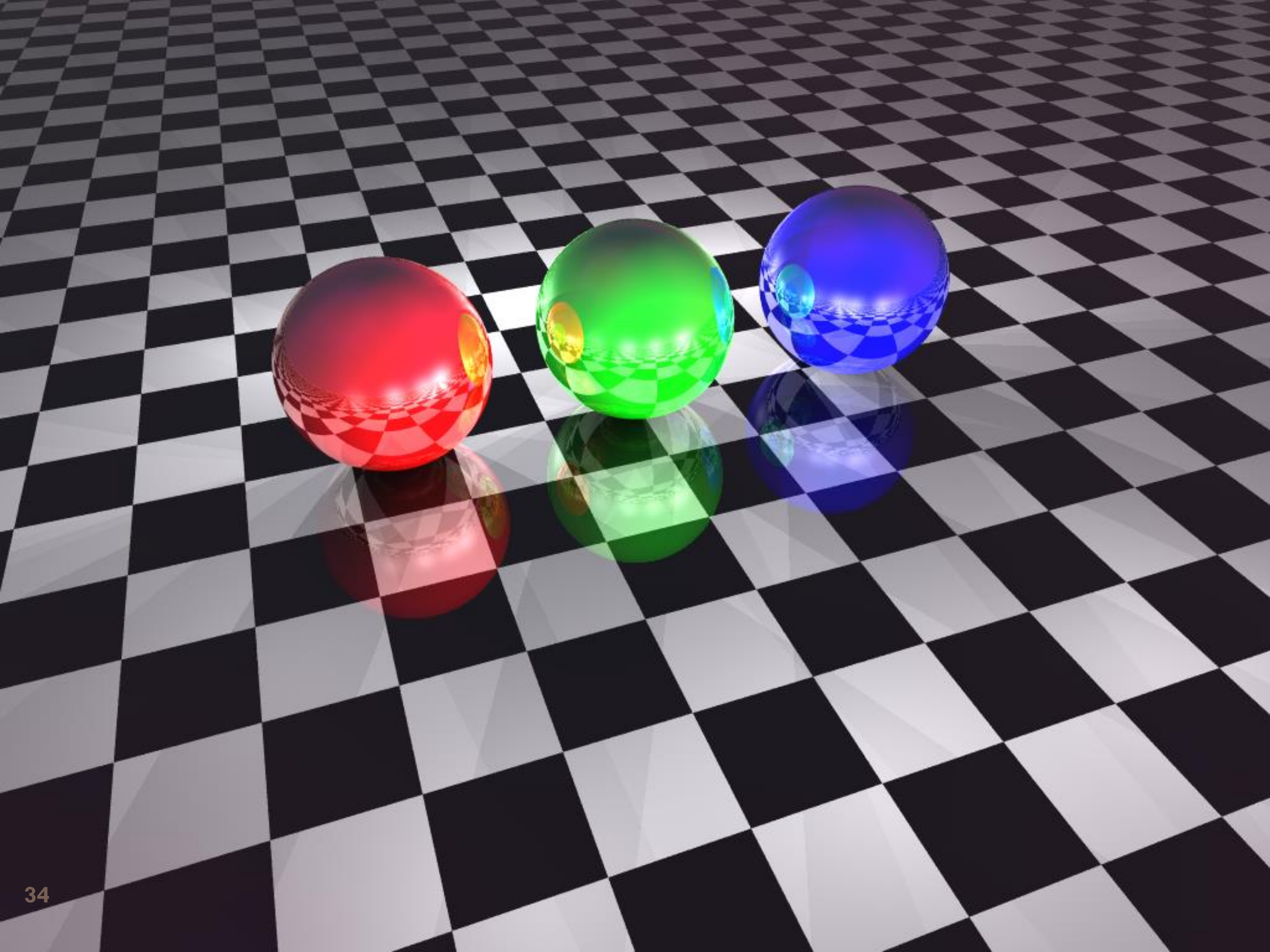


Ray Tracing and Geometric Optics

One way to form an image is to follow rays of light from a point source finding which rays enter the lens of the camera.

However, each ray of light may have multiple interactions with objects before being absorbed or going to infinity.



