

CSE528 Computer Graphics: Concepts, Theory, Algorithms, and Applications

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Goals

- **Systems:** be able to write fairly complex interactive 3D graphics programs (in OpenGL)
- **Theory:** Understand mathematical aspects and algorithms underlying modern 3D graphics systems
- This course is *not* about the specifics of 3D graphics programs and APIs like Maya, Alias, AutoCAD, DirectX but about the concepts underlying them

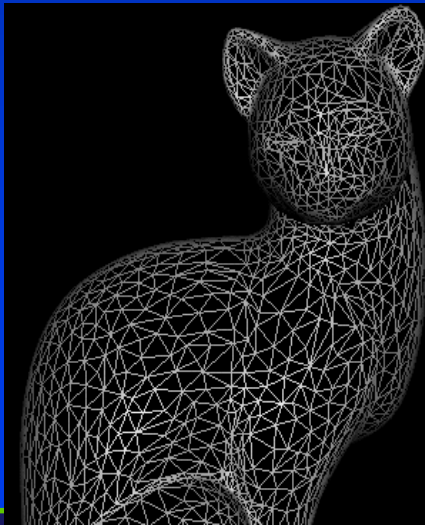
Key Elements for the Course

- 3D Graphics Pipeline

Modeling
(Creating 3D Geometry)



Rendering
(Creating, shading images from geometry, lighting, materials)



Application-driven Computer Graphics

- Entertainment (movies), art
- Design (CAD)
- Video games
- Education, simulators, augmented reality

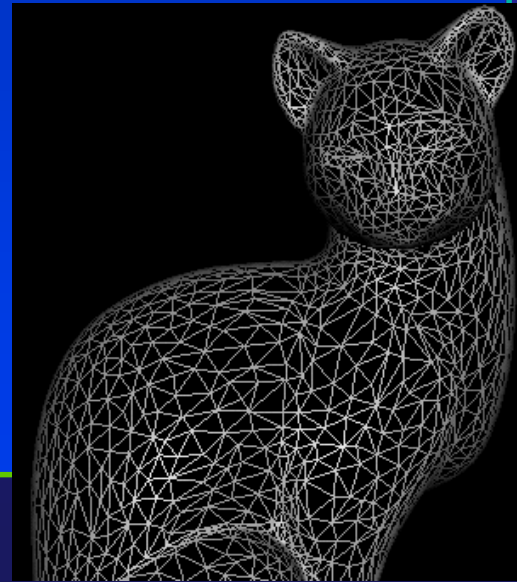


Modeling

- Polygons
- Constructive solid geometry
- Parametric surfaces
- Implicit surfaces
- Subdivision surfaces
- Particle systems
- Volumes

Modeling

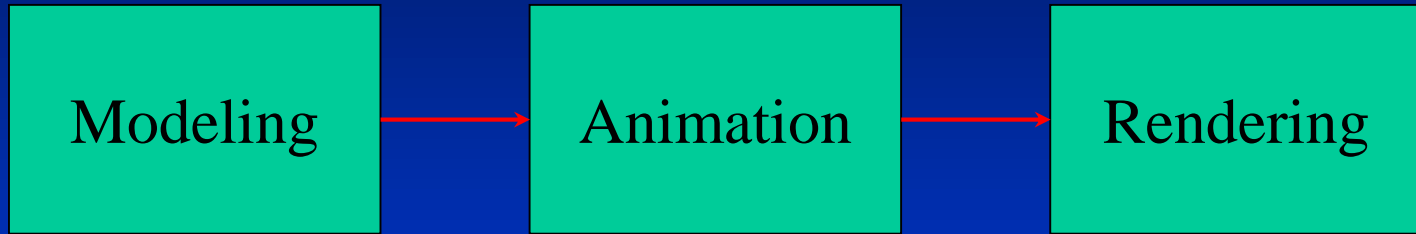
- Spline curves, surfaces: 70^s – 80^s
- Utah teapot: Famous 3D model
- More recently: Triangle meshes often acquired from real objects



Animation

- Scripted
- Key-frame interpolation
- Inverse kinematics
- Dynamics

The Graphics Pipeline



What is Computer Graphics?

- Anything to do with visual representations on a computer
- Includes much of 2D graphics we take for granted
- And 3D graphics modeling and rendering (focus of this course)
- Auxiliary problems: Display devices, physics and math for computational problems

The term Computer Graphics was coined by William Fetter of Boeing in 1960
First graphic system in mid 1950s USAF SAGE radar data (developed MIT)

Before Computer Graphics

Where Are We Coming From: TEXT



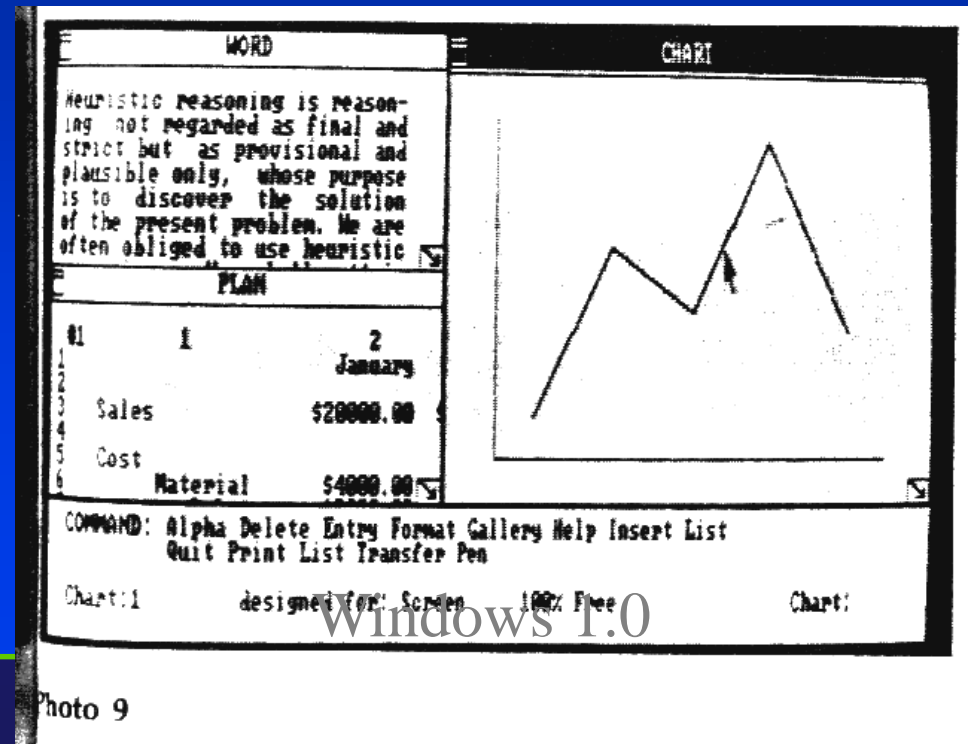
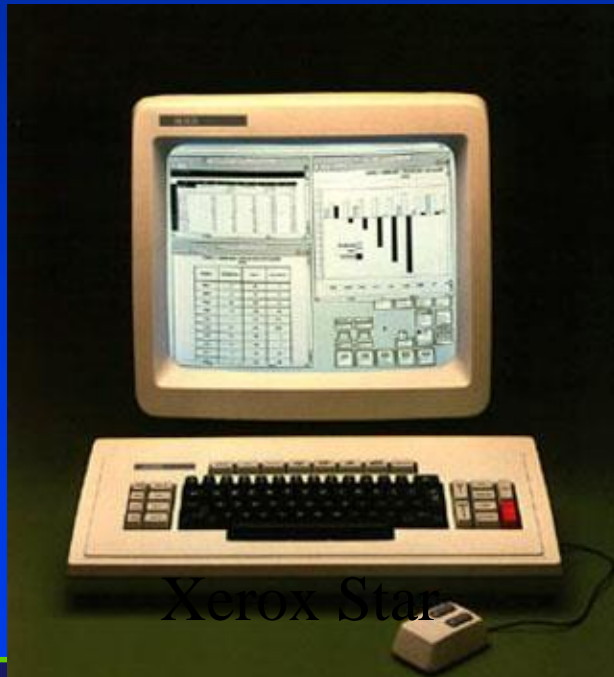
Manchester Mark I

Display



From Text to GUIs

- Invented at PARC about 1975. Used in the Apple Macintosh, and now prevalent everywhere.



