CSE328 Fundamentals of Computer Graphics: Concepts, Theory, Algorithms, and Applications

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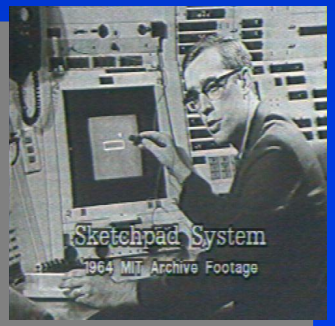
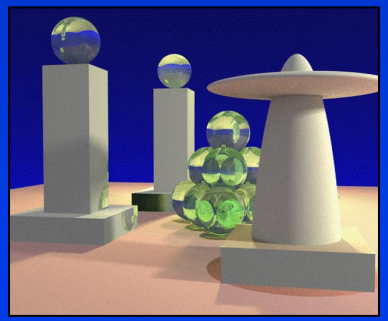
Computer Graphics History





Our 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

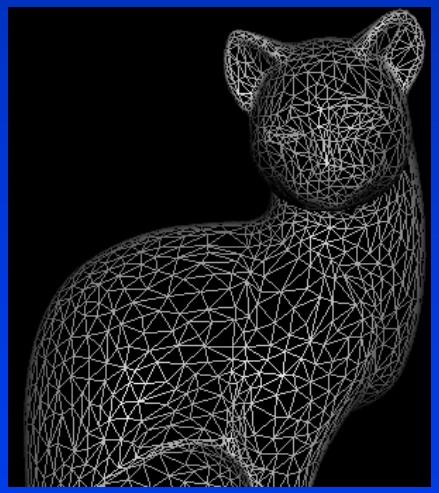
Computer Graphics Outline

- 3D Graphics Pipeline

Modeling
(Creating 3D Geometry)

→

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



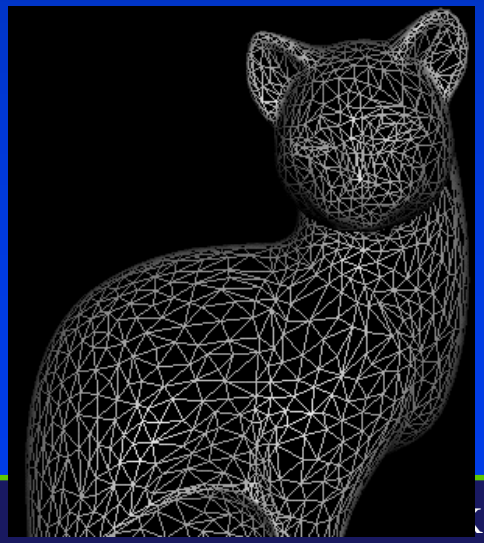
Applications

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

Modeling

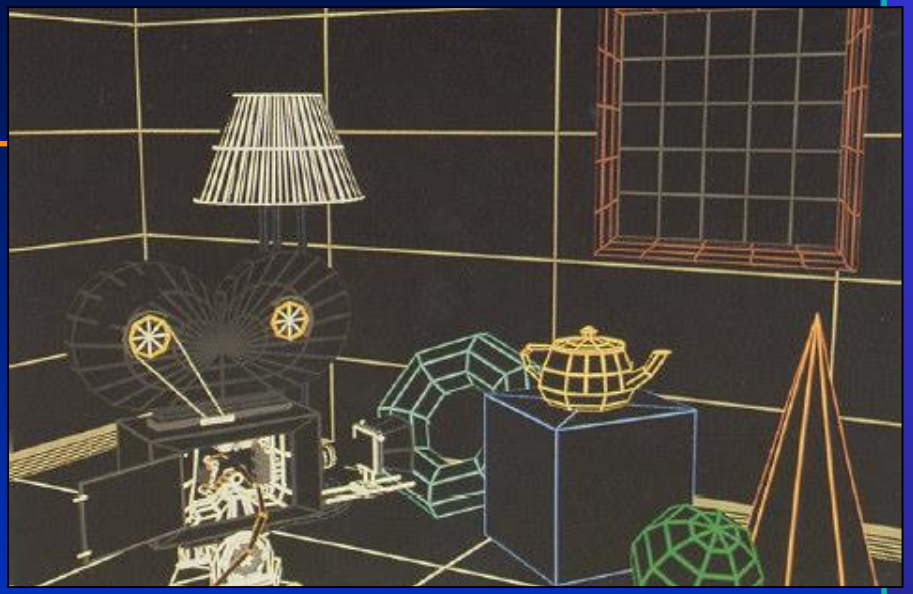
- Spline curves, surfaces: 70^s – 80^s
- Utah teapot: Famous 3D model

