Survey in Computer Graphics

Computer Graphics and Visualization

Pedher Johansson
Department of Computer Science
Fall 2016

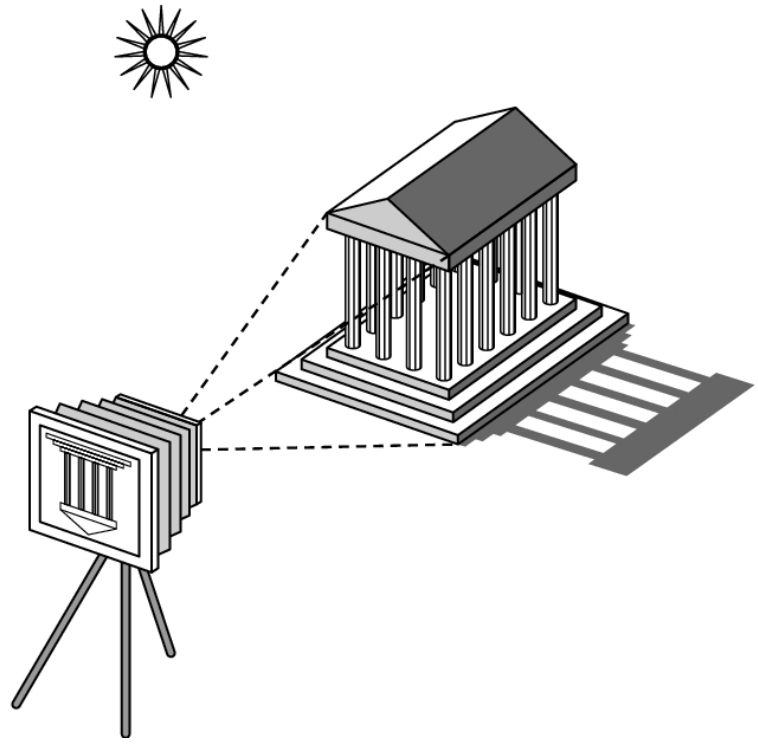
Example of a Marble Ball

- Where did this image come from?

- What hardware/software/algorithms do we need to produce it?

Elements of Image Formation

- Light source(s)
- Objects
- Viewer



- Note the independence of the objects, the viewer, and the light source(s)

Advantages

- Separation of objects, viewer, light sources
- Simple software API
  - Specify objects, lights, camera
- Fast hardware implementation

Light

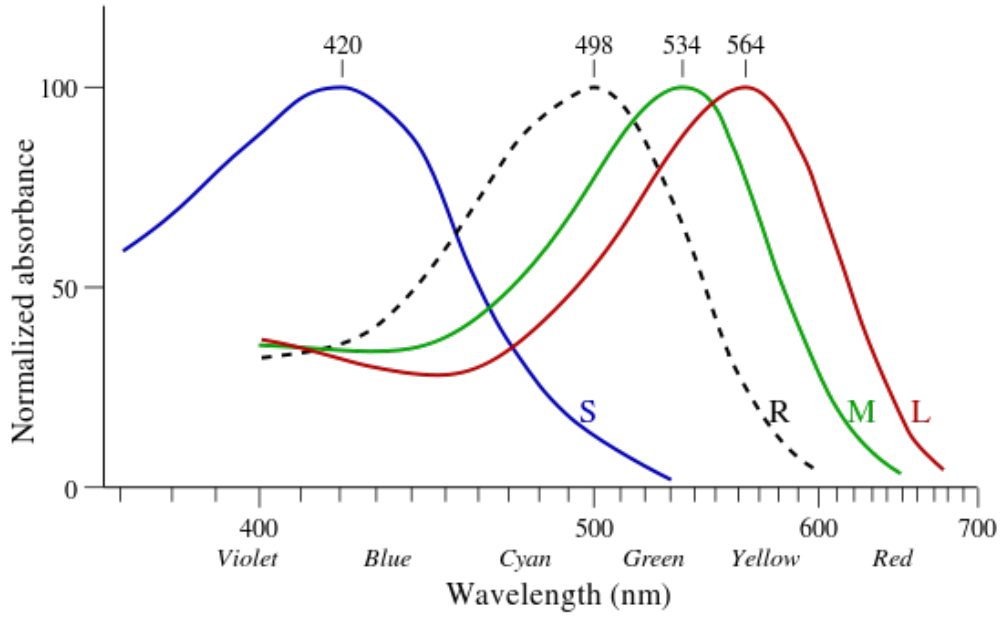
- Light is the part of the electromagnetic spectrum that causes a reaction in our visual systems
- Generally these are wavelengths in the range of about 350-750 nm (nanometers)
- Long wavelengths appear as reds and short wavelengths as blues

Colors (chromaticity and luminance)

- Luminance
  - How much light emitted
  - Luminous intensity per unit area (cd/m^2)
  - In imaging, it characterize the brightness.
- Chromaticity
  - Has perceptional attributes of hue and saturation

Three-Color Theory

- Human visual system has two types of sensors
  - Rods: Monochromatic, night vision
  - Cones: Color sensitive
- Three types of cones sensitive to different wavelengths