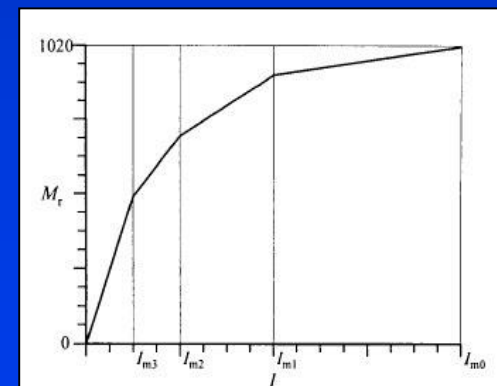
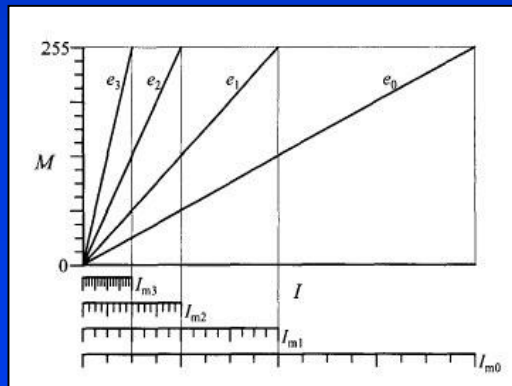
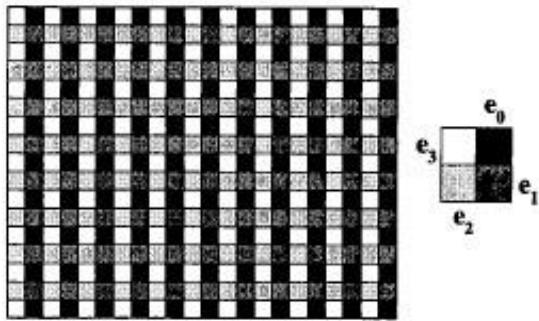
Input Hardware

2D

- light pen, tablet, mouse, joystick, track ball, touch panel, etc.
- 1970s & 80s - CCD analog image sensor + frame grabber
- 1990s & 2000's - CMOS digital sensor + in-camera processing
 - high- X imaging (dynamic range, resolution, depth of field,...)

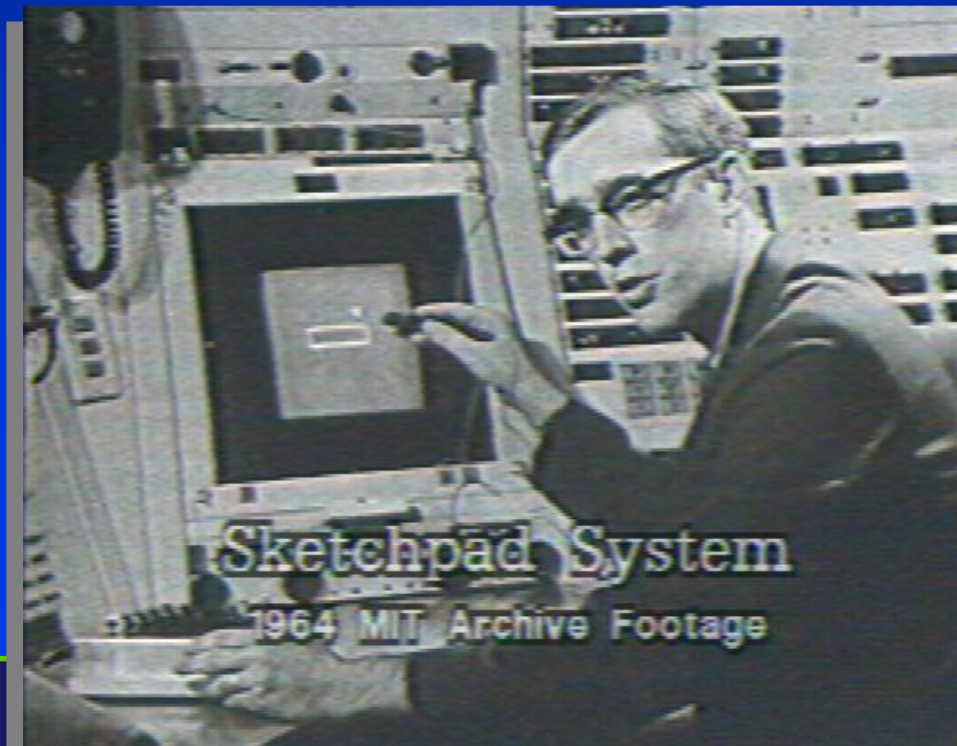
Input Hardware

[Nayar00]



Display Hardware

- **Vector displays**
 - 1963 – modified oscilloscope
 - 1974 – Evans and Sutherland Picture System



Ivan Sutherland (1963) – SKETCHPAD Drawing

- Sketchpad (Sutherland, MIT 1963)
- First interactive graphics system
- Many of concepts for drawing in current systems
 - Pop-up menus
 - Constraint-based drawing
 - Hierarchical modeling



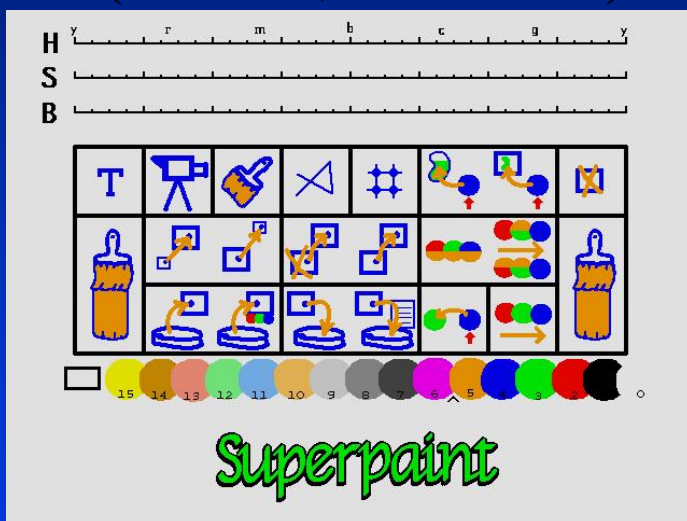
2D Graphics

Many of the standard operations you're used to:

- Text
- Graphical User Interfaces (Windows, MacOS, ..)
- Image processing and paint programs (Photoshop, ...)
- Drawing and presentation (Powerpoint, ...)

