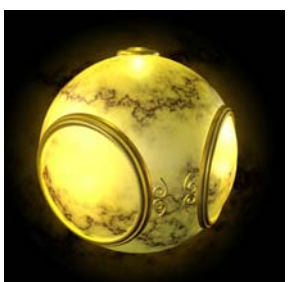
Computer Graphics

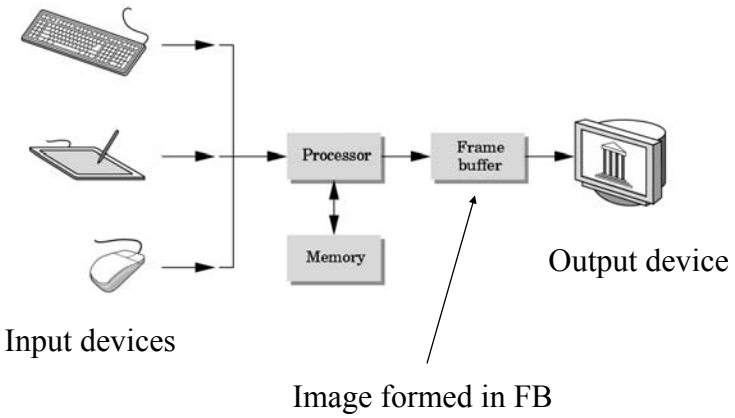
- Where did this image come from?



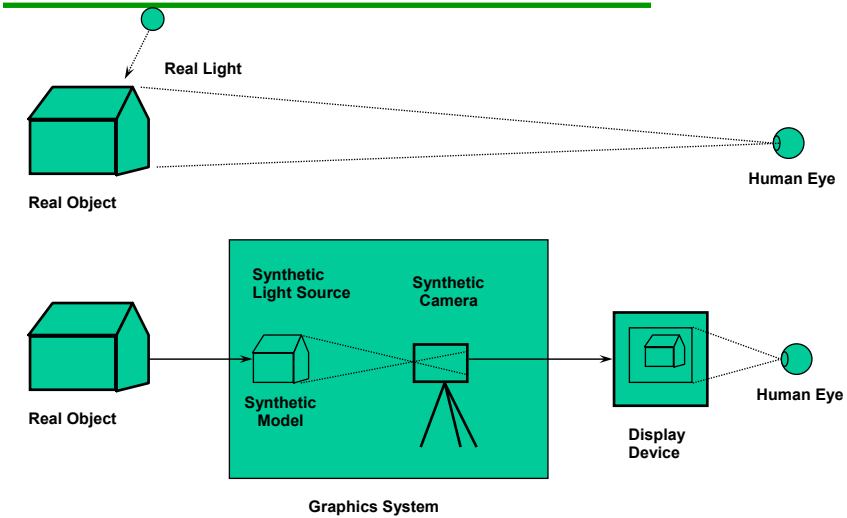
Preliminary Answer

- **Software**:
  - Maya for modeling and rendering
  - Maya is built on top of OpenGL
- **Hardware**:
  - PC with graphics cards for modeling and rendering

Basic Graphics Hardware

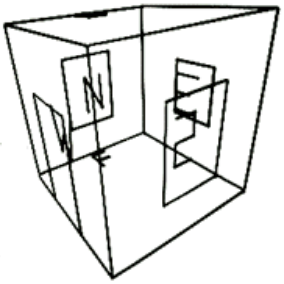


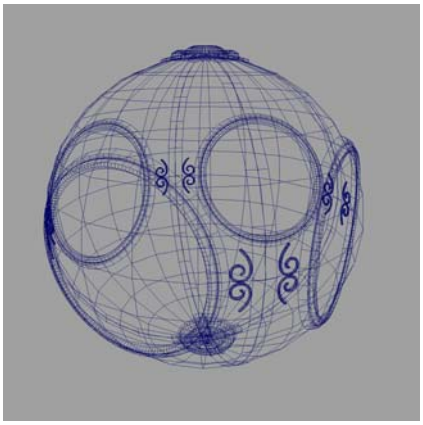
Software: Conceptual Model



Computer Graphics:1960's

- Wireframe graphics
- Vector display 2-2.5 D
- Project Sketchpad
- Display Processors