Color Models

Additive color model

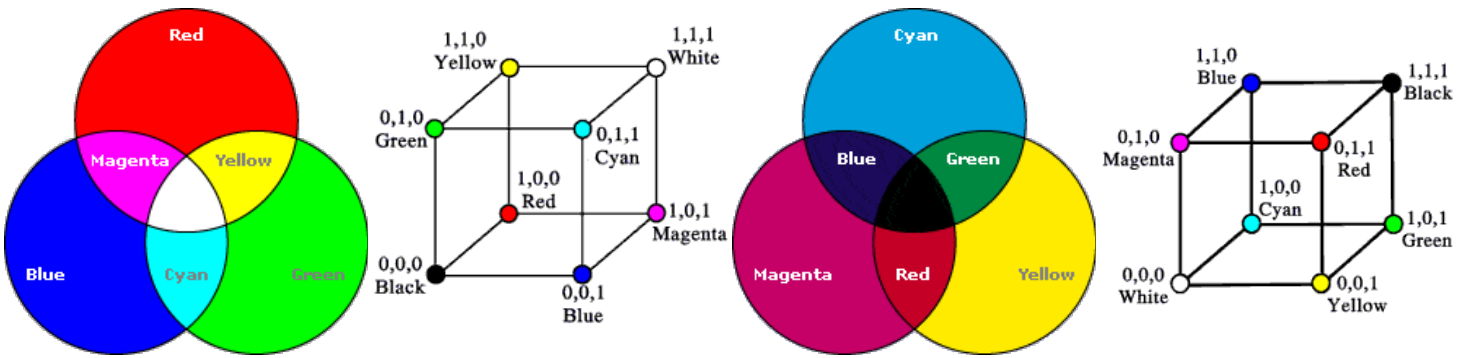
- Form a color by adding amounts of primaries
- RGB: Primaries are Red (R), Green (G), Blue (B)
  LCDs, projection systems, positive film

Subtractive color model

- Form a color by filtering white light
- CMY: Cyan (C), Magenta (M), and Yellow (Y) filters
  Printing, Negative film

Color Spaces

- Three primary colors gives us a 3D representation of all represented colors.



CIE XYZ Color system

- Commission Internationale d'Éclairage, 1931
- Practical studies of human perception
- Defines a 3D color space for the human visual spectrum
  - Y defined as luminace (also roughly the M cones)
  - X, and Z analogous to the spectral sensitivity of S and L cones.
  - XZ plane contains all possible chromatizities at that luminance.

CIE xyY Color Space

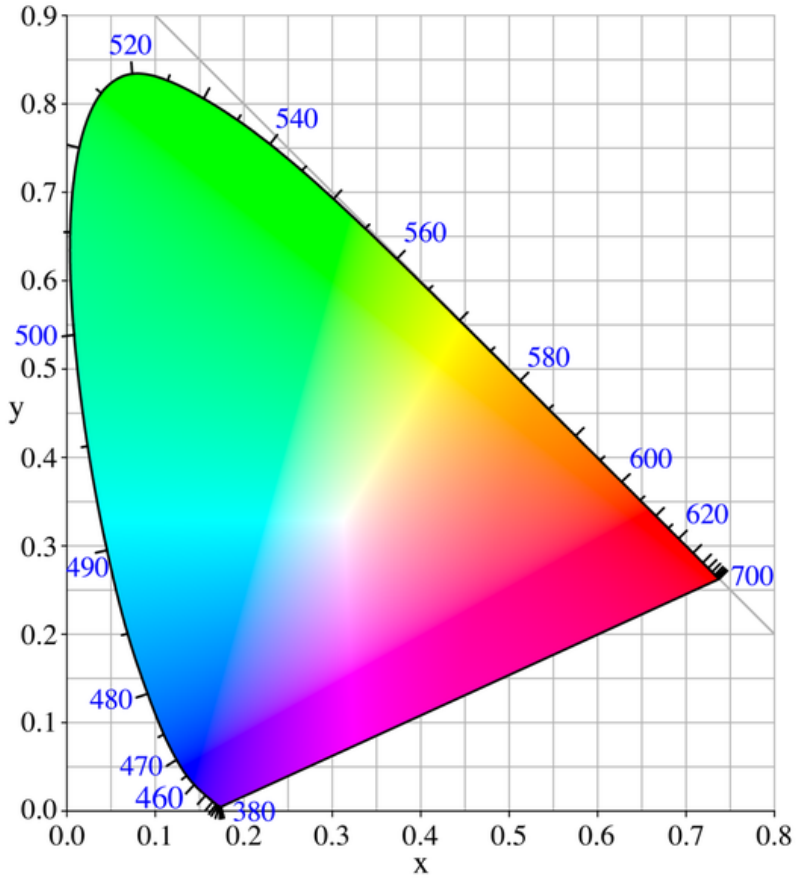
- By normalizing, we get the cromaticity of a color by the two derived parameters x and y

$$x = \frac{X}{X+Y+Z}$$
$$y = \frac{Y}{X+Y+Z}$$

  (z derived similarly or by $1 - x - y$)
- Results in the CIE 1931 color space chromaticity diagram.