Paint Systems

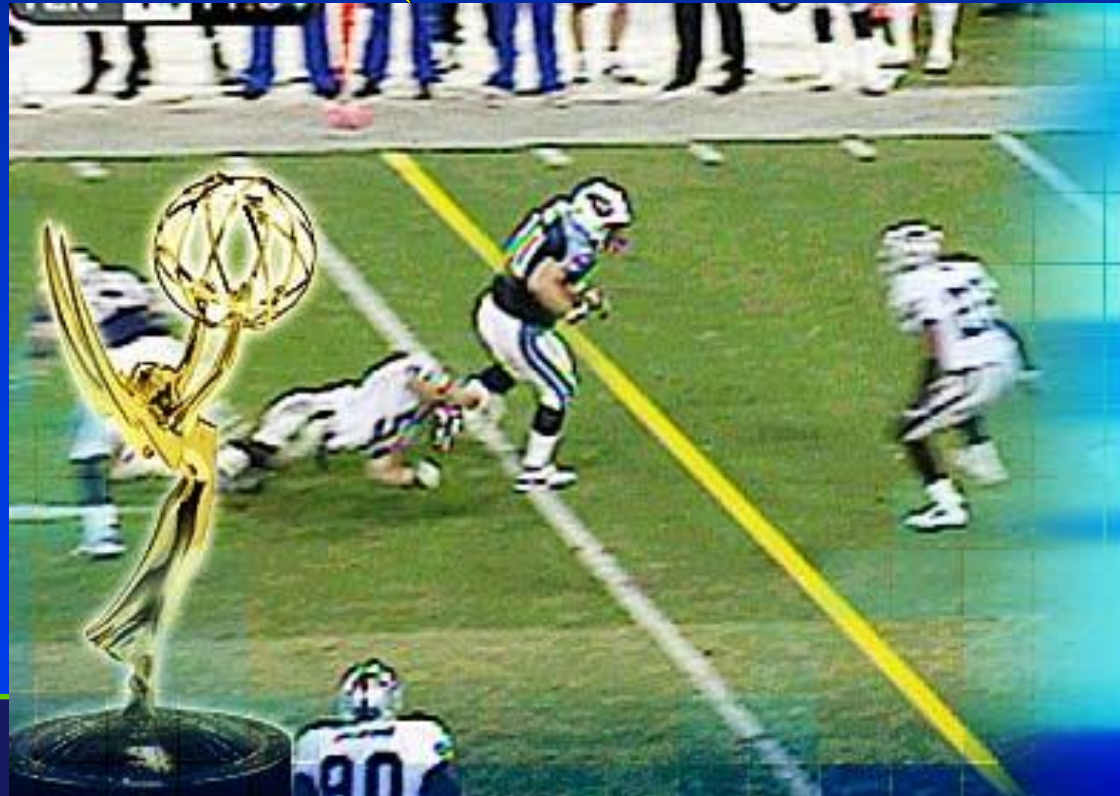
- SuperPaint system: Richard Shoup, Alvy Ray Smith (PARC, 1973-79)



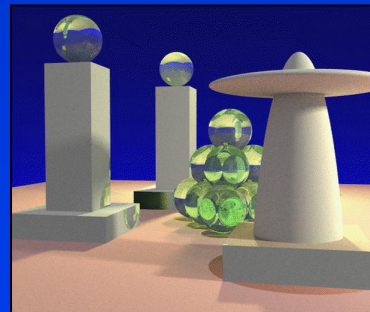
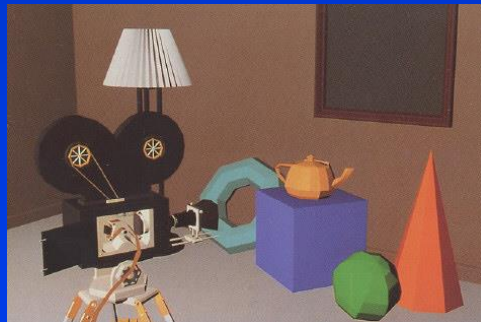
- Nowadays, image processing programs like Photoshop can draw, paint, edit, etc.

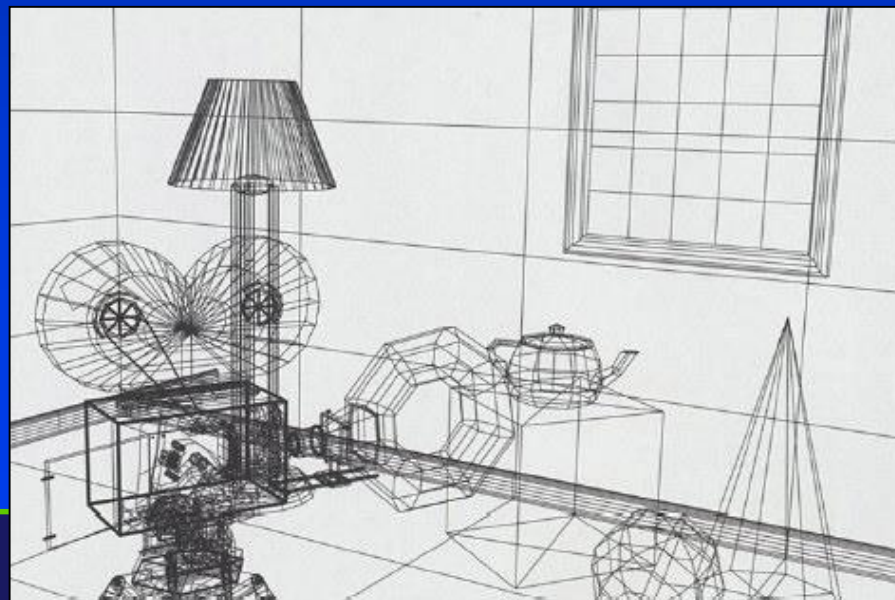
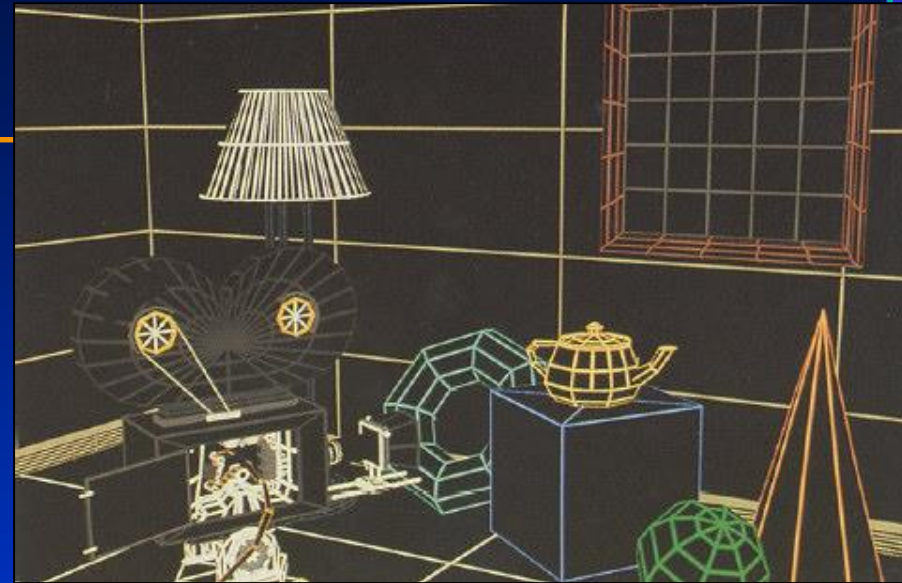
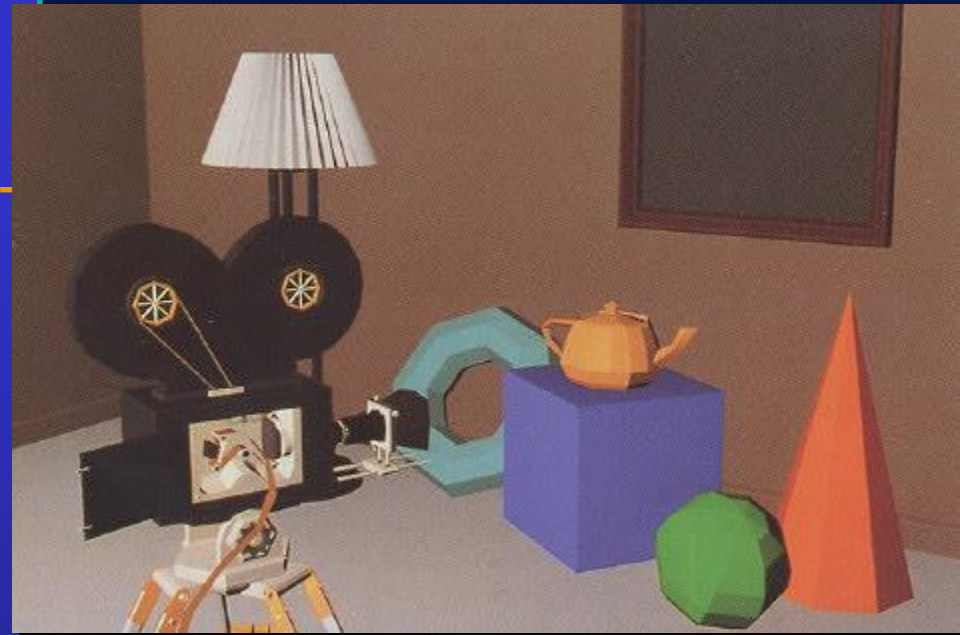
Image Processing