Computer Graphics:1960's

- Ivan Sutherland
  - PhD thesis at MIT
  - Recognized the potential of man-machine interaction
  - Sketchpad
    - Display something
    - User moves light pen
    - Computer generates new display
  - Sutherland also created many of the now common algorithms for computer graphics
- Sutherland joins Evans at Utah and "start" CG in CS

Utah Teapot

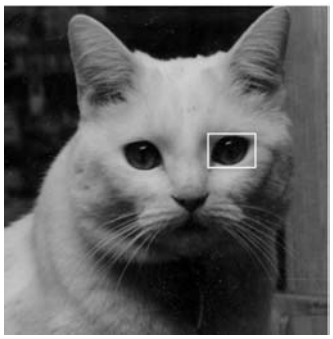
Computer Graphics: 1970's

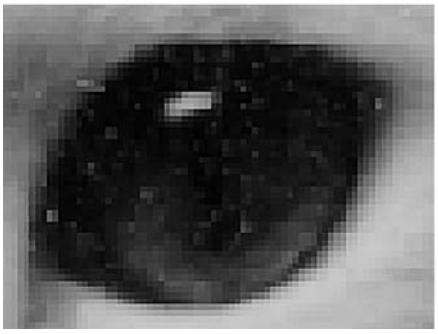
- Raster Graphics
- Flat and smooth "solid" models
- Beginning of graphics standards
- Microprocessors
  - Workstations and PCs
- Siggraph formed (73)
- Pong released (72)

  Star Wars released (76)

Raster Graphics

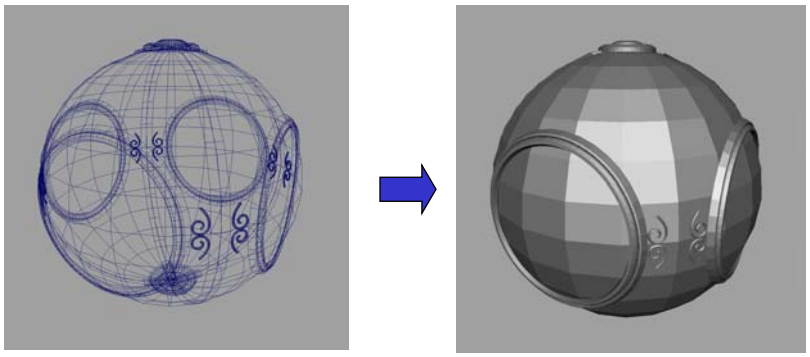
- Image produced as an array (or *raster*) of picture elements (*pixels*) in the *frame buffer*





Raster Graphics

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



Computer Graphics: 1980's

Realism comes to computer graphics

smooth shading

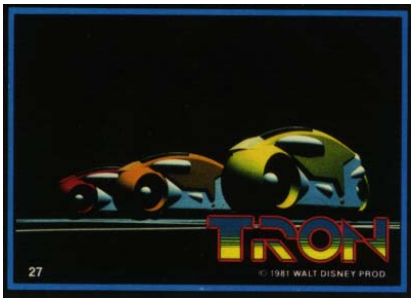
environmental mapping

bump mapping

Computer Graphics: 1980's

Realistic 3D, ray tracing

Vol Libre (1980)



Disney's Tron (1982)

Computer Graphics: 1980's

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

Computer Graphics: 1990's

- OpenGL API
- Completely computer-generated feature-length movies are successful
- New hardware for:
  - Texture mapping
  - Blending

First 3D Feature
Pixar's Toy Story
(1995)

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

Computer Graphics: 2000-

Display Devices

Active displays

- CRT
- LED
- LCD

  flat panel displays

  projectors

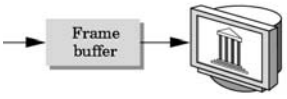
Passive displays

- Printers, film slides, others

What is being displayed?

