Computer Graphics

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(modified from Bing-Yu Chen's slides)

Introduction

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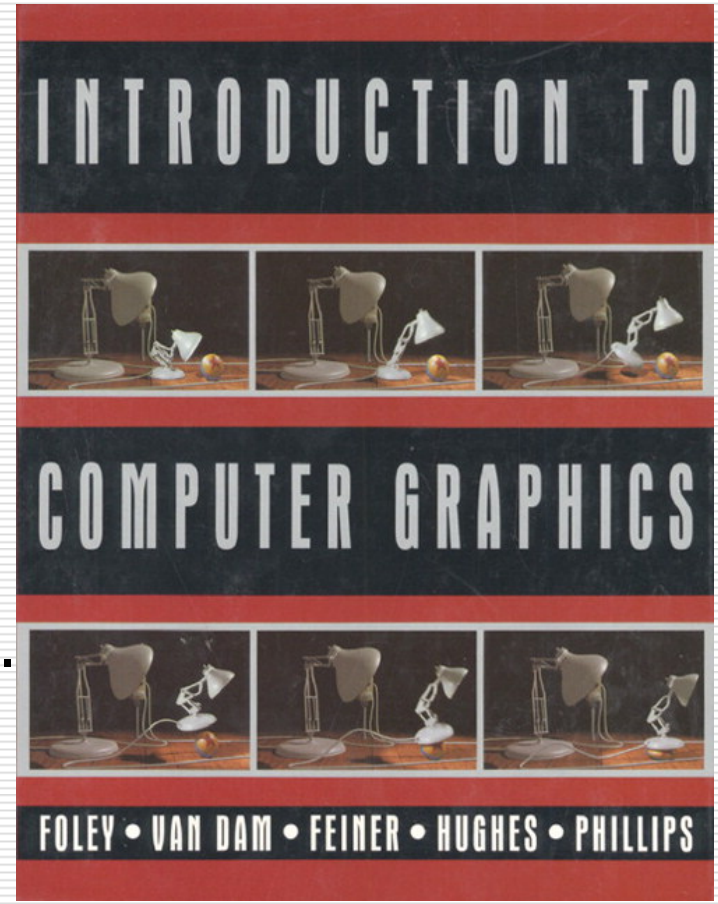
  - all the materials/info. are announced ASAP

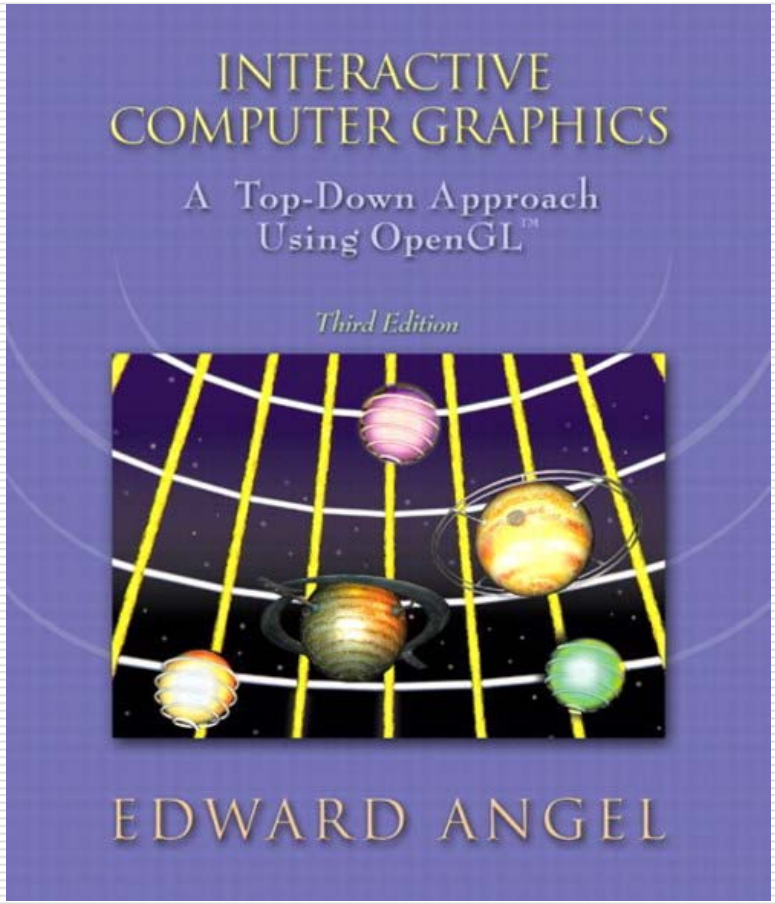
Textbook 1

- J. D. Foley,
  A. van Dam,
  S. K. Feiner,
  J. F. Hughes,
  R. L. Phillips.
  Introduction to Computer Graphics,
  Addison-Wesley, 1993.



Textbook 2

- E. Angel. *Interactive Computer Graphics: A Top-Down Approach Using OpenGL, 3rd ed.*, Addison-Wesley, 2002.