- Digitally alter images, crop, scale, composite
- Add or remove objects
- Sports broadcasts for TV (combine 2D and 3D processing)



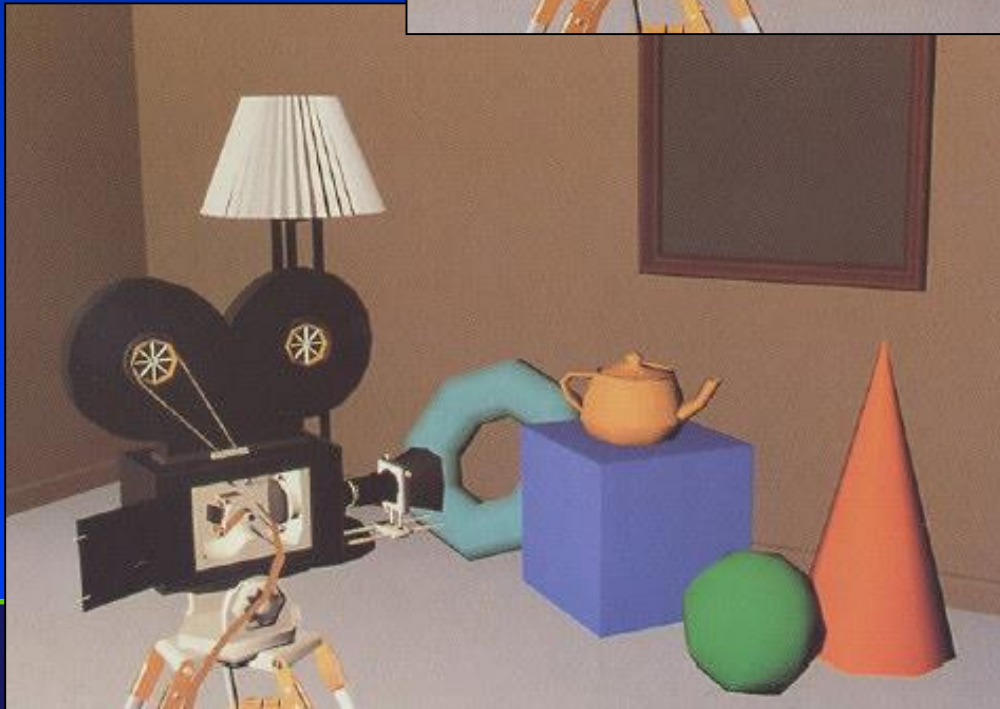
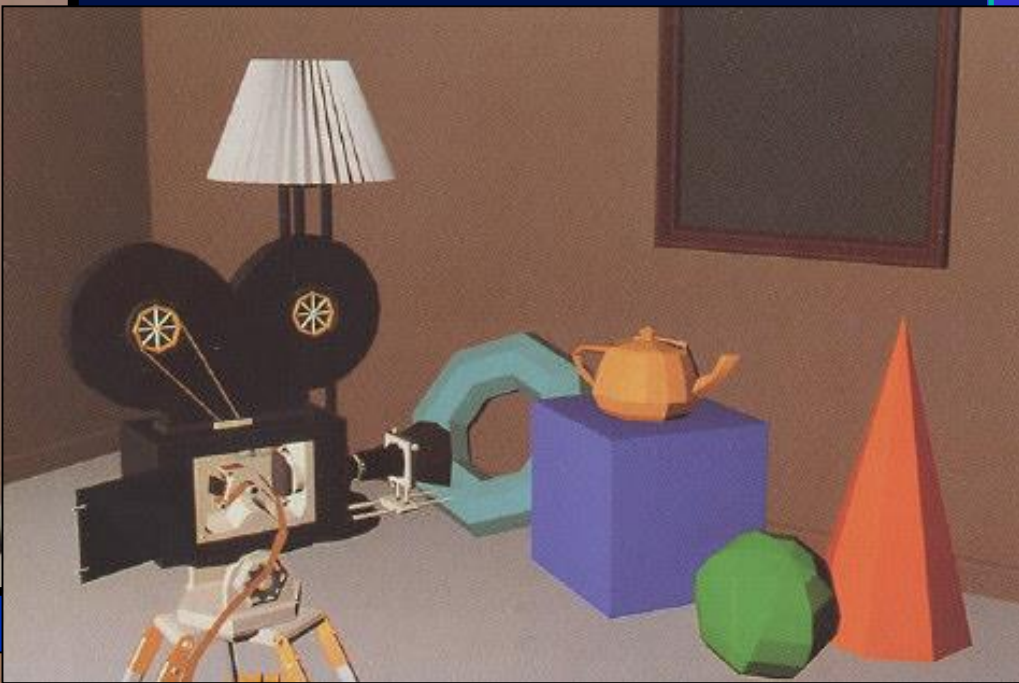
Computer Graphics History





Rendering: 1960s (Visibility)

- Roberts (1963), Appel (1967) - hidden-line algorithms
- Warnock (1969), Watkins (1970) - hidden-surface
- Sutherland (1974) - visibility = sorting



Rendering: 1970s (Lighting)

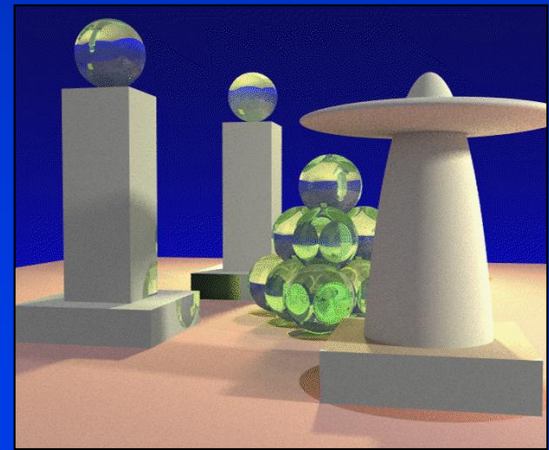
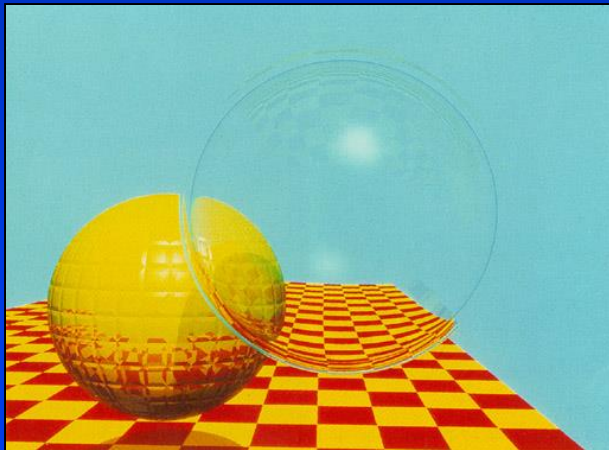
1970s - raster graphics