Usually, a color bitmap

Where?



Bit depth - defined by device standards

Bit-Depth	Number of Colors
1	2 (monochrome)
2	4 (CGA)
4	16 (EGA)
8	256 (VGA)
16	65,536 (High Color, XGA)
24	16,777,216 (True Color, SVGA)
32	16,777,216 (True Color + Alpha Channel)

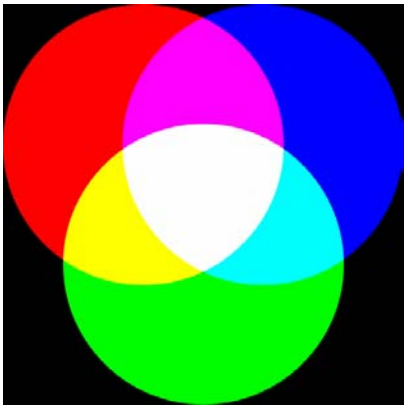
(Note alpha)

(Humans can perceive ~10,000,000 colors)

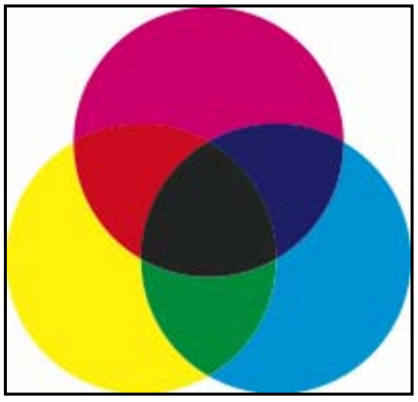
Color representation

- 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
    - Printing
    - Negative film