Reference 1

- J. D. Foley,
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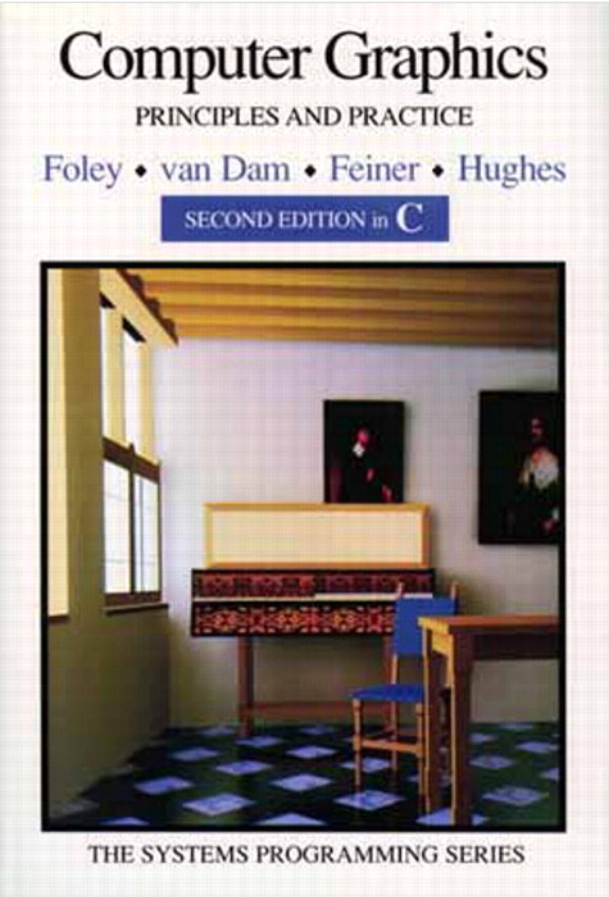
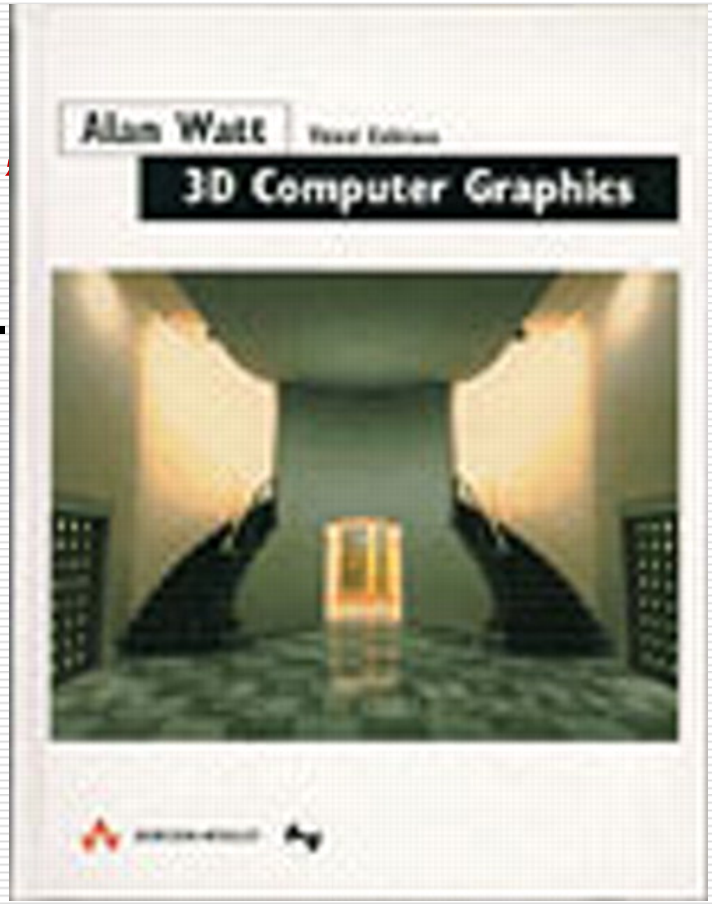
  S. K. Feiner,
  J. F. Hughes.
  Computer Graphics: Principles and Practice in C, 2nd ed.,
  Addison-Wesley, 1995.



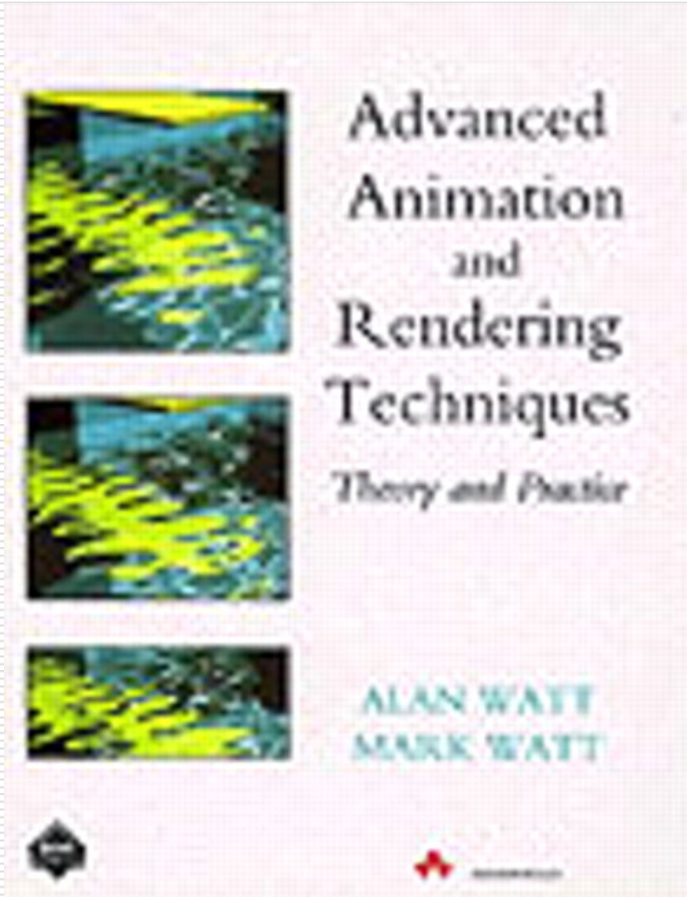
Reference 2

- A. Watt.
  3D Computer Graphics, 3rd ed.,
  Addison-Wesley, 1999.