- Gouraud (1971) - diffuse lighting, Phong (1974) - specular lighting
- Blinn (1974) - curved surfaces, texture
- Catmull (1974) - Z-buffer hidden-surface algorithm

Rendering (1980s, 90s: Global Illumination)

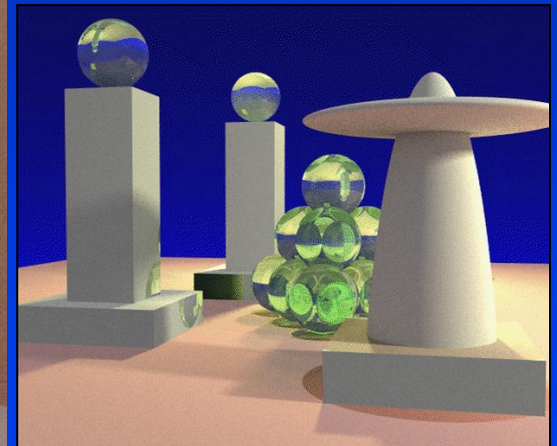
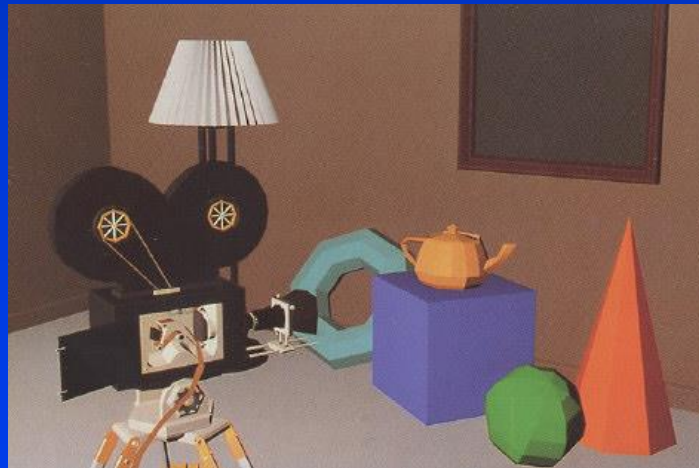
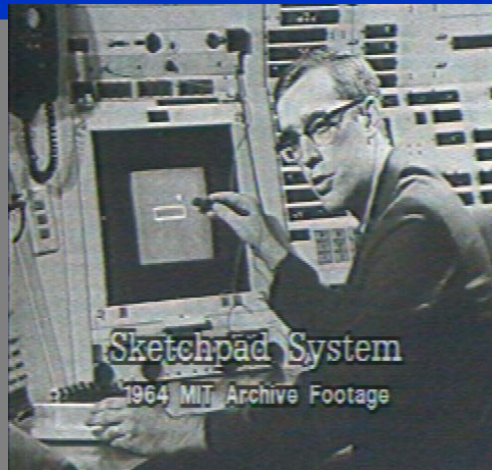
Early 1980s - global illumination

- Whitted (1980) - ray tracing
- Goral, Torrance et al. (1984) radiosity
- Kajiya (1986) - the rendering equation



History

- Brief history of significant developments in computer graphics field



Display Hardware

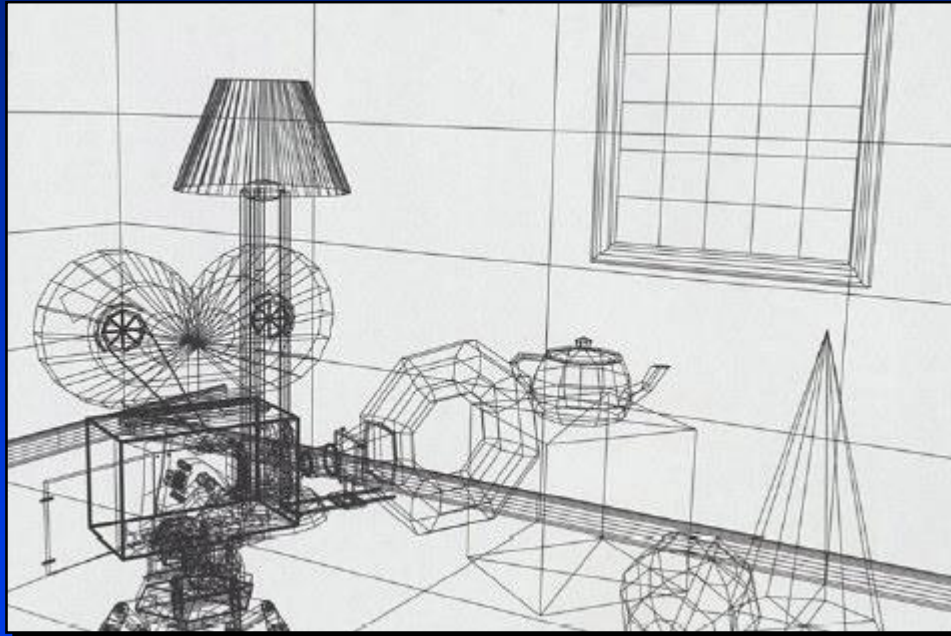
- **Raster displays**
 - 1975 – Evans and Sutherland frame buffer
 - 1980s – cheap frame buffers → bit-mapped personal computers
 - 1990s – liquid-crystal displays → laptops
 - 2000s – micro-mirror projectors → digital cinema
- **Others**
 - stereo, head-mounted displays
 - autostereoscopic displays
 - tactile, haptic, sound

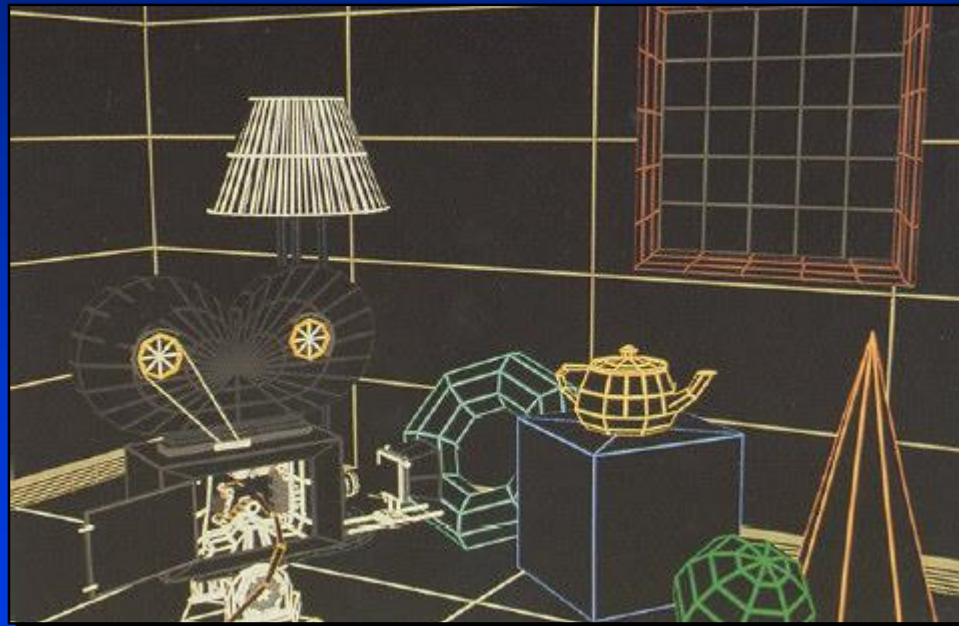
Input Hardware

- 3D
 - 3D trackers
 - multiple cameras
 - active rangefinders
- Others
 - data gloves
 - voice