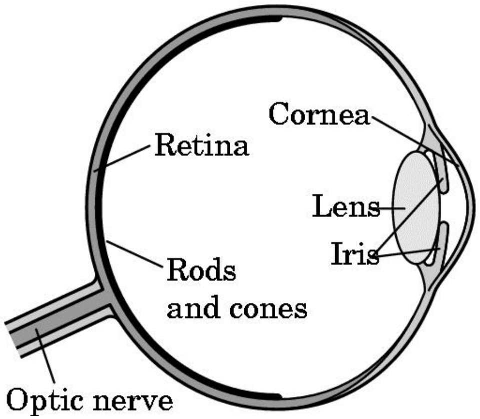


Luminance and Color Images

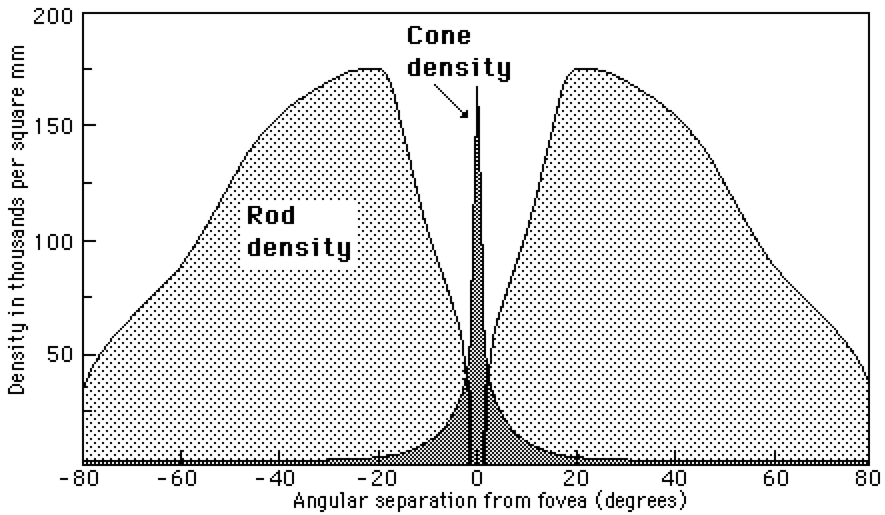
- Luminance Image
  - Monochromatic
  - Values are gray levels
  - Analogous to working with black and white film or television
- Color Image
  - Has perceptional attributes of hue, saturation, and lightness
  - Do we have to match every frequency in visible spectrum? No

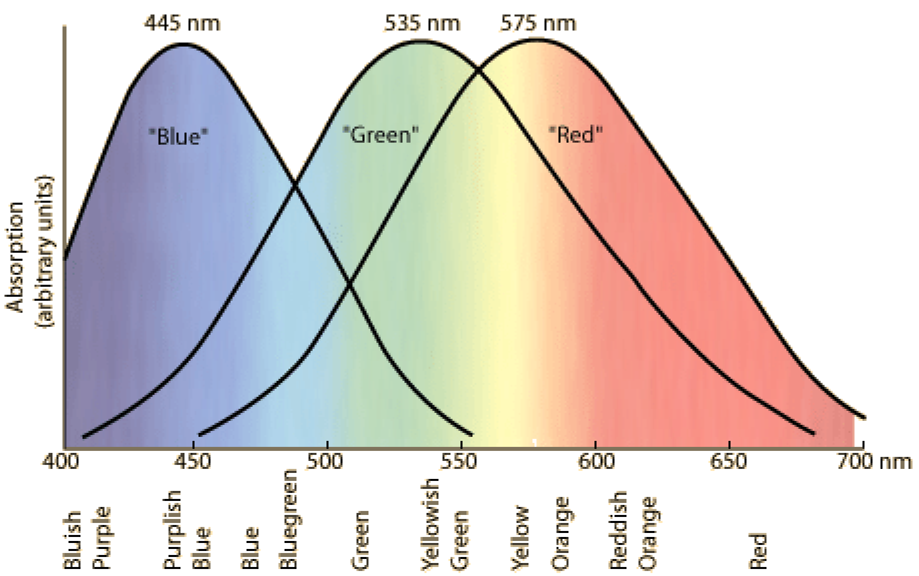
Three-Color Theory

- Human visual system has two types of sensors
  - Rods: monochromatic, night vision
    - About 120 million
  - Cones
    - About 7 million
    - Color sensitive
    - Three types of cones
    - Only three values (the *tristimulus* values) are sent to the brain
- Need only match these three values
  - Need only three *primary* colors