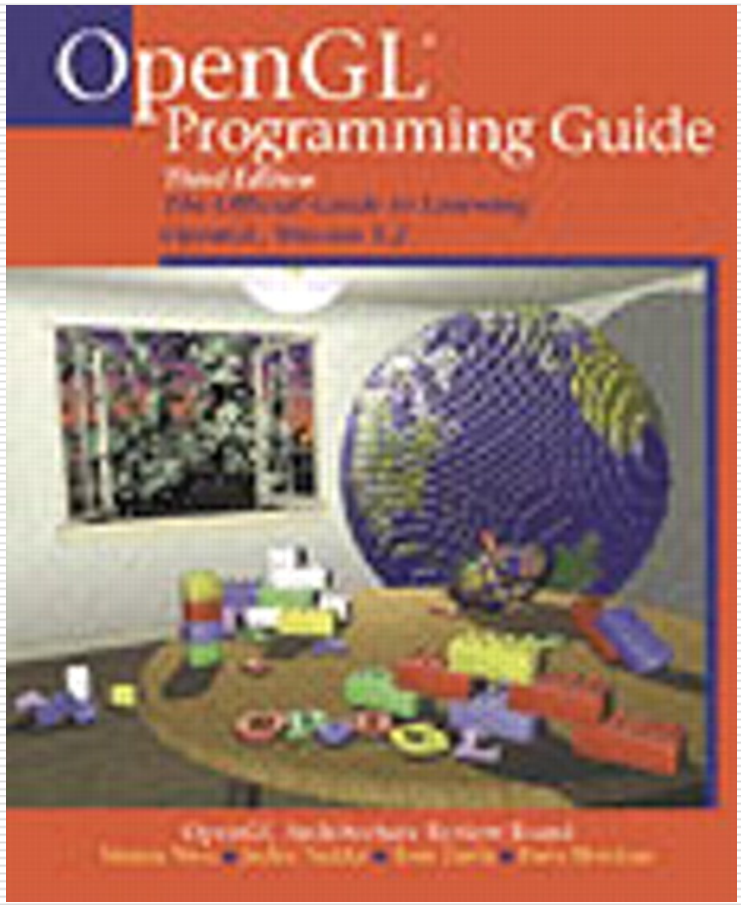
Reference 3

- A. Watt,
  M. Watt.
  Advanced Animation and Rendering Techniques: Theory and Practice,
  Addison-Wesley, 1992.



Reference 4

- M. Woo,
  J. Neider,
  T. Davis,
  D. Shreiner.
  OpenGL® Programming Guide: The Official Guide to Learning OpenGL, ver. 1.2, 3rd. ed.,
  Addison-Wesley, 1999



Pre-requirements (better-to-have)

- Linear Algebra
- Data Structures
- Algorithms
- Programming Skills
  - C/C++
  - Java

Requirements

- Participants
- 3 Programming Homework
  - Deadlines = 5/11,5/18,5/25
- Examination

What is Computer Graphics ?

- Definition
  - the pictorial *synthesis* of real or imaginary objects from their computer-based models

INPUT \ OUTPUT	descriptions	images
descriptions		Computer Graphics
images	Computer Vision Pattern Recognition	Image Processing

What is Computer Graphics ?

- *Computer Graphics* deals with all aspects of creating images with a computer
  - hardware
  - software
  - applications

Example

- Where did this image come from?

- What hardware/software did we need to produce it?

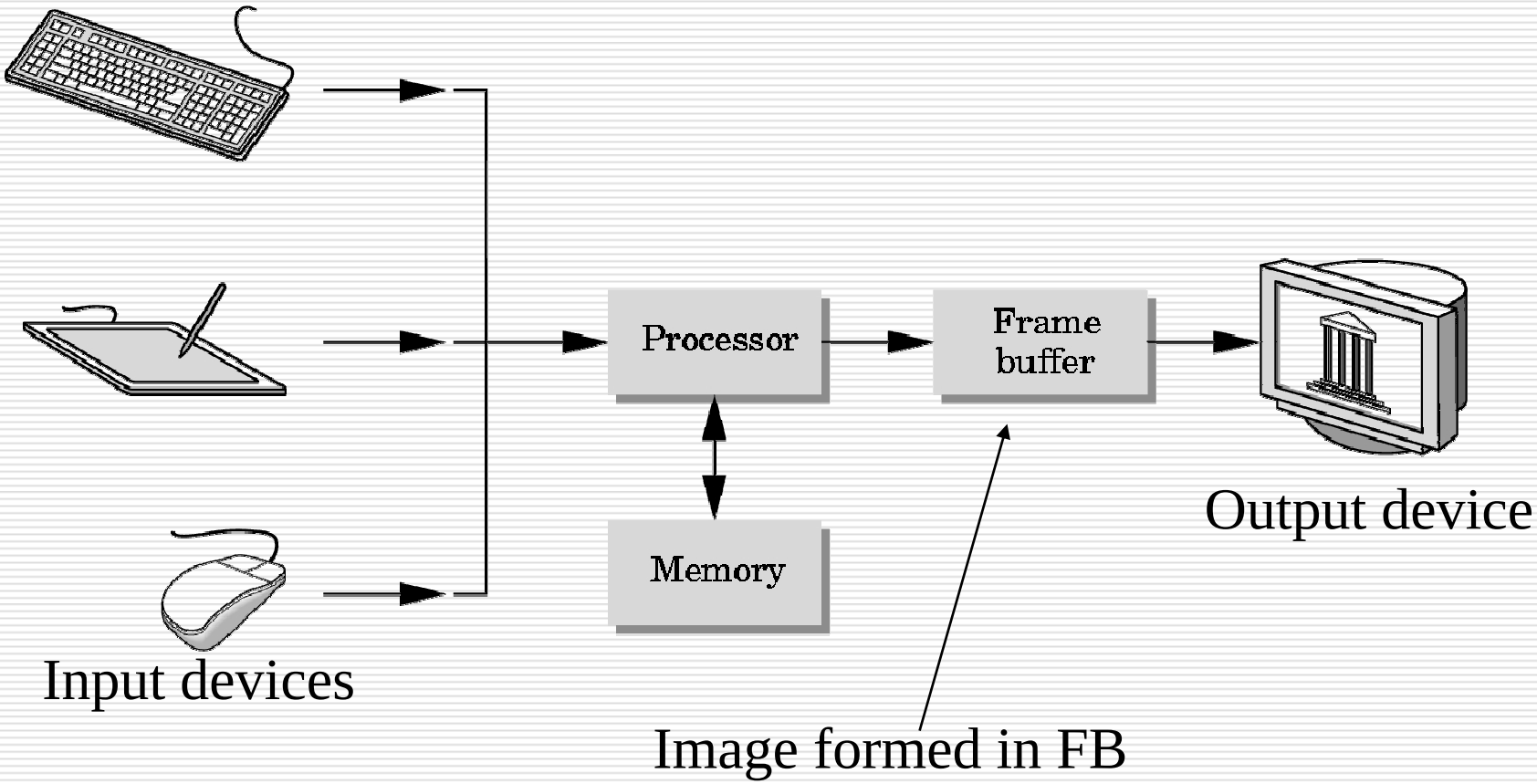
Preliminary Answer

- 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 cards for modeling and rendering