CIE 1931 Color Space Chromaticity Diagram

- Gamut of human vision (visible colors at full luminance)
- The straight edge on the lower part is called *the line of purples*

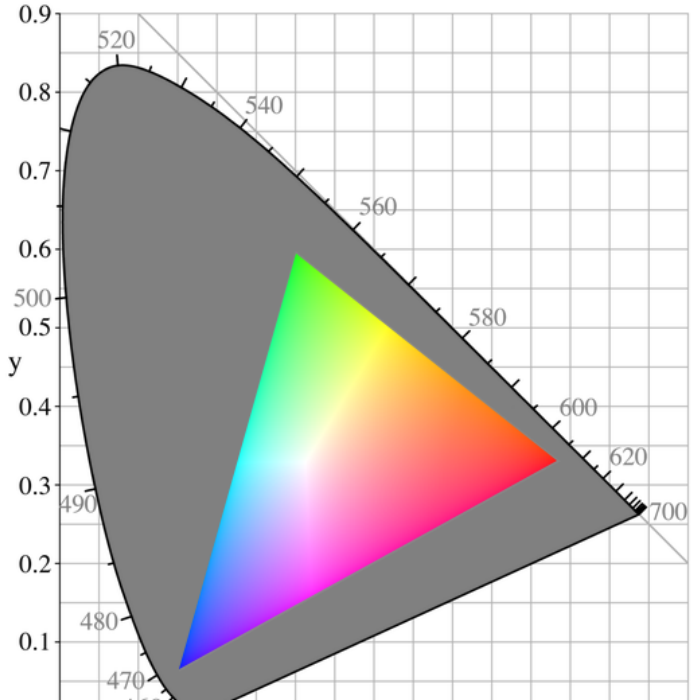


LIGHT

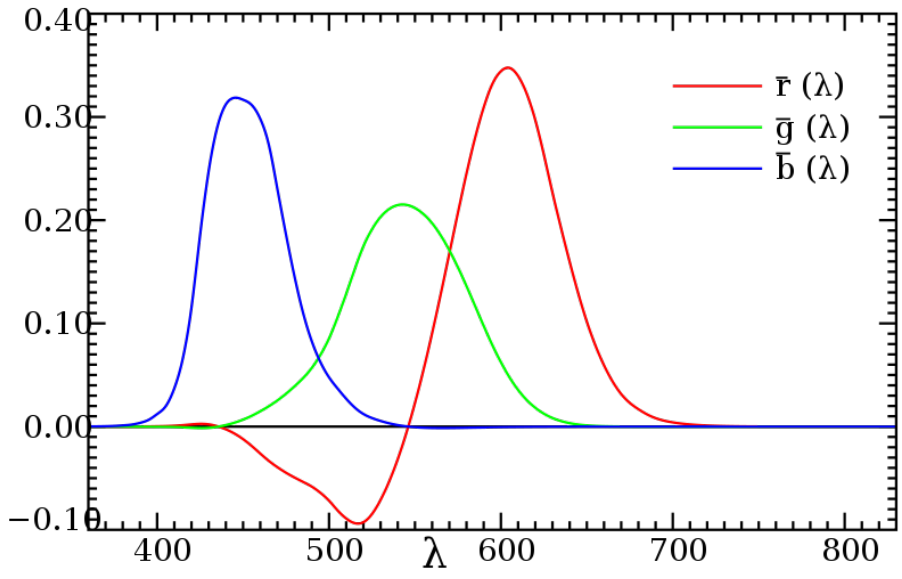
Gamut

The subset of colors which can accurately be represented in a given circumstance

- A human eye
- A given color space
- An output device.



xyY vs. RGB



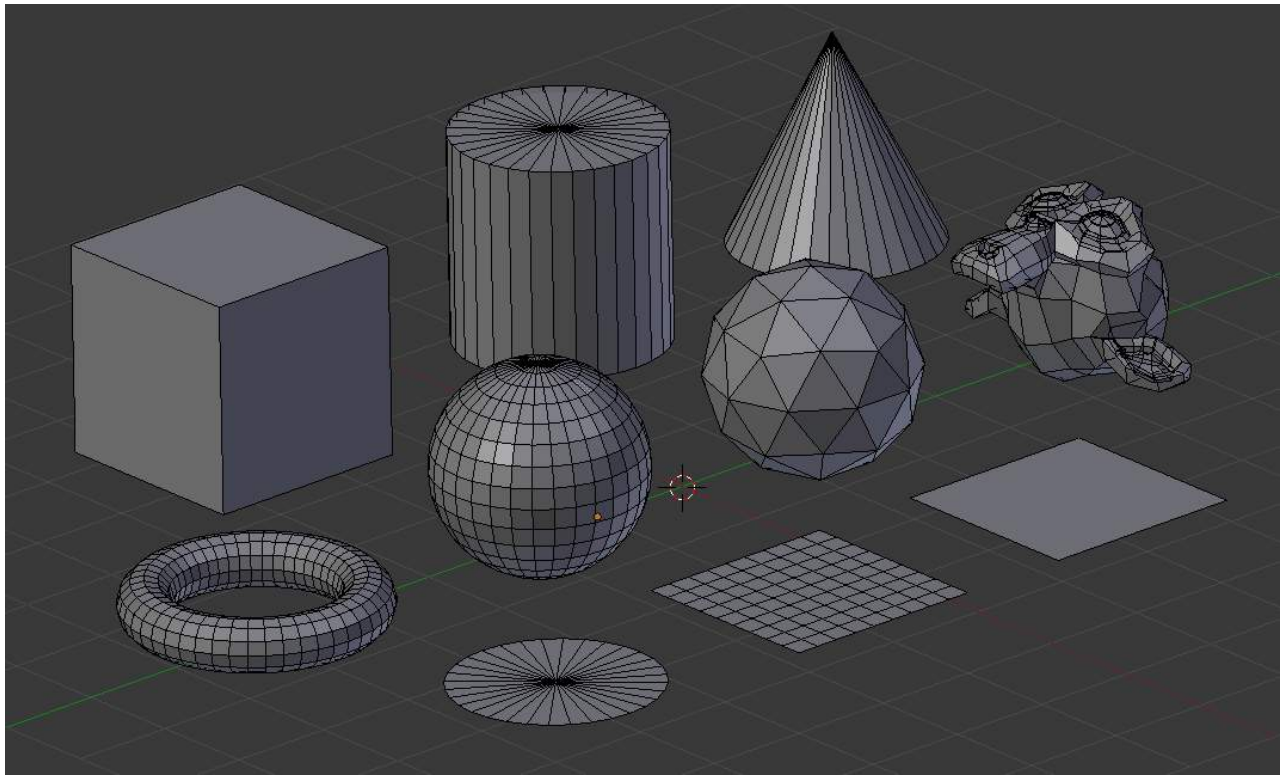
- RGB model can not represent the entire visual spectrum (why?)
- xyY model can not easaly be implemented in hardware