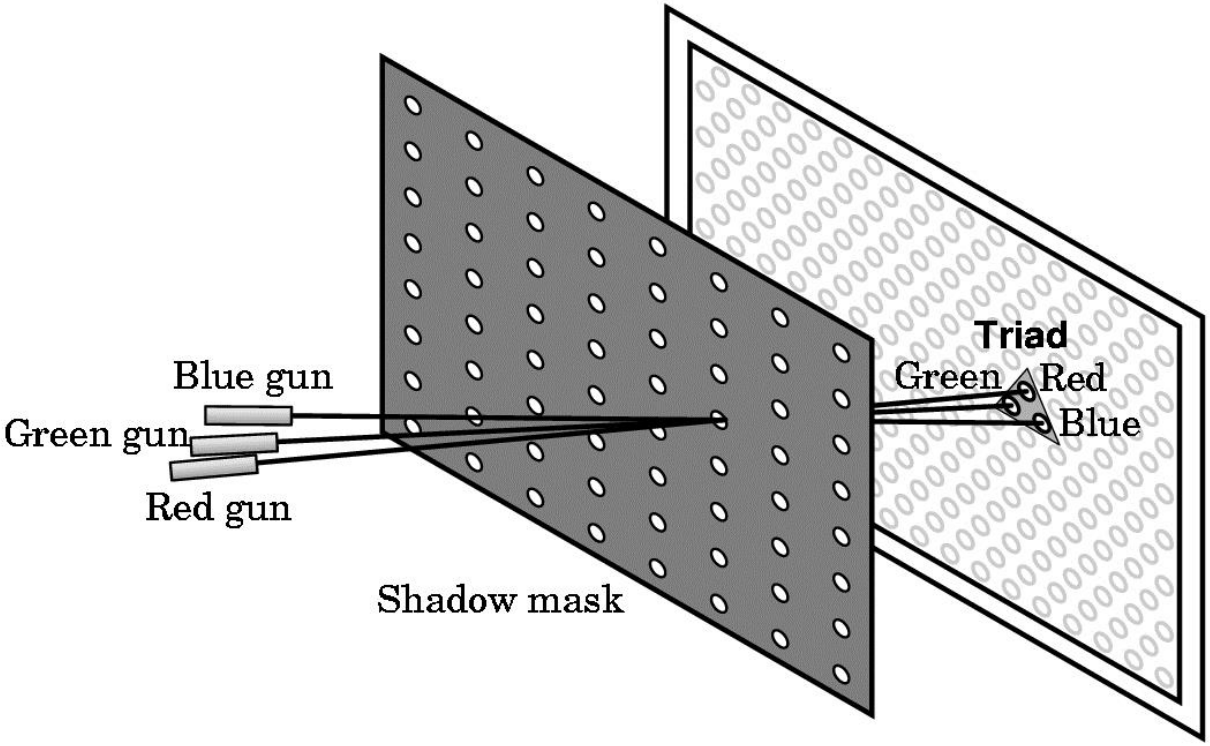


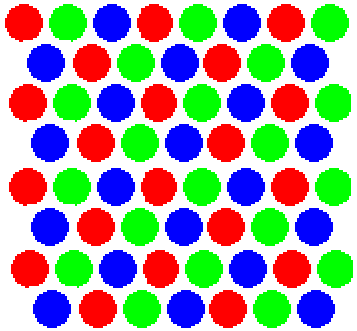
Color Sensitivity





Shadow Mask CRT

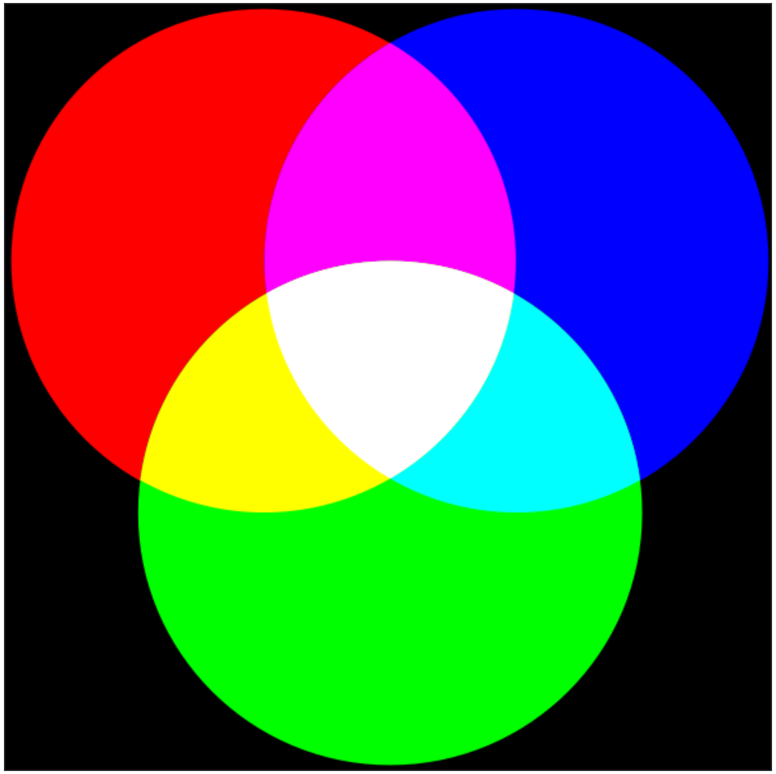


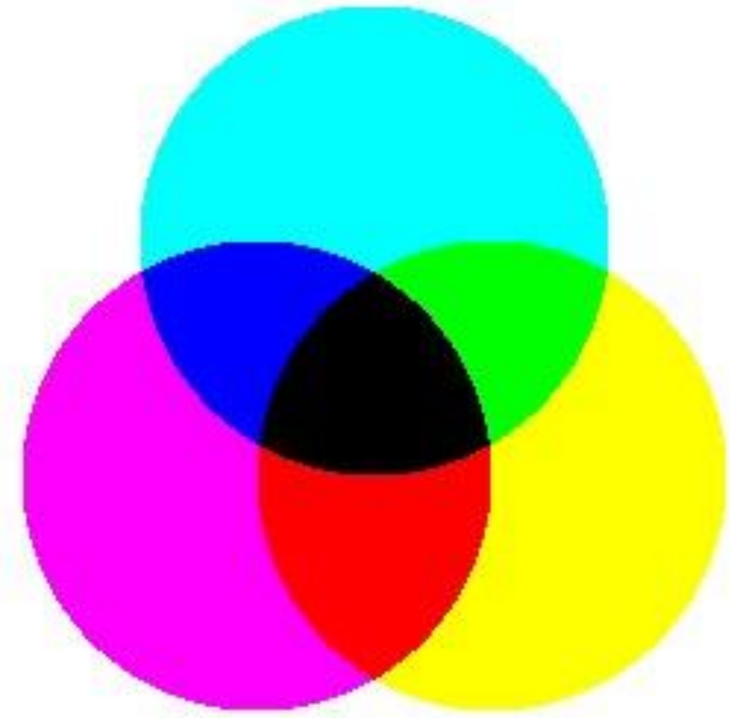


Additive and Subtractive Color

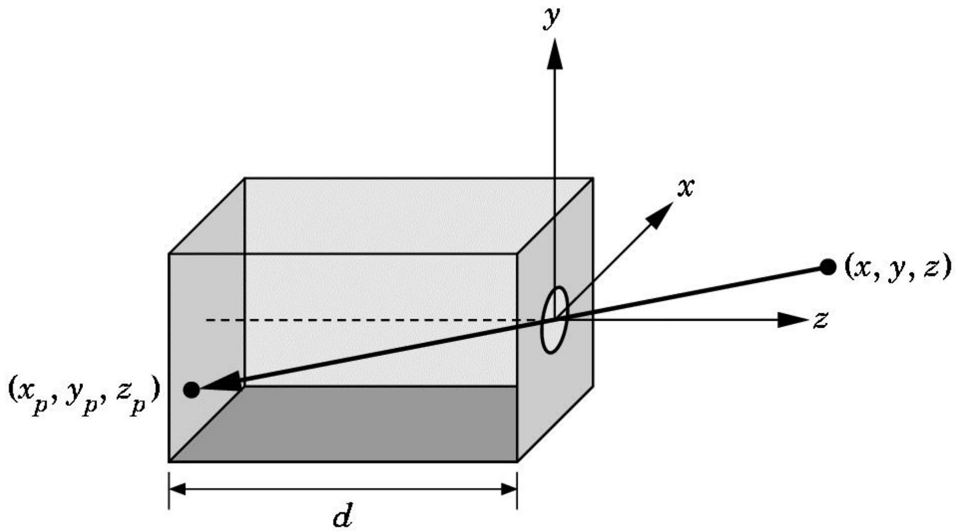
- Additive color
  - Form a color by adding amounts of three primaries
    - CRTs, projection systems, positive film
  - Primaries are Red (R), Green (G), Blue (B)
- Subtractive color
  - Form a color by filtering white light with cyan (C), Magenta (M), and Yellow (Y) filters
    - Light-material interactions
    - Printing
    - Negative film