The Advantages of Interactive Graphics

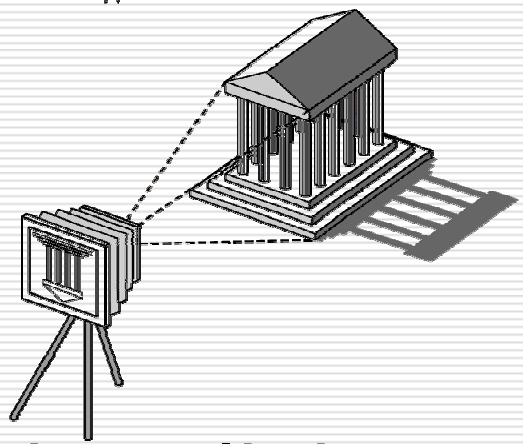
- one of the most natural means of communicating with a computer
- a picture is worth then thousand words
- a *moving* picture is worth than thousand *static* ones
  - movie, motion dynamics
- Graphical User Interface

Basic Graphics System



Elements of Image Formation

- Objects
- Viewer
- Light source(s)



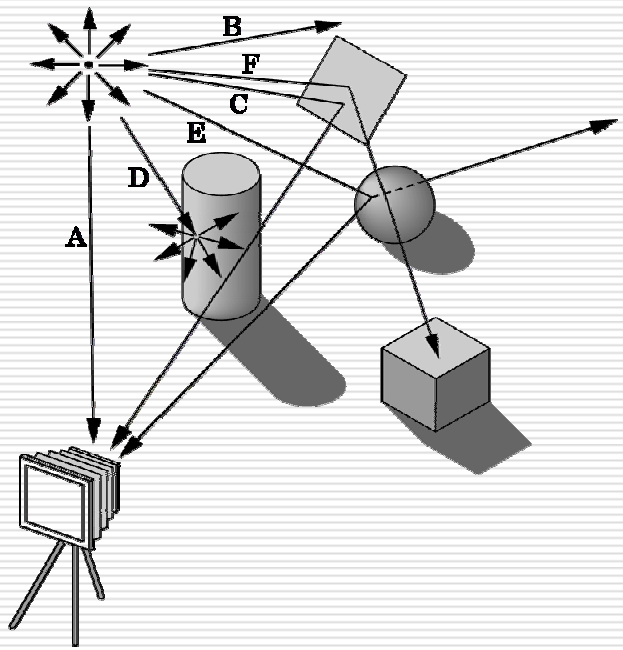
- Attributes that govern how light interacts with the materials in the scene
- Note the independence of the objects, viewer, and light source(s)

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

Ray Tracing and Geometric Optics

One way to form an image is to follow rays of light from a point source determine 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.

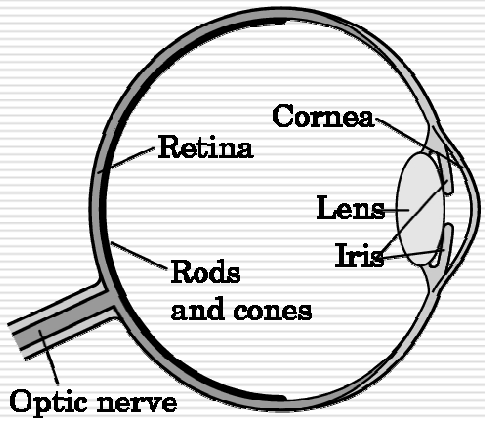


Luminance and Color Images

- Luminance
  - Monochromatic
  - Values are gray levels
  - Analogous to working with black and white film or television
- Color
  - 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
  - Cones
    - Color sensitive
    - Three types of cone
    - Only three values (the *tristimulus* values) are sent to the brain