Global vs Local Lighting

- In *Local Lighting* we compute color or shade of each object independently
- But!
  - Some objects are blocked from light.
  - Light can reflect from object to object.
  - Some objects might be translucent.

Specification

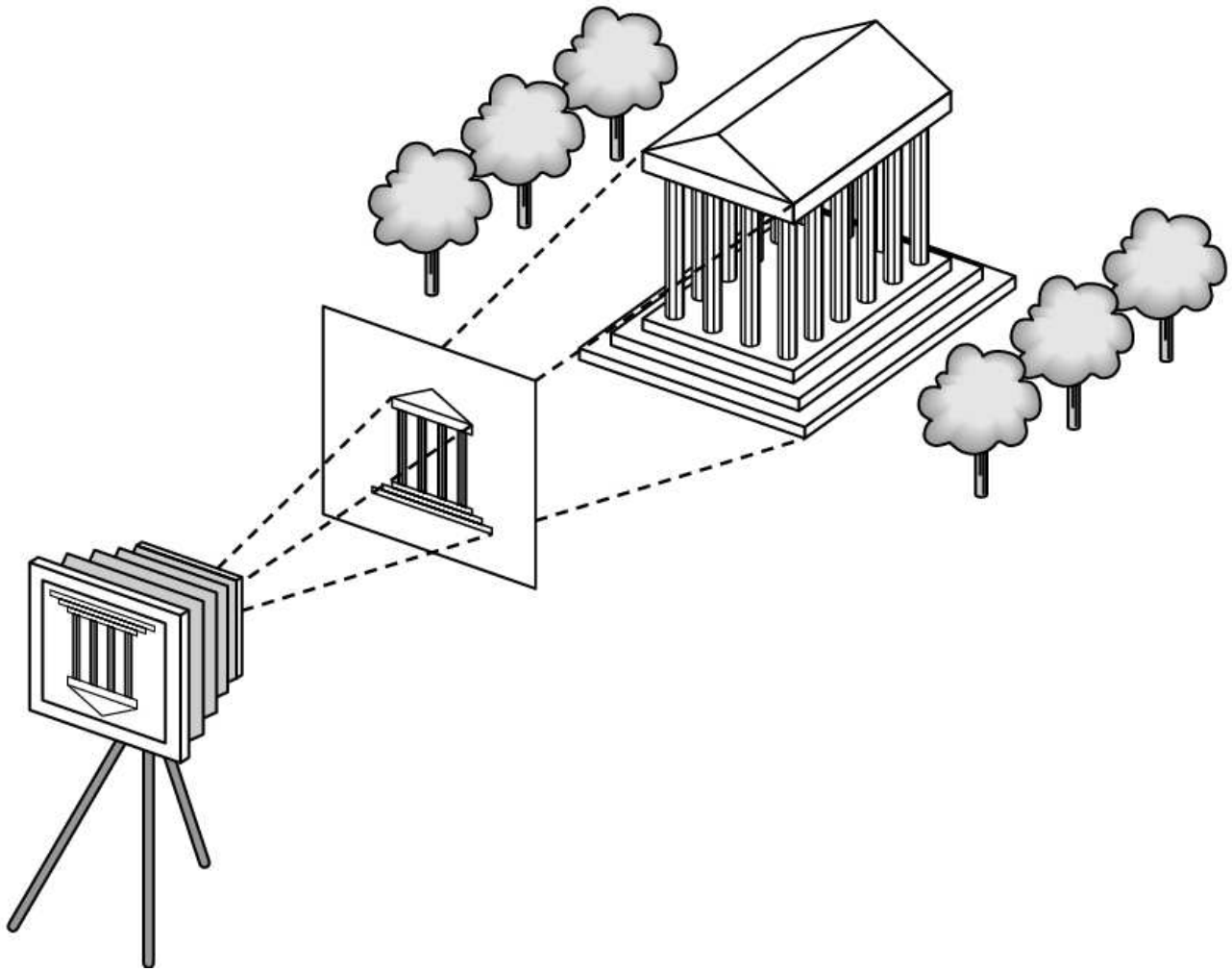
- List of vertices
- Specification of which vertices makes which primitive (triangle, quad, polygon)