RGB vs CMYK





Pinhole Camera

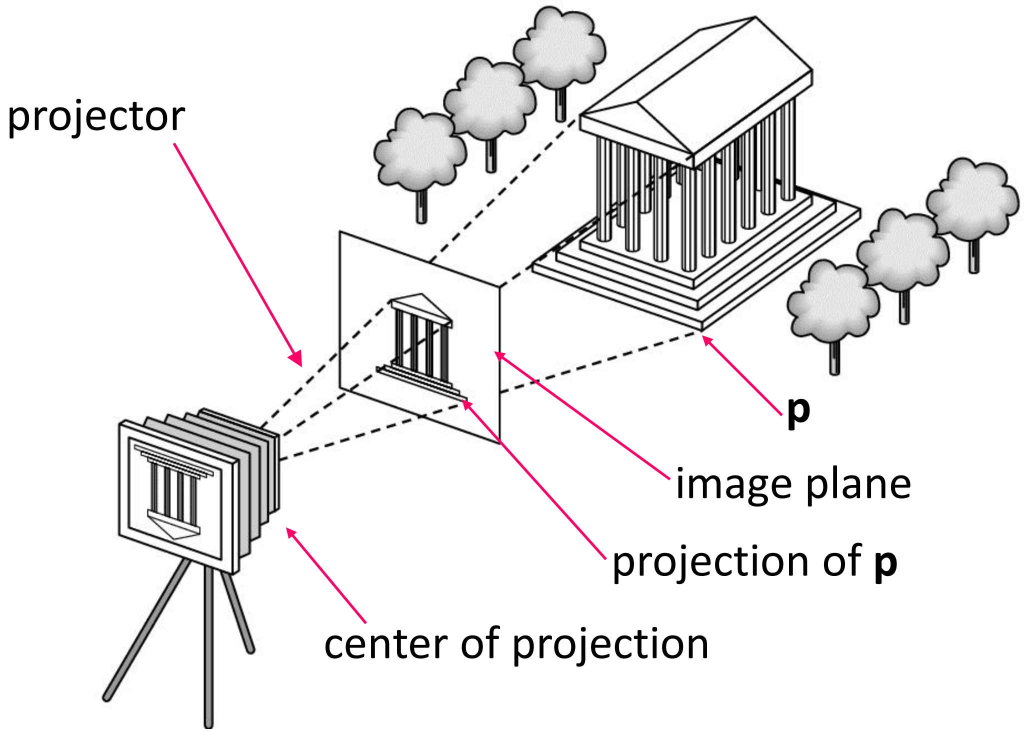


Use trigonometry to find projection of point at (x,y,z)