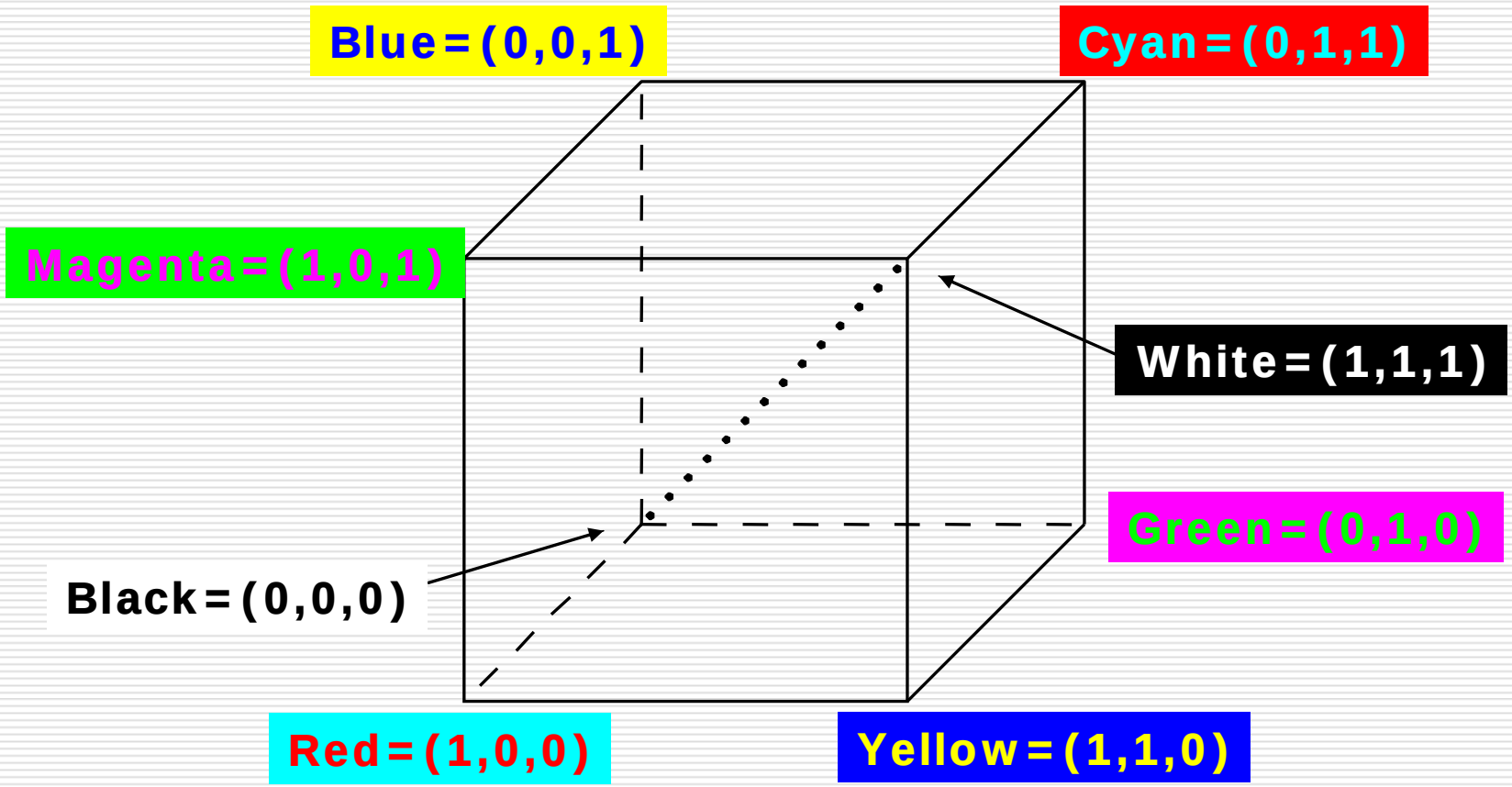


- Need only match these three values
  - Need only three *primary* colors

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

The RGB Color Model – for CRT



The CMY Color Model – for hardcopy

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$K = \min(C, M, Y)$$
$$C = C - K$$
$$M = M - K$$
$$Y = Y - K$$