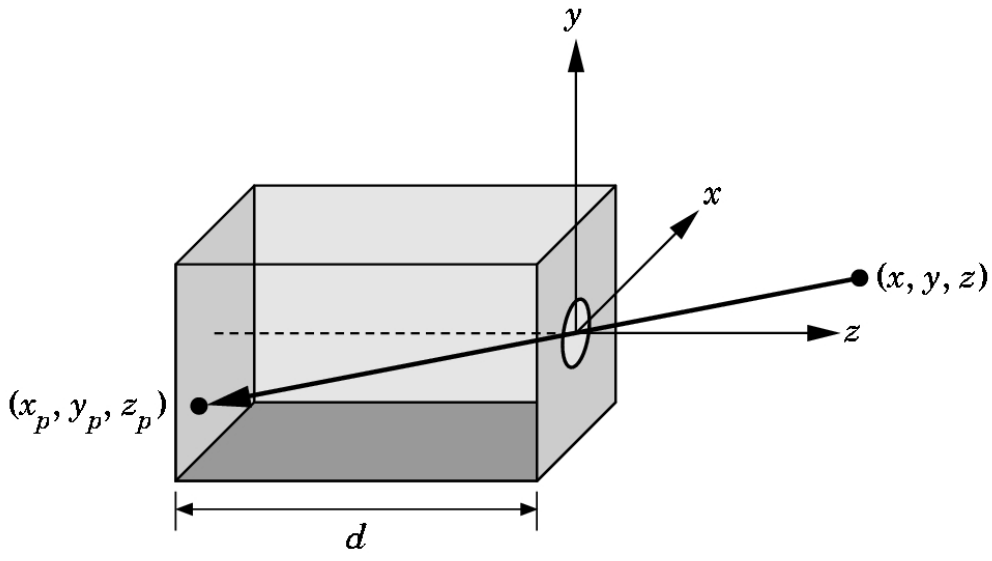
Material Properties

- Attributes govern how light interacts with objects.
- Light energy can be absorbed in different wavelengths, reflecting the rest

Synthetic Camera Model



Pinhole Camera



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

$$x_p = -\frac{x}{z/d} \quad y_p = -\frac{y}{z/d} \quad z_p = d$$

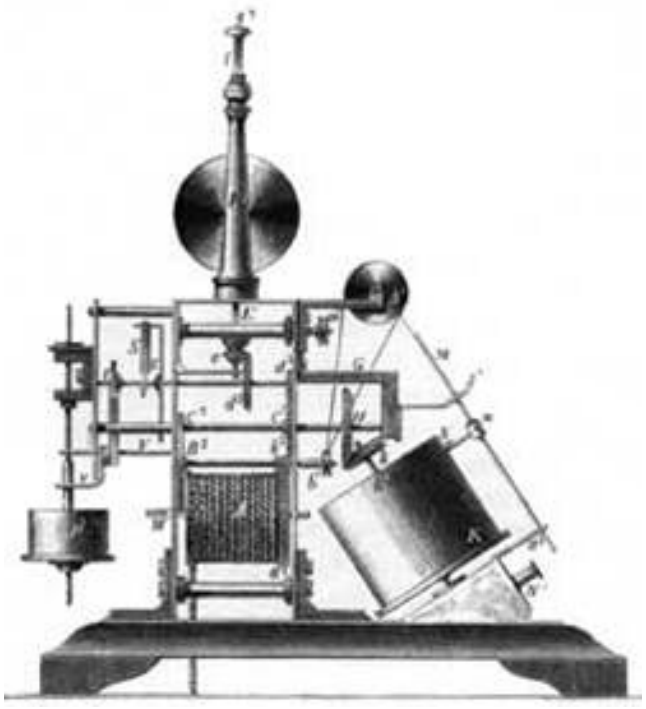
History of Computer Graphics

-2012

Before 1960

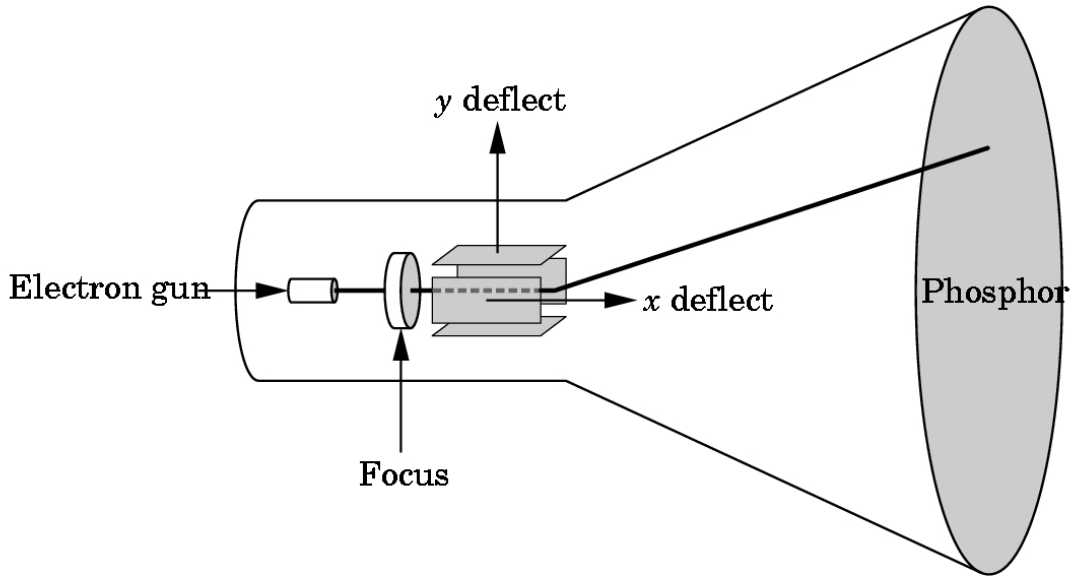
150BC	The Antikythera mechanism
1450	Gutenberg
1826	Photography (Niepce)
1842	FAX (Alexander Bain)
1885	CRT
1888	Record Motion pic. on vax cylinder (Edison, Dickson)
1926	First television (J.L. Baird)
1946	ENIAC Computer
1954	Fortran
1958	Integrated circuit

Alexander Bain's Fax Machine



Bain's fax machine used a detector to scan an image. As the detector passed over the page it emitted an electrical signal which registered at one strength as it passed through the image's black points and at a different strength as it passed over white points. The two distinct signals were transmitted over telegraph wires to a receiver which applied them to chemically treated paper to reproduce the image.