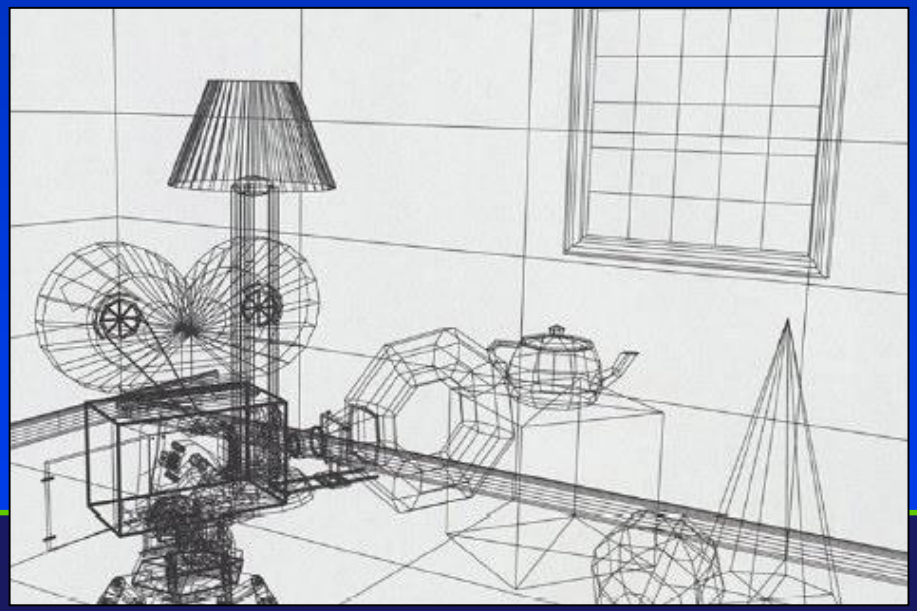
- More recently: Triangle meshes often acquired from real objects