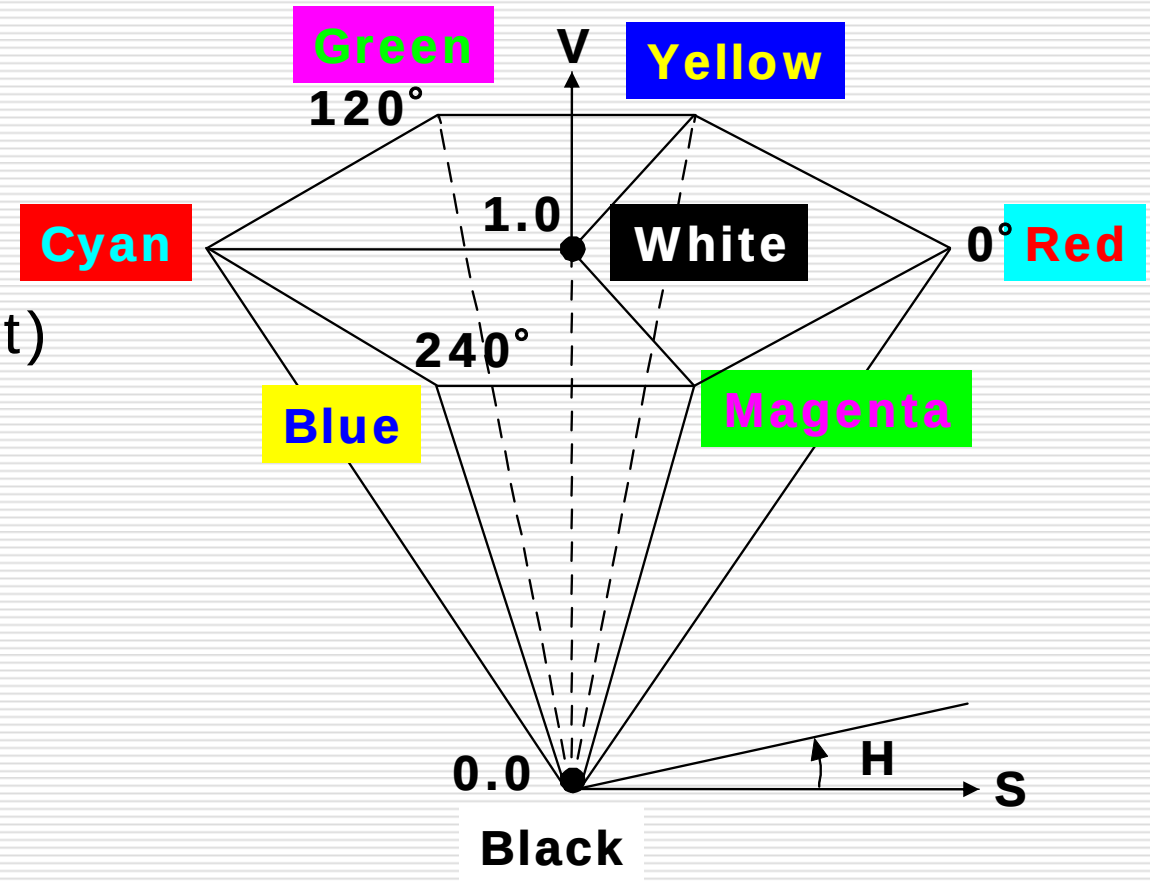
The YIQ Color Model – for color-TV

- Y : luminance
- I and Q : chromaticity

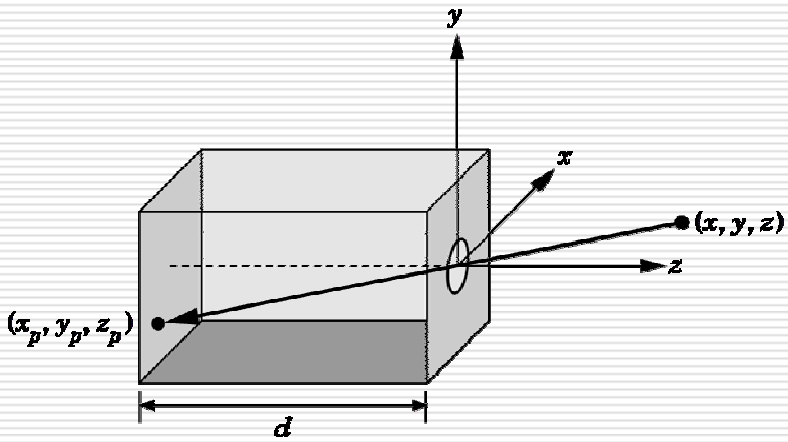
$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

The HSV Color Model – for user-oriented

- H : hue
- S : saturation
- V : value
  - (or B for blight)



Pinhole Camera

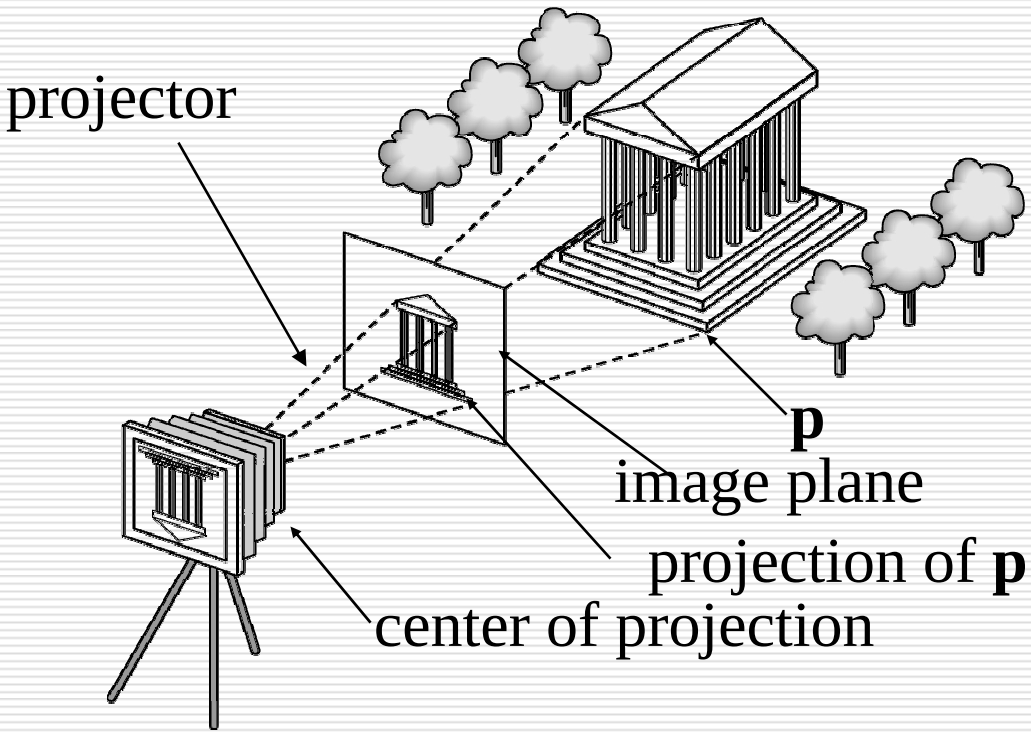


Use trigonometry to find projection of a point

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

These are equations of simple perspective

Synthetic Camera Model

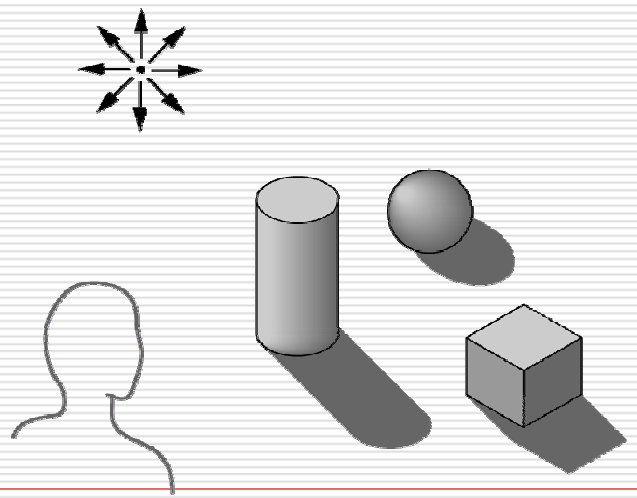


Advantages

- 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



Why not ray tracing?