$x_p = -x/z/d \qquad y_p = -y/z/d \qquad z_p = d$

These are equations of simple perspective

Synthetic Camera Model

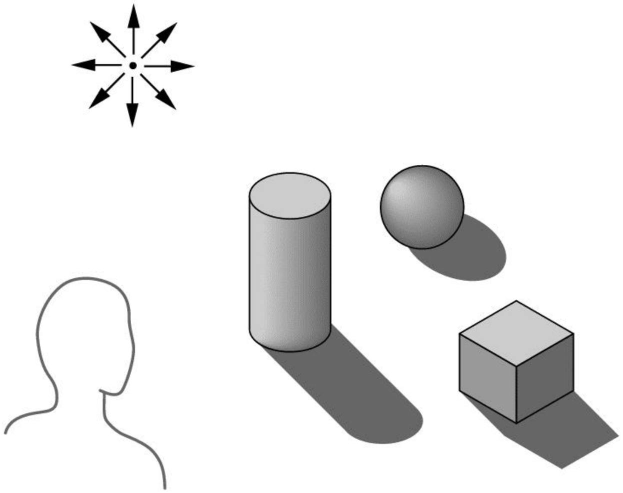


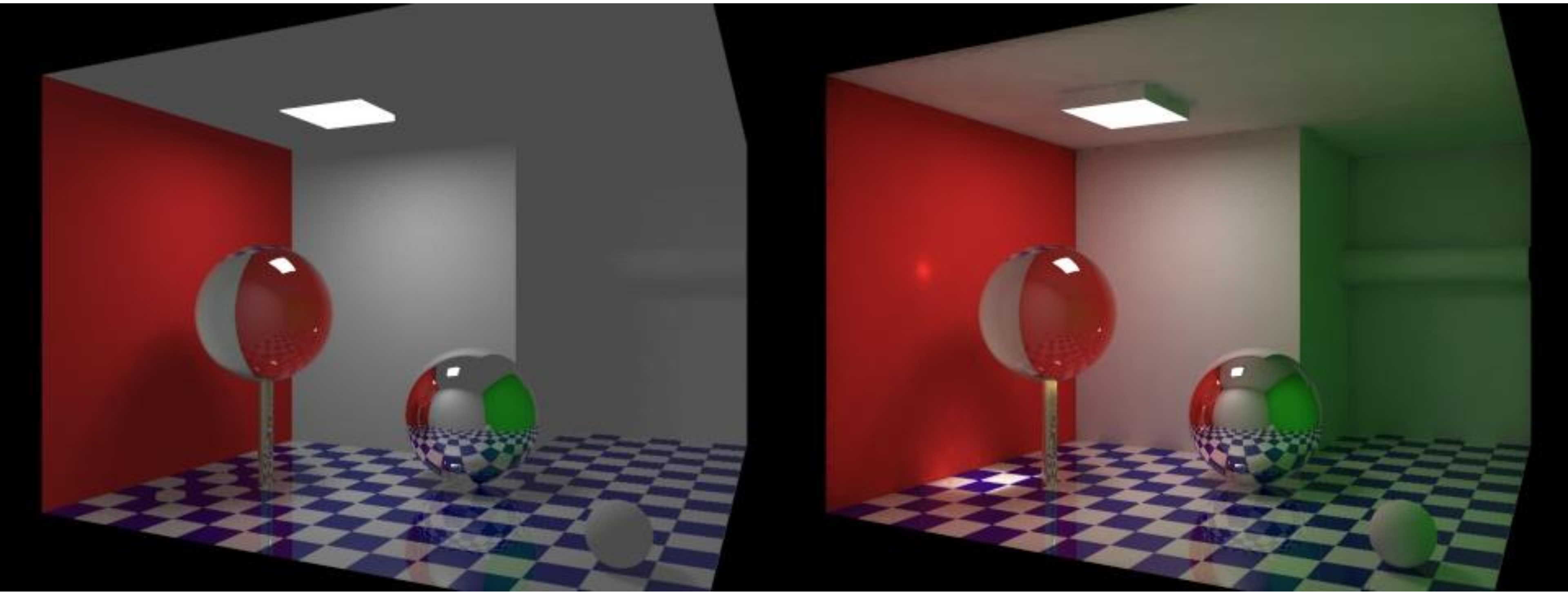
Advantages

- Separation of objects, viewer, light sources
- Two-dimensional graphics is a special case of three-dimensional graphics
- Leads to simple software API
  - Specify objects, lights, camera, attributes
  - Let implementation determine image
- Leads to fast hardware implementation

Global vs Local Lighting

- Cannot compute color or shade of each object independently
  - Some objects are blocked from light
  - Light can reflect from object to object
  - Some objects might be translucent





Left: No Global Illumination

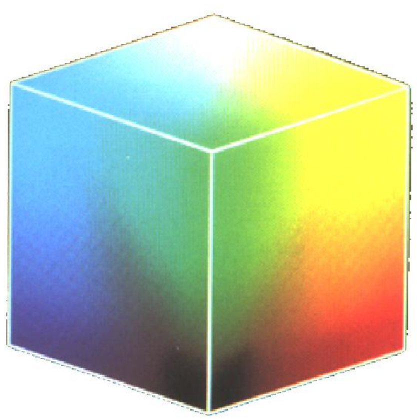
Right: Global Illumination

Why not raytracing?

- Raytracing seems more physically based
  - Why not use it to design a graphics system?
- Perfectly possible
  - Simpler for simple objects such as polygons and quadrics with simple point sources
  - Can produce global lighting effects such as shadows and multiple reflections
- Main problem
  - Slow and not well-suited for interactive applications
  - Might change with programmable pipelines…

Frame Buffer

- Frame Buffer: memory used to store the image
- Images are 2-dimensional arrays
- Color is typically encoded as red-green-blue triple (8 bit red, 8 bit green, 8 bit blue)



red	green	blue	
0	0	0	black
0	0	1	blue
0	1	0	green
0	1	1	cyan
1	0	0	red
1	0	1	magenta
1	1	0	yellow
1	1	1	white