CRT



Can be used as

- line-drawing device (calligraphic) or to
- display contents of frame buffer (raster mode).

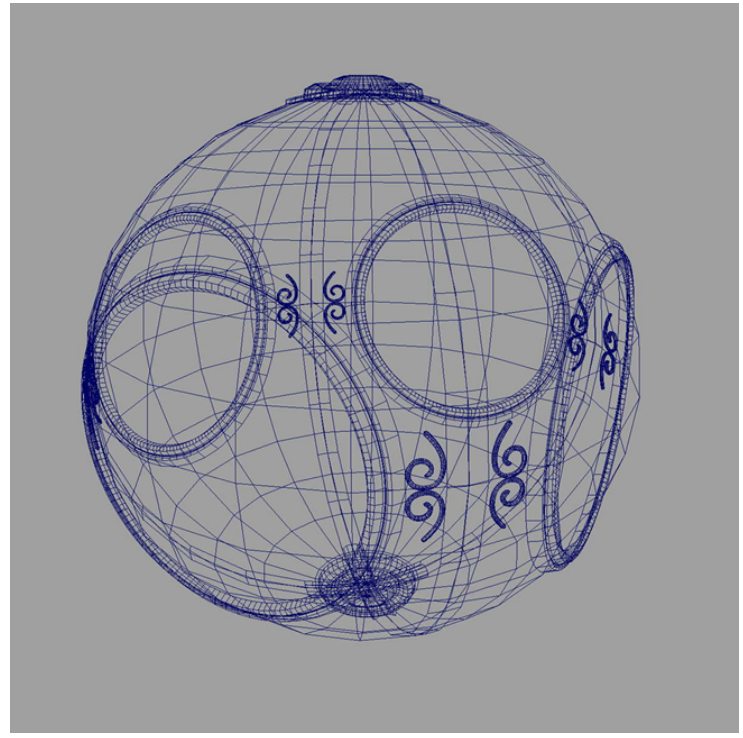
1960-1969

1961	Spacewars, One of the 1st released games
1963	DEC-1 First comersial CAD system
1963-1969	Hidden line, Warnock, Watkins alg., lineclippng
1969	UNIX developed
1969	GUI developed by Xerox (Alan Kay)

Spacewars

1960-1969

- Wireframe graphics
- Draw only lines
- Storage tube

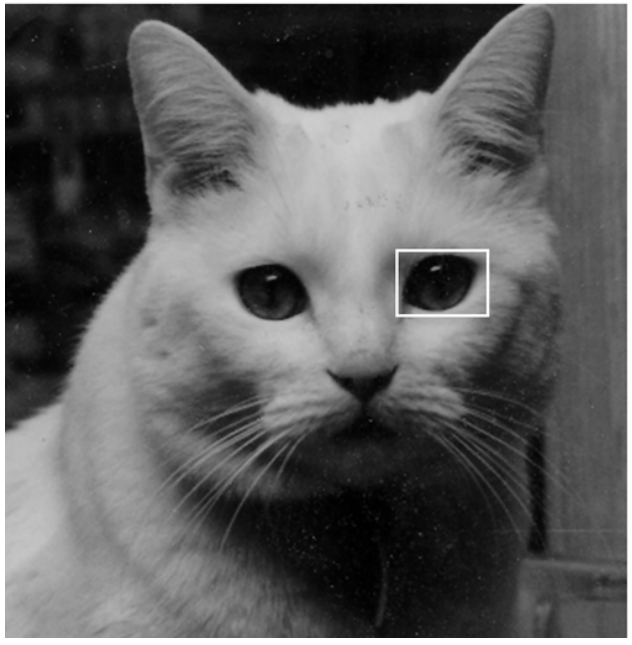


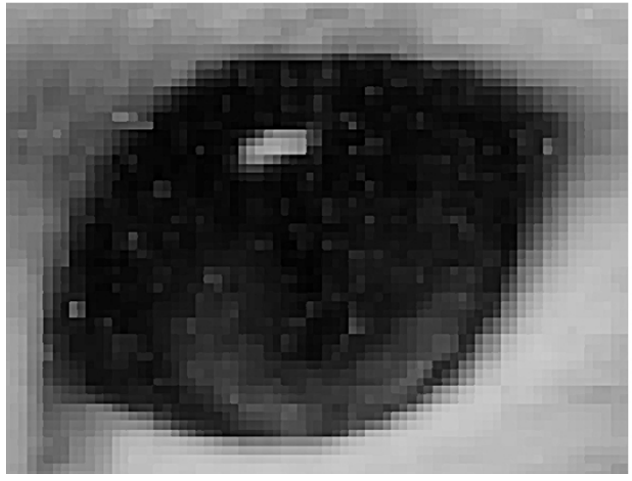
1970-1979

1972	Atari founded
1973,1975	z-buffer, phong shading
1975	Microsoft founded
1976	Apple founded
1977	Death Star simulation for Star Wars