- Ray tracing seems more physically based so why don't we use it to design a graphics system?
- Possible and is actually simple for simple objects such as polygons and quadrics with simple point sources
- In principle, can produce global lighting effects such as shadows and multiple reflections but is slow and not well-suited for interactive applications

APPENDIX:

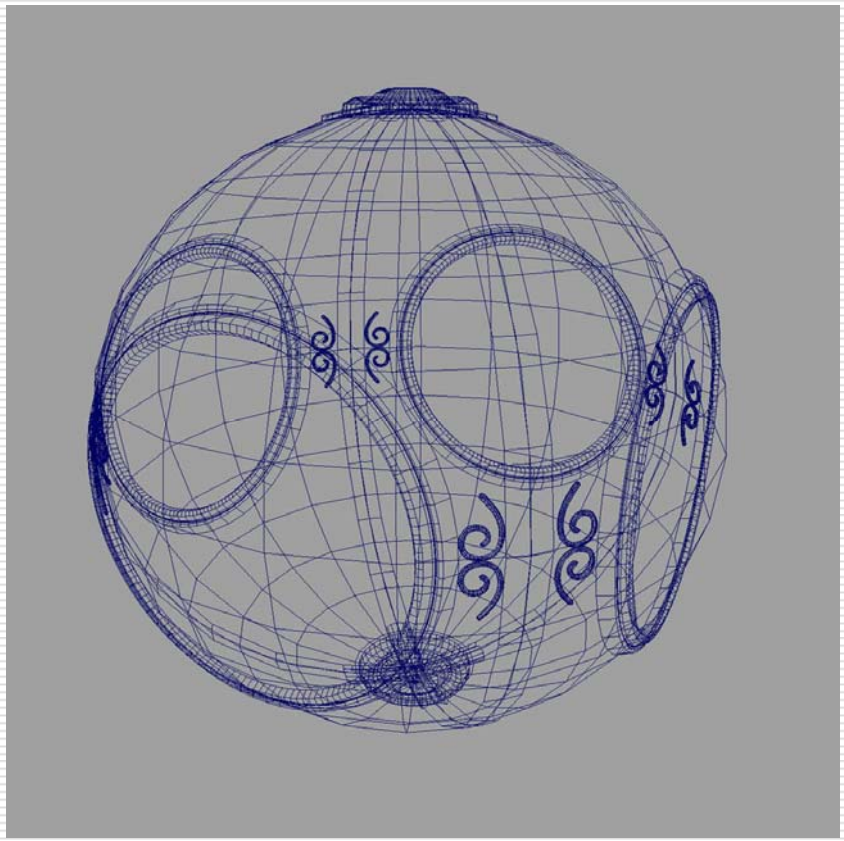
History of Computer Graphics

Computer Graphics: 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
- Cost of refresh for CRT too high
  - Computers slow, expensive, unreliable

Computer Graphics: 1960-1970

- Wireframe graphics
- Project Sketchpad
- Display Processors
- Storage tube

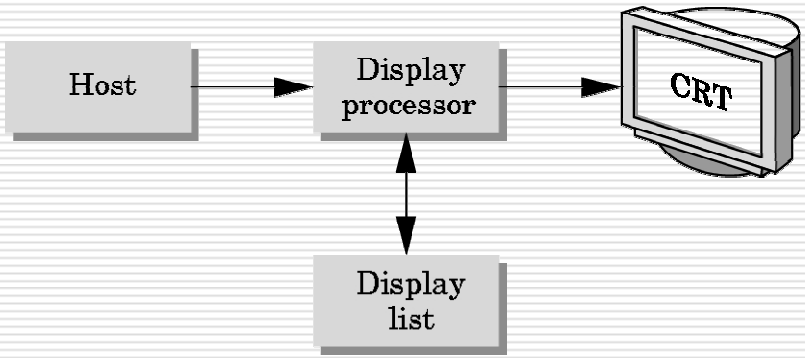


Project Sketchpad

- Ivan Sutherland's PhD 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

Display Processor

- Rather than have 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

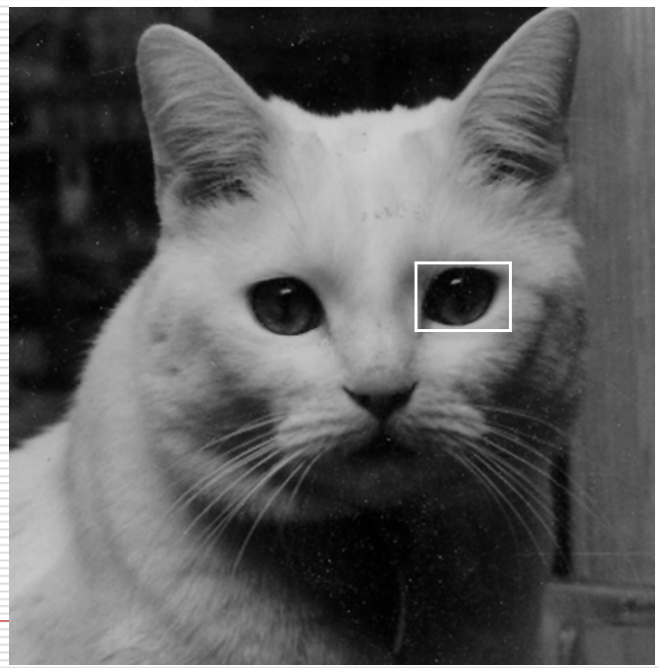
- Created by Tektronix
  - Did not require constant refresh
  - Standard interface to computers
    - Allowed for standard software
    - Plot3D in Fortran
  - Relatively inexpensive
    - Opened door to use of computer graphics for CAD community