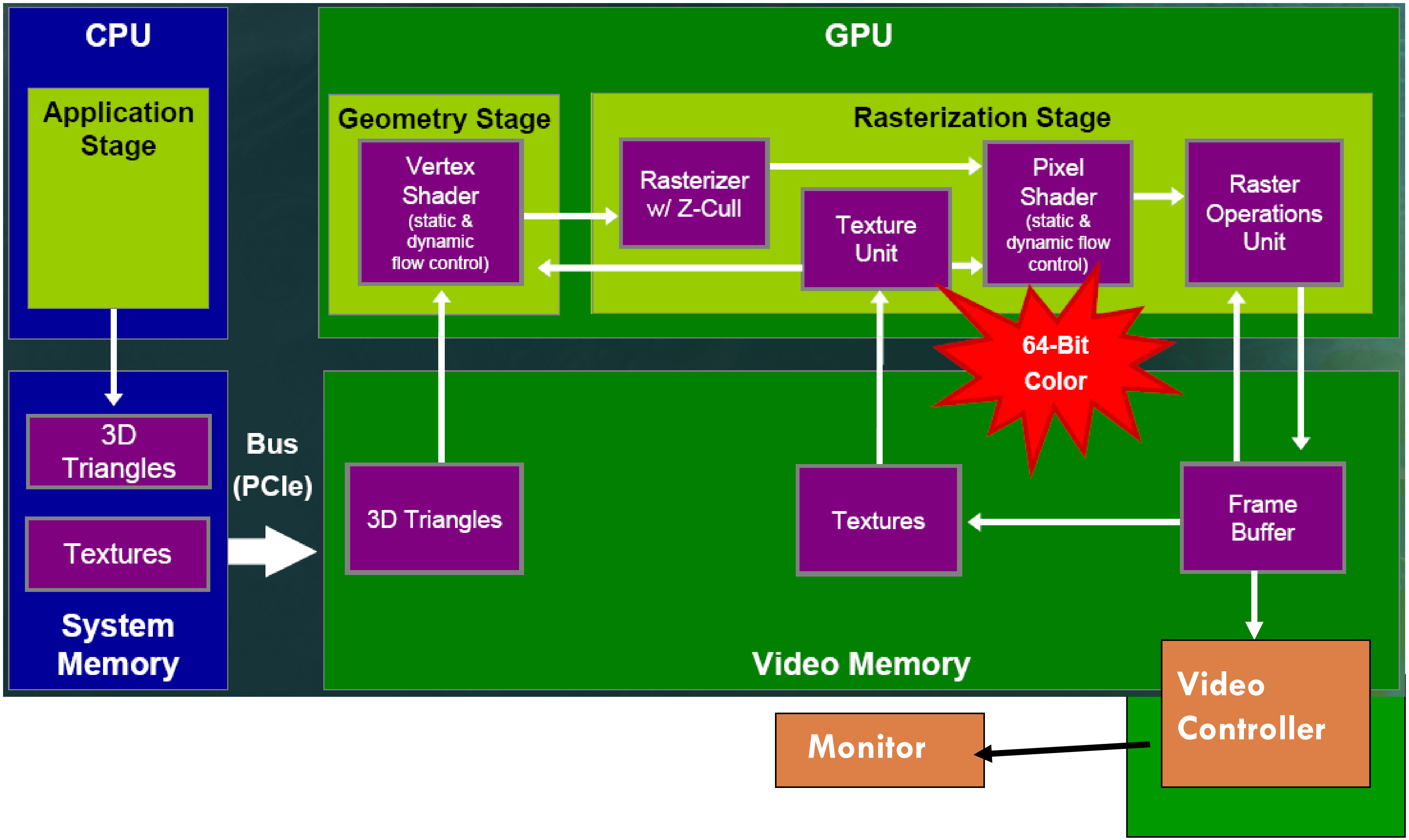
Frame Buffer

- Resolution
  - Image: dimensions of the array
  - Monitor: number of points that can be displayed without overlap, e.g. 1600 x 1200
- Display
  - Video Controller copies values: frame buffer to monitor

CRT: Terms

- Depth
  - number of bits per pixel in the (frame) buffer
  - typical: 3 * 8 = 24 bits for the color = true-color system
  - more bits for
    - **H**igh **D**ynamic **R**ange (HDR) displays
    - general purpose calculations
  - Alpha (8bit), stencil(8bit), z = depth (32bit)

Architecture



Terms

- Refresh Rate
  - frequency at which an image is redrawn
  - 60 Hz (gives me headache on CRT) / better 75 – 120 Hz
- Raster scan
- Horizontal Retrace before new scan line
- Vertical Retrace before new frame
- Random-Scan Displays (old technology)