Rendering

- **1960s - the visibility problem**
 - Roberts (1963), Appel (1967) - hidden-line algorithms
 - Warnock (1969), Watkins (1970) - hidden-surface algorithms
 - Sutherland (1974) - visibility = sorting

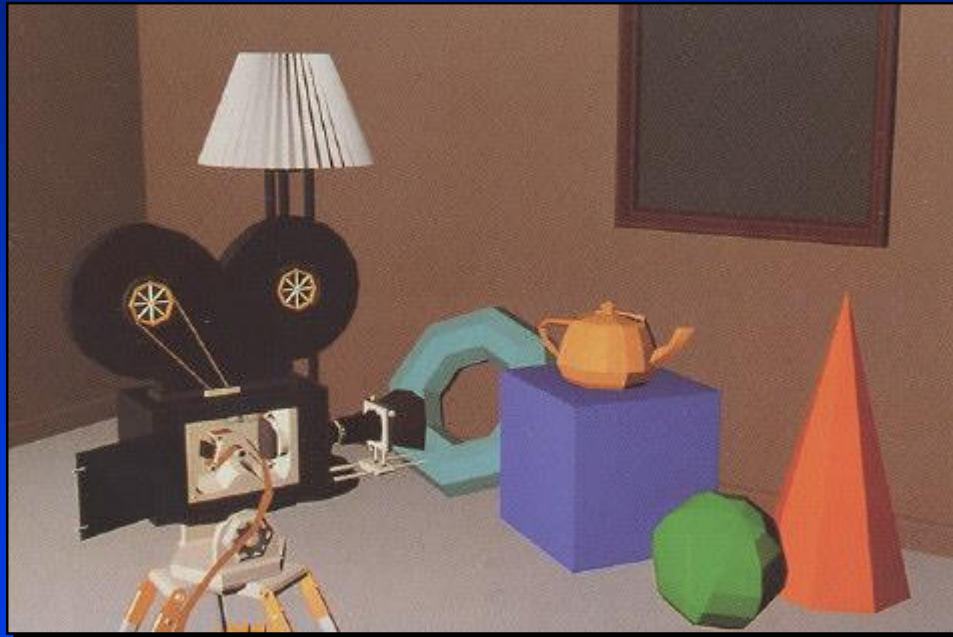


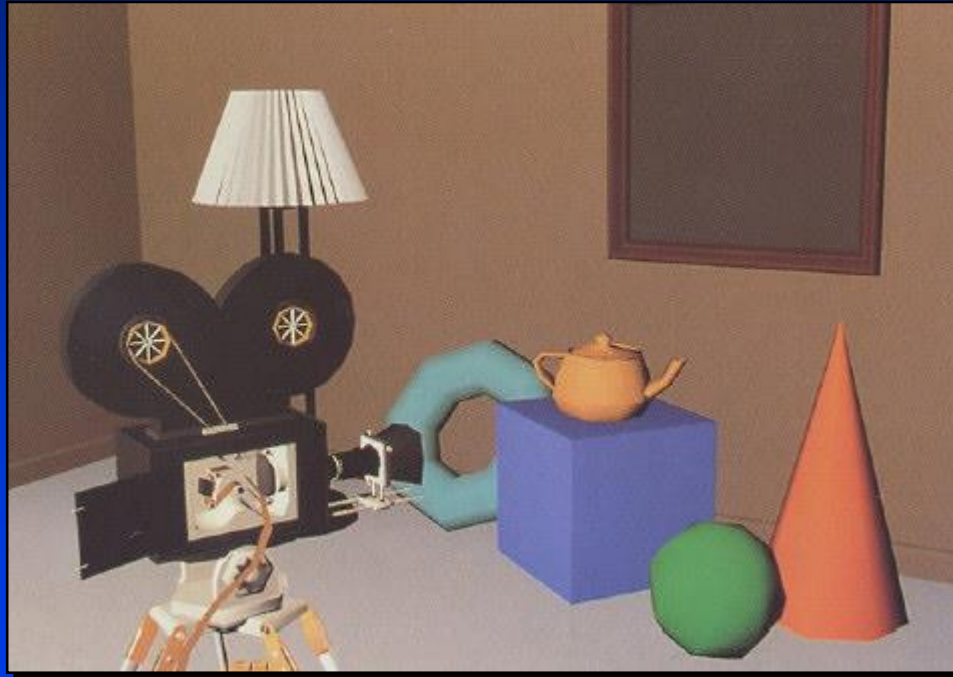




1970s

- Raster graphics
- Gouraud (1971) - diffuse lighting
- Phong (1974) - specular lighting
- Blinn (1974) - curved surfaces, texture
- Catmull (1974) - Z-buffer hidden-surface algorithm
- Crow (1977) - anti-aliasing







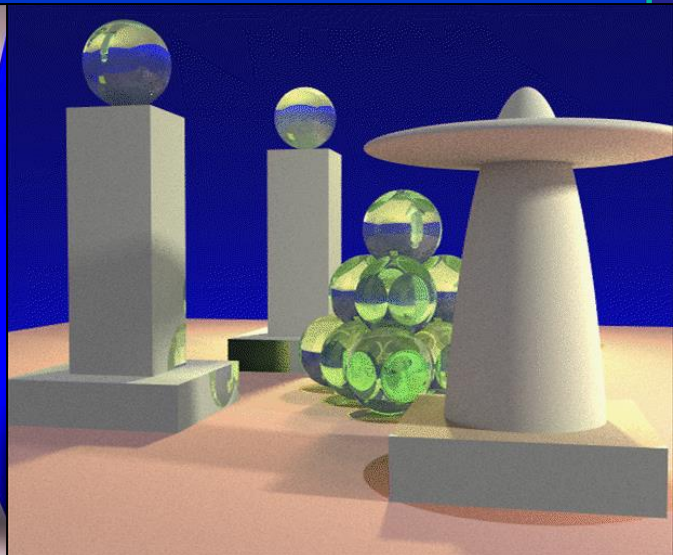
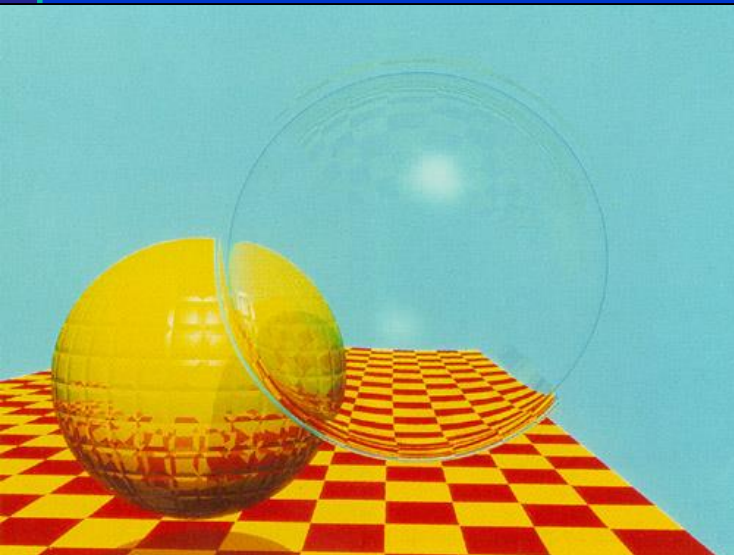