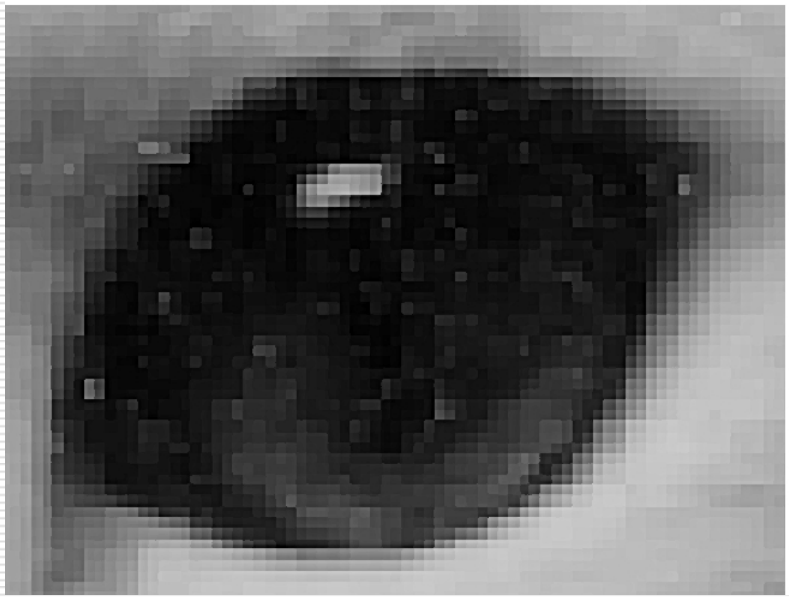
Computer Graphics: 1970-1980

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

Raster Graphics

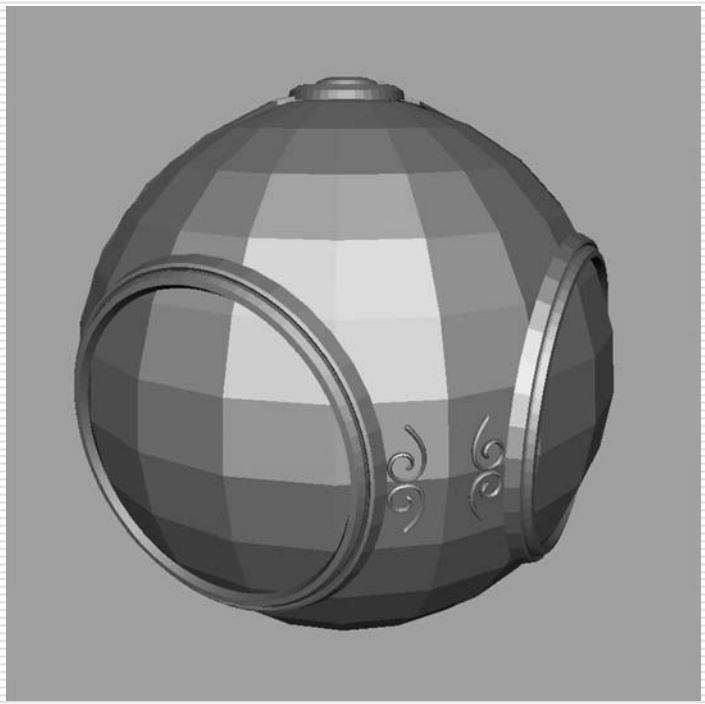
- Image produced as an array (the *raster*) of picture elements (*pixels*) in the *frame buffer*





Raster Graphics

- Allow us to go from lines and wireframes to filled polygons

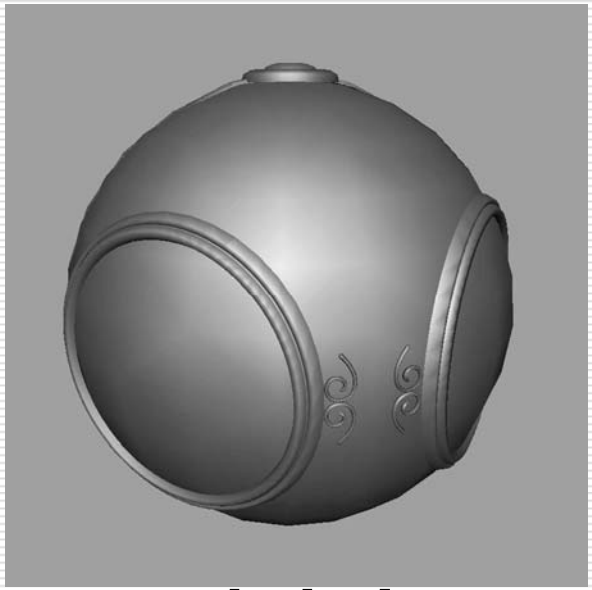


PCs and Workstations

- 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
    - High-level of interactivity
  - Early PCs included frame buffer as part of user memory

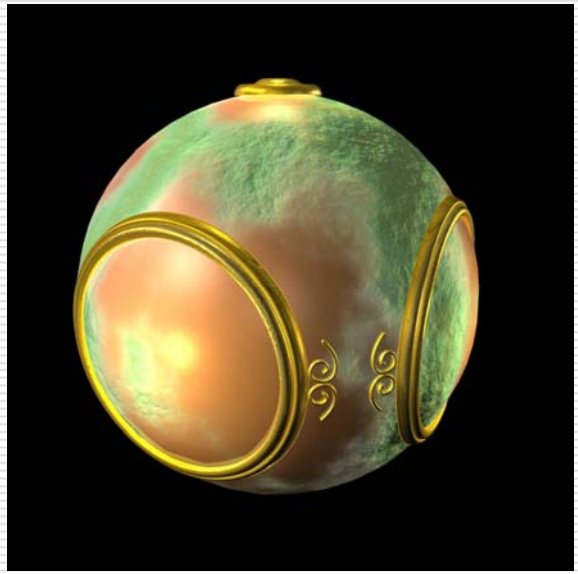
Computer Graphics: 1980-1990

- Realism comes to computer graphics



smooth shading

environmental mapping



bump mapping

Computer Graphics: 1980-1990

- Special purpose hardware
  - Silicon Graphics geometry engine
    - VLSI implementation of graphics pipline
- Industry-based standards
  - PHIGS
  - RenderMan
- Networked graphics: X Window System
- Human-Computer Interface (HCI)

Computer Graphics: 1990-2000

- OpenGL API
- Completely computer-generated feature-length movies (Toy Story) are successful
- New hardware capabilities
  - Texture mapping
  - Blending
  - Accumulation, stencil buffer

Computer Graphics: 2000-

- Photorealism
- Graphics cards for PCs dominate market
  - Nvidia, ATI, 3DLabs
- Game boxes and game players determine direction of market
- Computer graphics routine in movie industry: Maya, Lightwave