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
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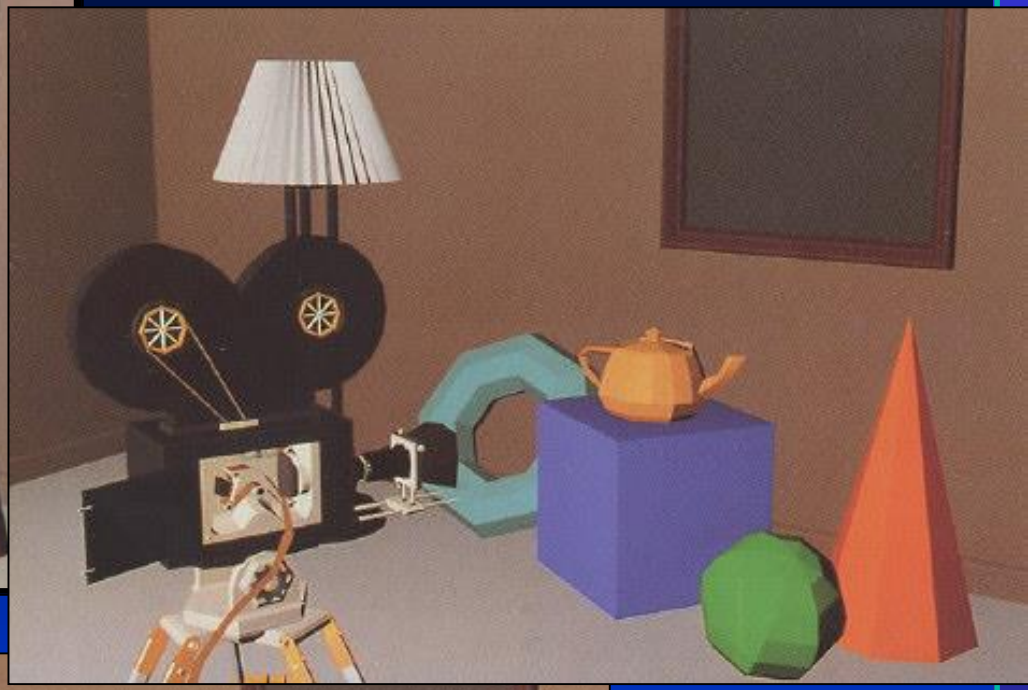
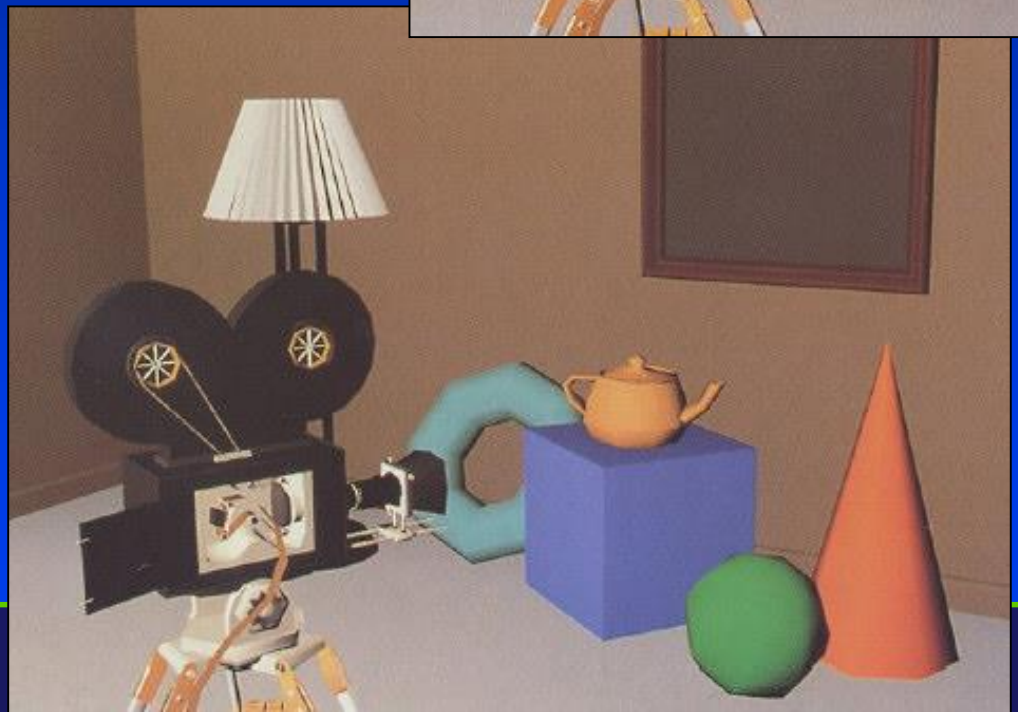




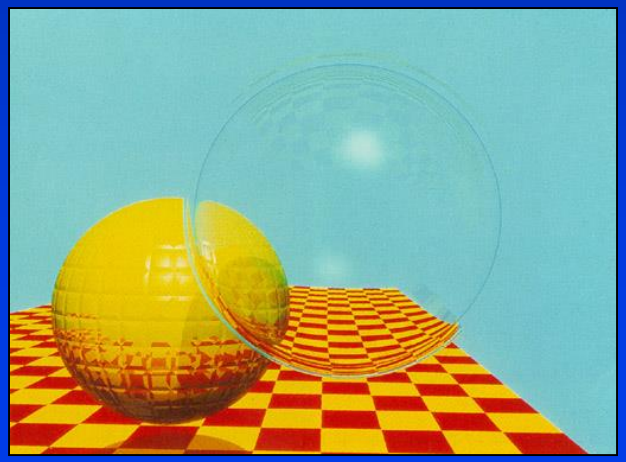
Department of Computer Science
Center for Visual Computing