Early 1980s

- **Global illumination**
 - Whitted (1980) - ray tracing
 - Goral, Torrance et al. (1984), Cohen (1985) - radiosity
 - Kajiya (1986) - the rendering equation



Late 1980s

- **Early 1980s - Global illumination**
 - Whitted (1980) - ray tracing
 - Goral, Torrance et al. (1984), Cohen (1985) – radiosity
 - Kajiya (1986) - the rendering equation
- **Photorealism**
 - Cook (1984) - shade trees
 - Perlin (1985) - shading languages
 - Hanrahan and Lawson (1990) - RenderMan

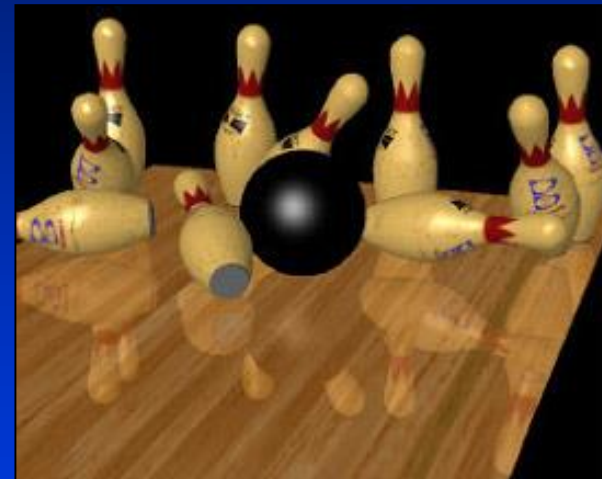
Photorealism

- Driving force behind computer graphics for many years
- Quality of image is judged by how closely they resemble a photograph
- Images are rendered by running a physics-simulation which emulates the behavior of light inside the modeled scene

Effects needed for Photorealism

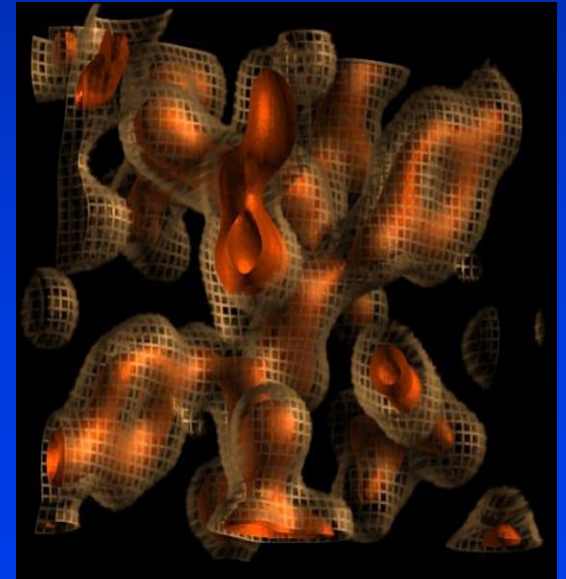
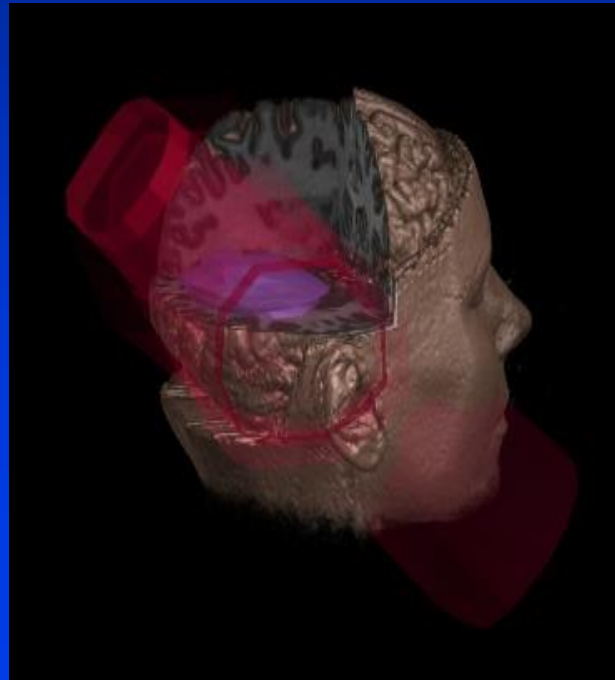
- **Shadows**
- **Reflections (Mirrors)**
- **Transparency**
- **Interreflections**
- **Detail (Textures etc.)**
- **Complex Illumination**
- **Realistic Materials**
- **And many more**





Early 1990s

- **Non-photorealistic rendering**
 - Drebin et al. (1988), Levoy (1988) - volume rendering
 - Haeberli (1990) - impressionistic paint programs
 - Salesin et al. (1994-) - automatic pen-and-ink illustration
 - Meier (1996) - painterly rendering

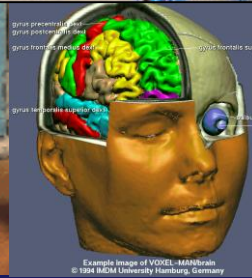
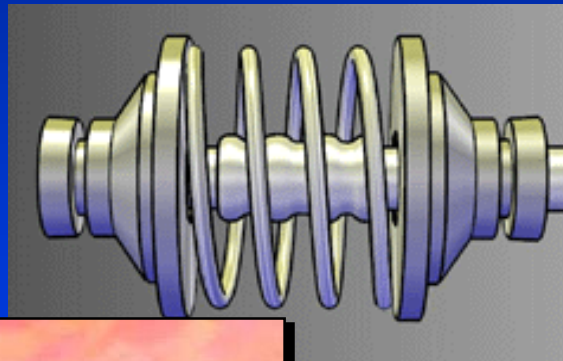
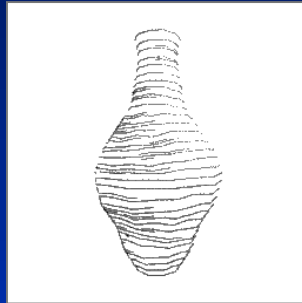
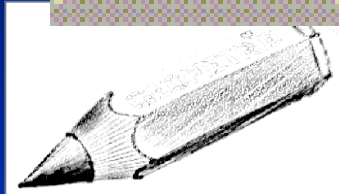
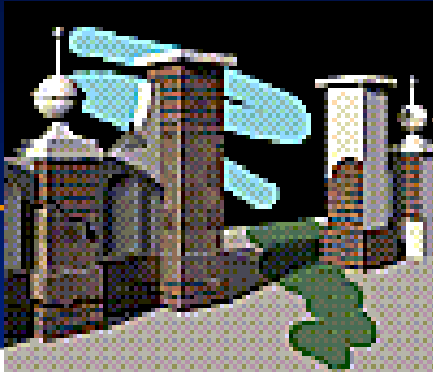


Non-Photorealistic Rendering (NPR)

- Images are judged by how effectively they communicate
- Involves stylization and communication, usually driven by human perception
- Knowledge and techniques long used by artists and illustrators
- Emphasis on specific features of a scene, expose subtle attributes, omit extraneous information
- Brings together art and science