CRT: Raster Scan

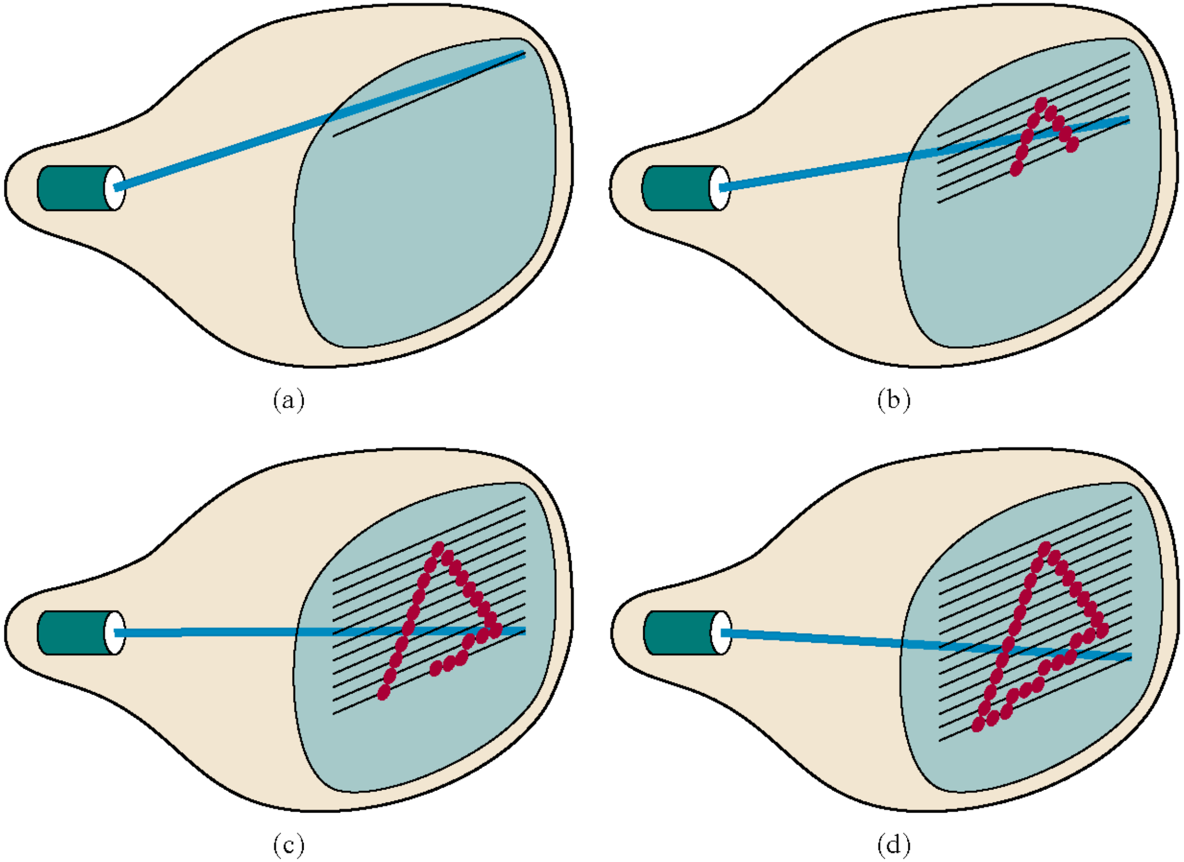


Figure 2-7
A raster-scan system displays an object as a set of discrete points across each scan line.

CRT: Terms

- Scan Line
- Pixel = picture element
- Aspect Ration
  - 4:3 most monitors
  - 16:9 HDTV
  - 16:10 some monitors (show 2 pages of text side by side)
  - beware: alternate definitions exist

Double Buffering

- Double Buffering Algorithm:

```
While (not finished)
   render frame t+1 in the back buffer
   display image t in the front buffer

   switch front and back buffer
   increase frame counter t
```

- Notes:
  - Rendering is actively done by the software
  - Display is done by the monitor
    - Important: image in the front buffer has to be constant

Example

- How many bits for the frame buffer?
  - Double buffering
  - 8bit for RGBA
  - 8bit stencil
  - 32bit depth

Example

- How many bits for the frame buffer?
  - Double buffering
  - 8bit for RGBA
  - 8bit stencil
  - 32bit depth
  - 1600 * 1200 resolution

8 bit alpha channel + 8 bit stencil + 32 bit depth (z-buffer)

- Answer: ((8 + 8 + 8) * 2 + 8 + 8 + 32) * 1600 * 1200

8 Bits for RGB (respectively)

Need RGB for front and back buffer

Reading & Homework #1

- Reading
  - Read Chapter 1 in Interactive Computer Graphics
- Homework
  - Do Exercises 1.2, 1.4, 1.5, 1.6, 1.8, 1.9
  - Homework due Thursday March 27^{th} (9PM), 2014
  - Turn in the Homework on lms.sejong.ac.kr
  - Exercise problems will be similar in scope to test problems

Questions?

- Ask now or e-mail later
- Acknowledgements
  - Previous instructors at Purdue
    - David Ebert, ECE
    - Niklas Elmqvist, ECE
  - Previous instructors at Arizona state university
    - Ross Maciejewski
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