Color representation



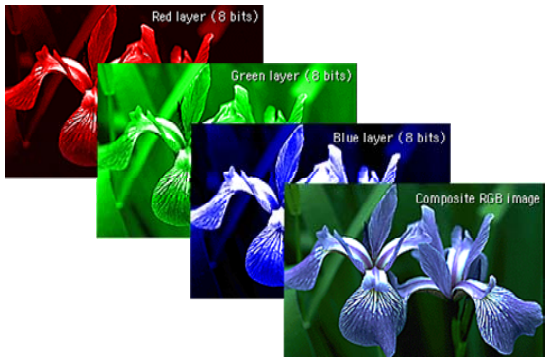
additive



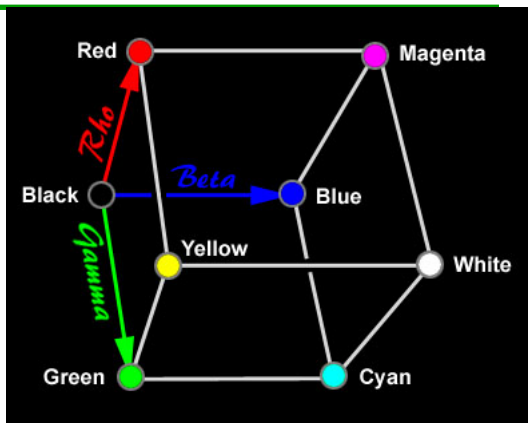
subtractive

Color representation

- Additive color

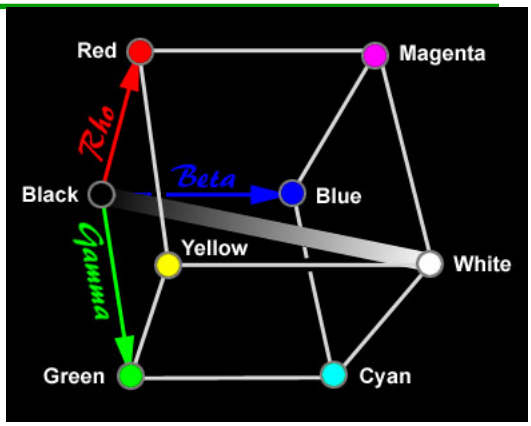


Color representation

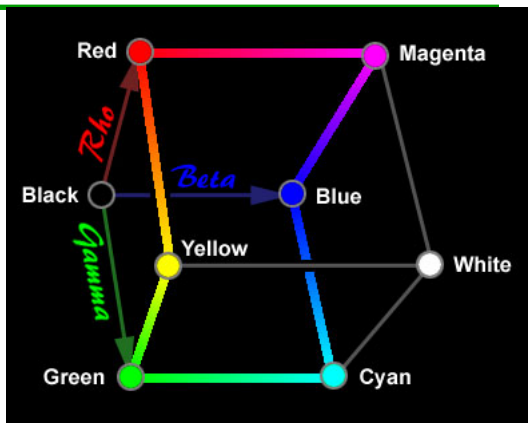


The RGB Cube

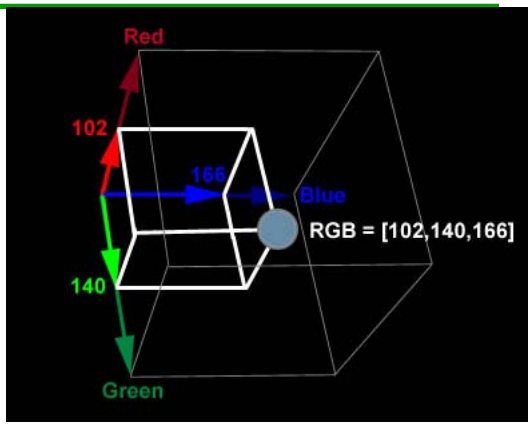
Color representation



Color representation

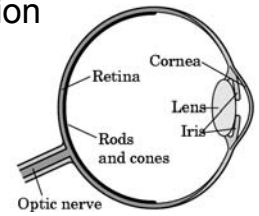


Color representation



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

Display Devices

Active displays

- CRT
- LED
- LCD

  flat panel displays

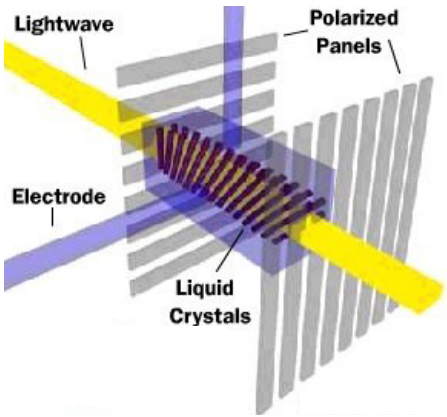
  projectors

Passive displays

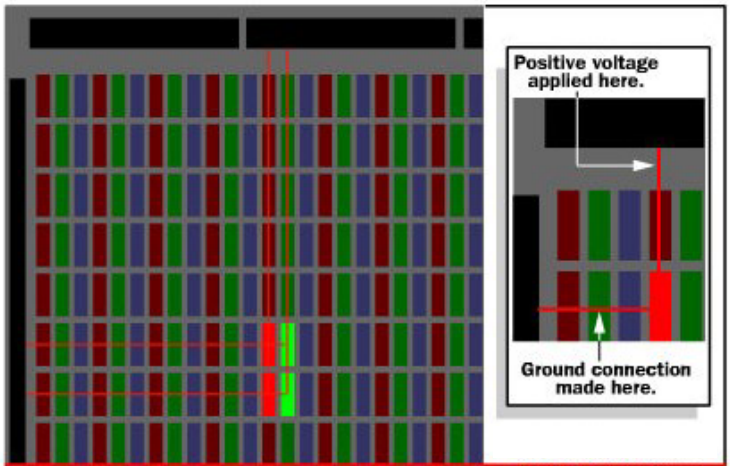
- Printers, film slides, others

LCD flat panel monitors

- Liquid Crystal Displays
- LC emit light based on temperature (very sensitive)
- Electrical pulse excites LC to control display