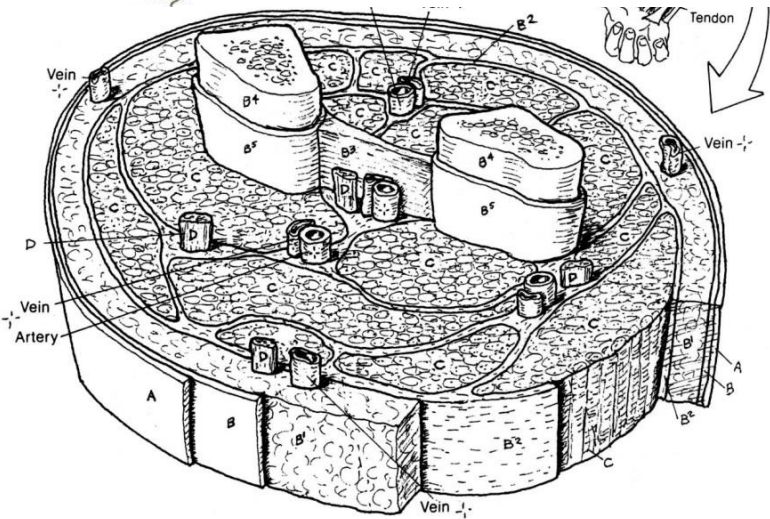
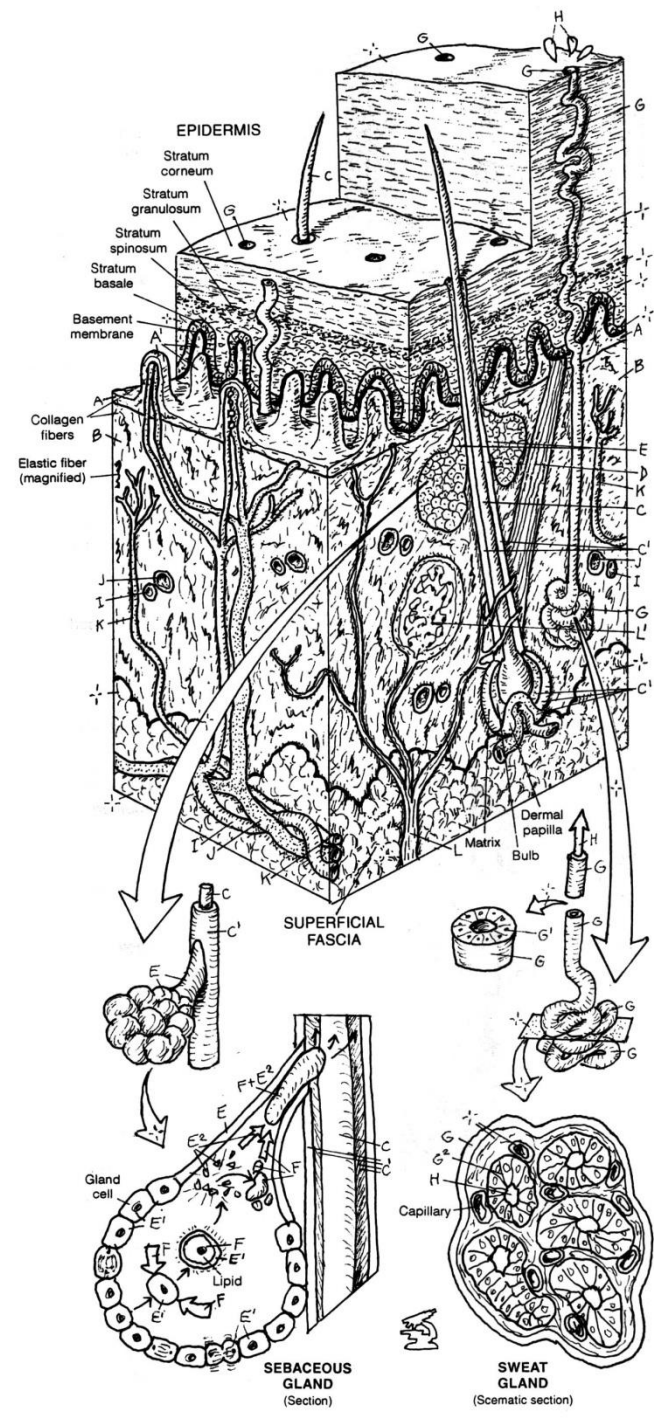
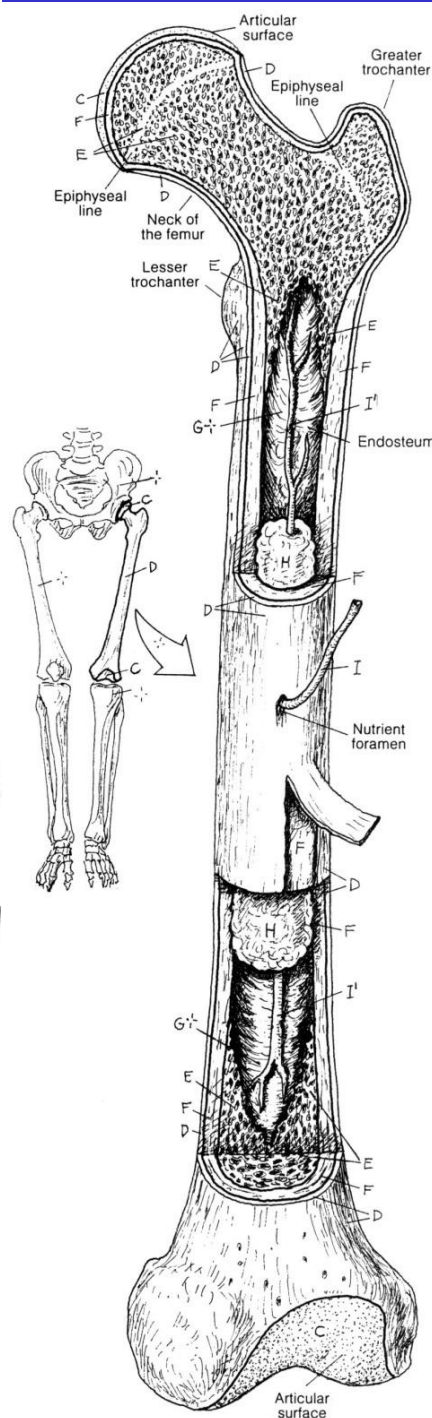
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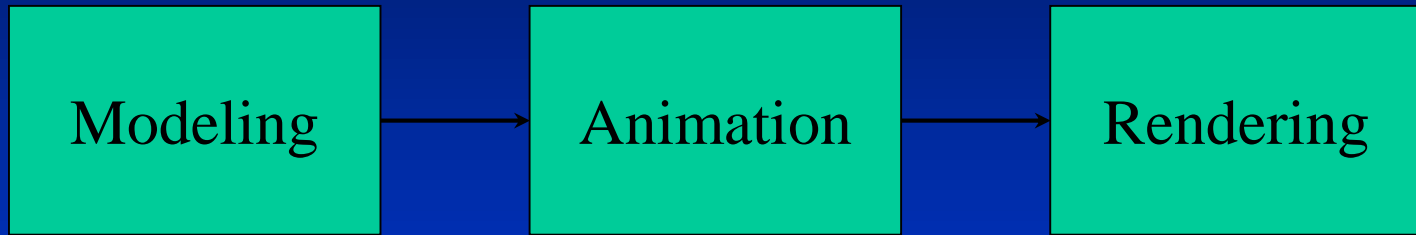
Example image of VOREL-MANIBRAN
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The Graphics Pipeline

The Traditional Pipeline



The New Pipeline?