1970-1979

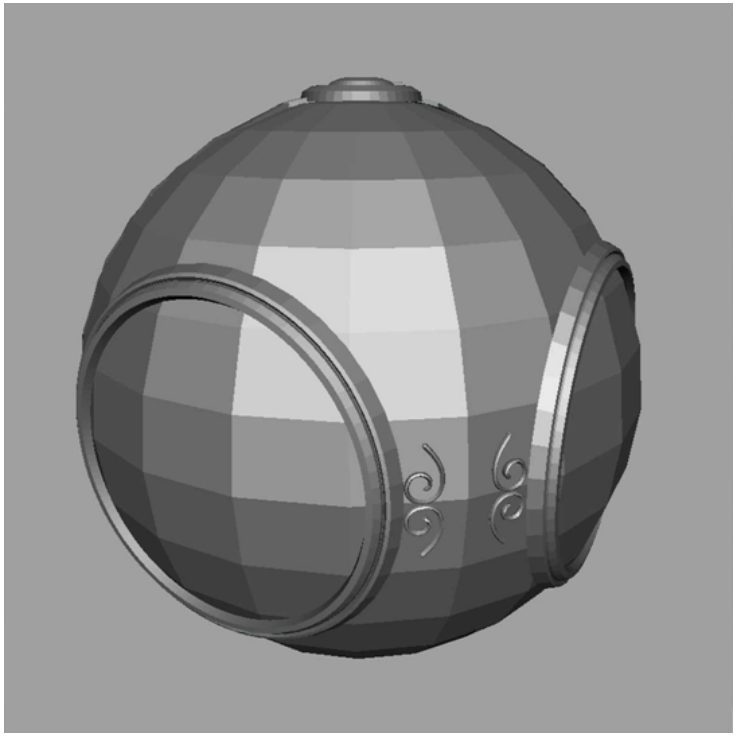
- Raster Graphics
- Beginning of graphics standards
- Workstations and PCs





Raster Graphics

- Image produced as an array (the raster) of picture elements (pixels) in the frame buffer
- Allows us to go from lines and wire frame images to filled polygons

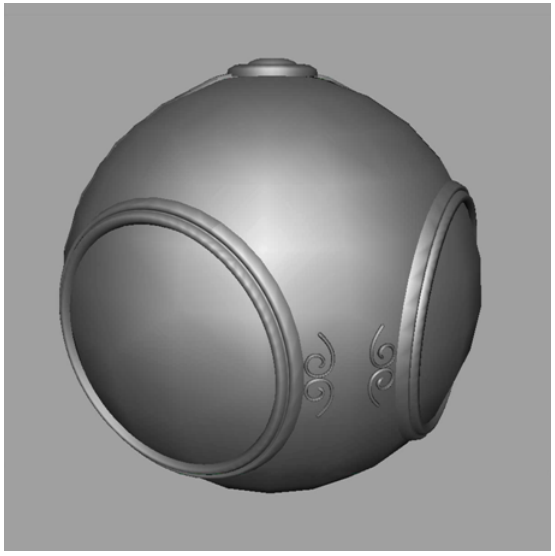


1980-1989

1980	Donkey Kong introduced by Nintendo
1980	Hanna-Barbera, comp. automation of anim. process
1982	Silicon Graphics Inc, Sun microsystems, Adobe
1984	Macintosh
1985	Pixar Image Computer goes to market
1986-1987	TIFF, GIF
1987	VGA
1988	Willow (Lucasfilm) morphing,
	Who Framed Roger Rabbit
1989	Photoshop

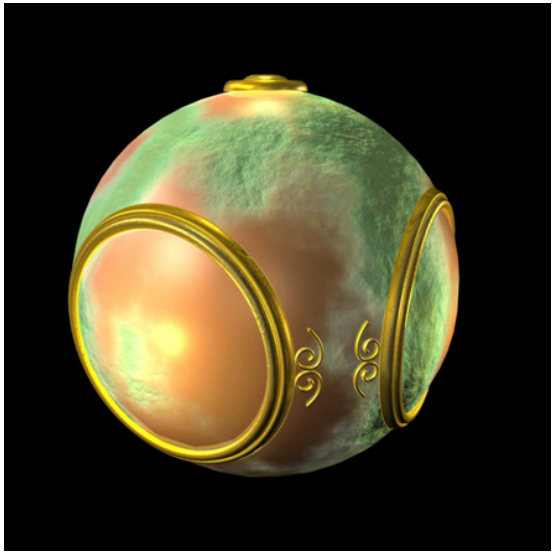
1980-1989

- Realism comes to computer graphics



Smooth Shading

Environment Mapping



Bump Mapping

1991-1999

1991	World Wide Web (CERN)
1991	Terminator 2
1991	JPEG/MPEG
1992	OpenGL
1993	Doom, Myst
1994	Linux 1.0
1995	Toy Story
1995	Java
1996	Quake
1998	MPEG-4

1991: February (premiere) issue of DV magazine advises

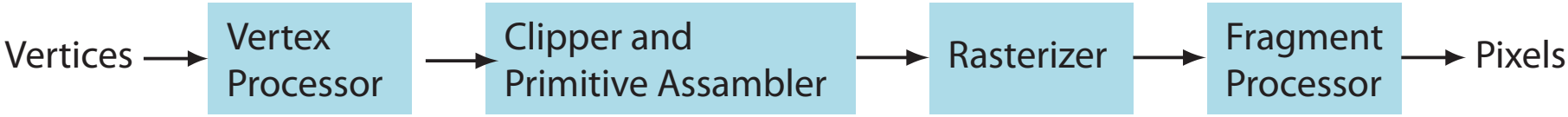
"[to be able to do digital video, get] the most souped up system you can get your hands on. A fast processor (68040 on Amiga or Mac, 80486 on PC) and lots of RAM (8-64 MB) are in order. So is a large hard drive (200 MB - 1 GB) if you want to take on serious production."