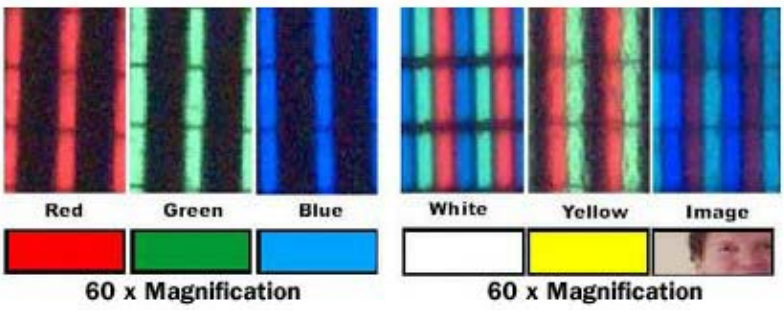


LCD flat panel monitors



LCD flat panel monitors

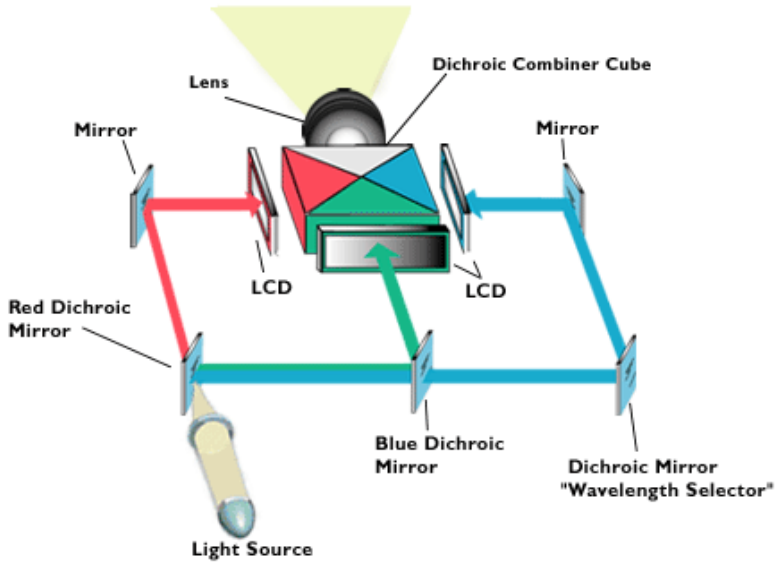
- Color representation



LCD projectors

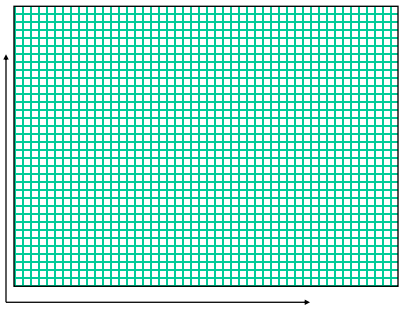
Similar technology as LCD displays

Screen much smaller (~2in)



Introduction

- Image Plane is a N x M grid of pixels
- This grid is similar to a coordinate system only it is discrete.

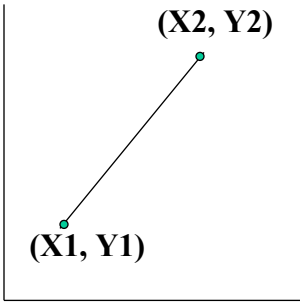


3

Math Review

- 2D math for lines

How do we determine the equation of the line?

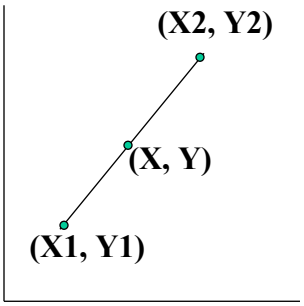


4

Math Review

- 2D math for lines

Slope-Intercept formula for a line



Slope = (Y2 – Y1)/(X2 – X1)
(Y - Y1)/(X - X1)

Solving For Y

Y = [(Y2 – Y1)/(X2 – X1)]X
+ [-(Y2 – Y1)/(X2 - X1)]X1 + Y1 or
Y = m X + b

5

Math Review

- Explicit (functional) representation

y = f(x)

y is the dependent, x independent variable

Find value of y from value of x

Example, for a line: for a circle:

$y = mx + b$ $x^2 + y^2 = r^2$

6

Math Review

- Implicit representation

  $f(x,y) = 0$

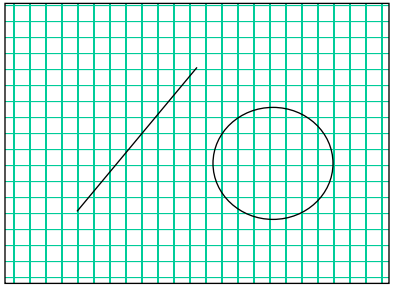
  Called a membership function, test value of (x,y) to see if it *belongs* to the curve

  x,y treated the same, axis invariant

  Example, for a line: $ax + by + c = 0$

  for a circle: $x^2 + y^2 - r^2 = 0$

Scan conversion



Scan conversion is taking the graphic from the continuous (thin) line to turning on pixels

12

Scan conversion

Scan conversion algorithms compute integer coordinates for pixels near the line or circle

Algorithms are invoked many, many times and so must be efficient

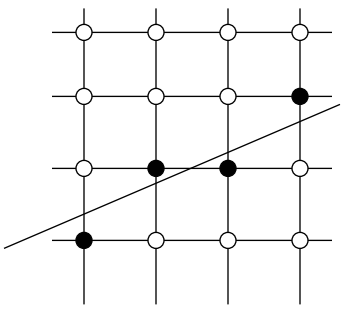
Lines should be visually pleasing, for example, they should have constant density

Obviously, they should be able to draw the gamet of possible lines/circles and remain defined

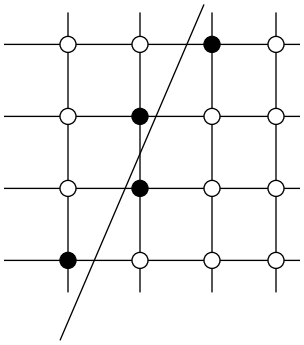
13

Scan conversion for lines

$0 < M < 1$



$M > 1$



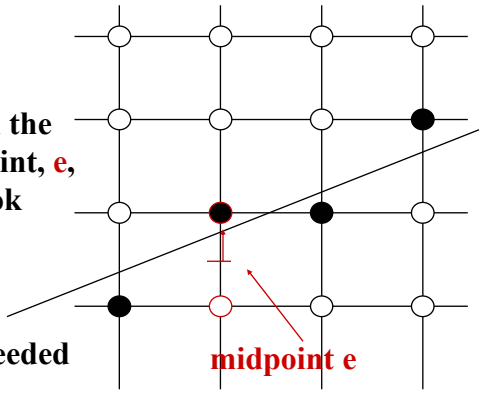
14

Midpoint Algorithm

For lines in the first octant, the next pixel is to the right or to the right and up one

By looking at the difference between the line and the midpoint, e, we only need to look at the sign

i.e.) no Round( ) needed



17

Midpoint: Decision Variable

Rewrite such that f(x,y) = ax + by + c

Then, f(x + 1, y + 1/2) is the next column's midpoint

= a(x + 1) + b(y + 1/2) + c = d

(this d is called the decision variable)

if (d = 0) then the line passes on the midpoint

if (d > 0) then the line passes above
if (d < 0) then the line passes below

18