1991-1999

- OpenGL API
- Completely computer-generated feature-length movies (Toy Story) are successful
- New hardware capabilities

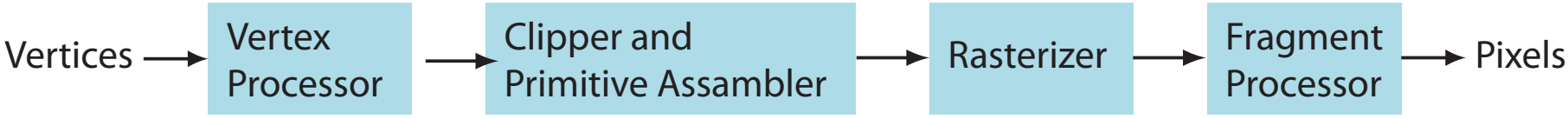
Pipeline Architecture

- Process objects one at a time in the order they are generated by the application
- All steps can be implemented in hardware on the graphics card



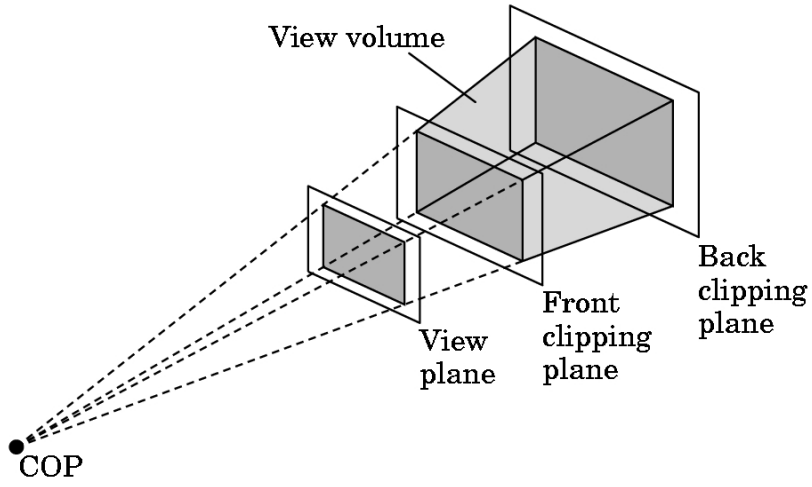
Vertex Processing

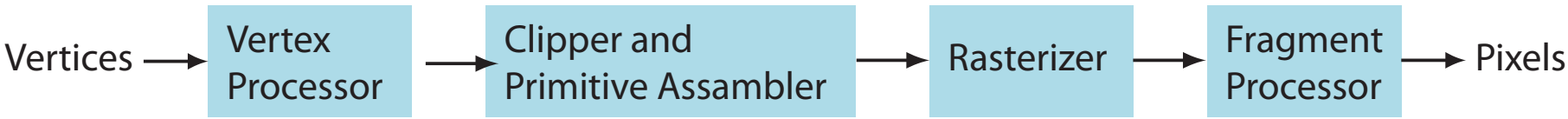
- Much of the work in the pipeline is in converting object representations from one coordinate system to another
  - Object coordinates
  - World/Sceene coordinates
  - Camera coordinates
  - NDC (Projected) coordinates
- Every change of coordinates is equivalent to a matrix transformation
- Vertex processor also computes vertex colors



Clipping and Primitive Assembly

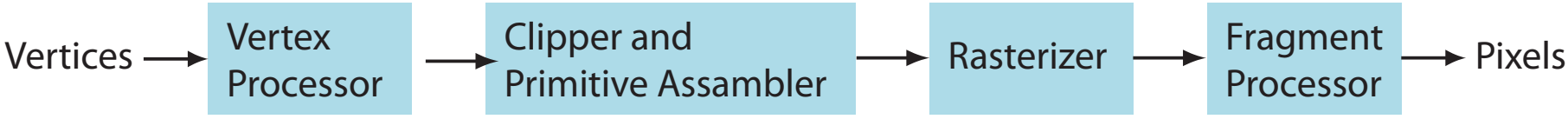
- Vertices must be collected into geometric objects before clipping and rasterization can take place
- Objects that are not within this volume are clipped out of the scene





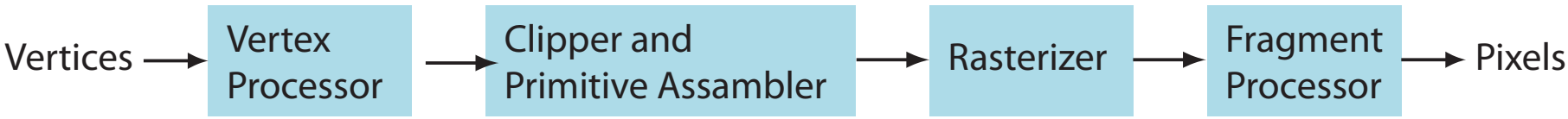
Rasterization

- If an object is not clipped out, the appropriate pixels in the frame buffer must be assigned colors
- Rasterizer produces a set of fragments for each object
- Fragments are ”potential pixel”
  - Have a location in frame buffer
  - Color and depth attributes
- Vertex attributes are interpolated over objects by the rasterizer



Fragment Processing

- Fragments are processed to determine the color of the corresponding pixel in the frame buffer
- Colors can be determined by texture mapping or interpolation of vertex colors
- Fragments may be blocked by other fragments closer to the camera (Hidden-surface removal)



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
- 3-D reenters animations

Programmable Pipeline