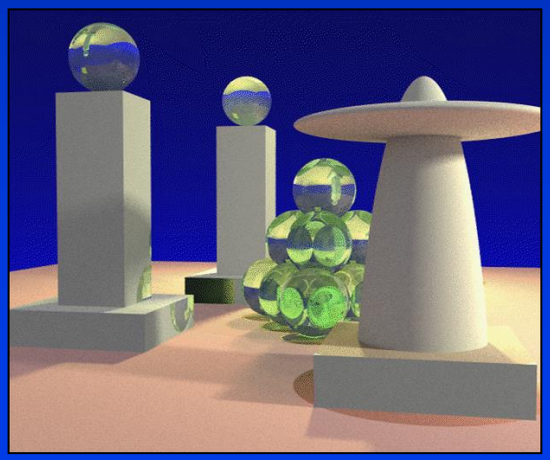
STONY BROOK
STATE UNIVERSITY OF NEW YORK

Rendering (1980s, 90s: Global Illumination)

early 1980s - Global illumination

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





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 course)
- Auxiliary problems: Display devices, physics and math for computational problems

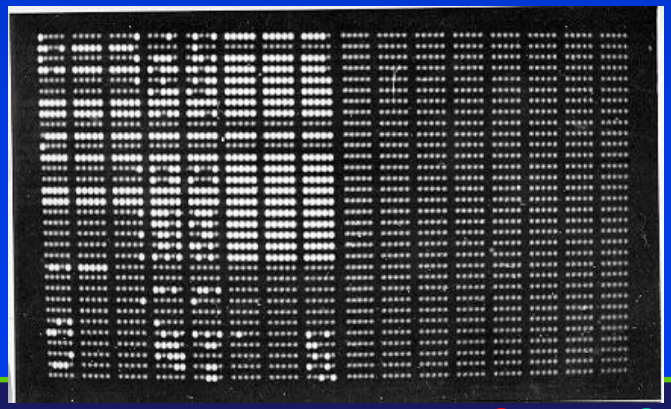
The term Computer Graphics was coined by William Fetter of Boeing in 1960
First graphic system in mid 1950s USAF SAGE radar data (developed at MIT)

Before Computer Graphics

Where Are We Coming From: TEXT

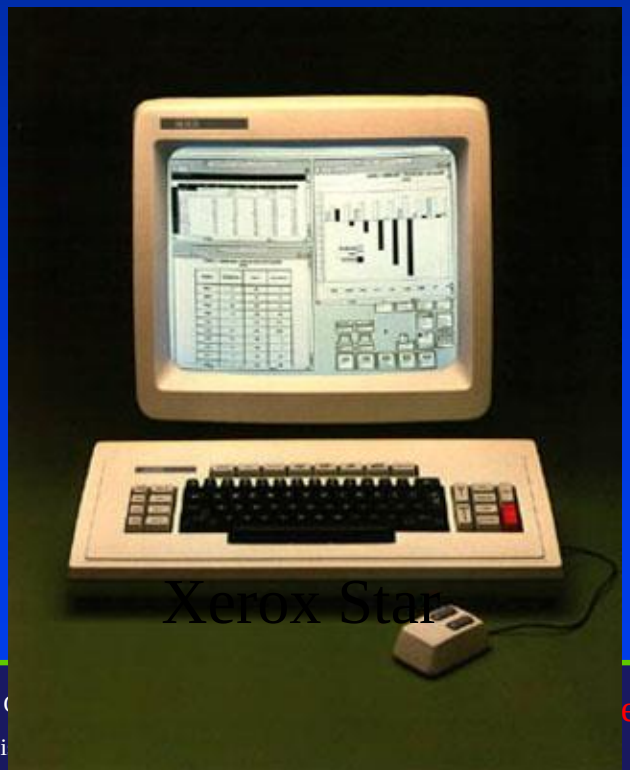
Manchester Mark I

Display →

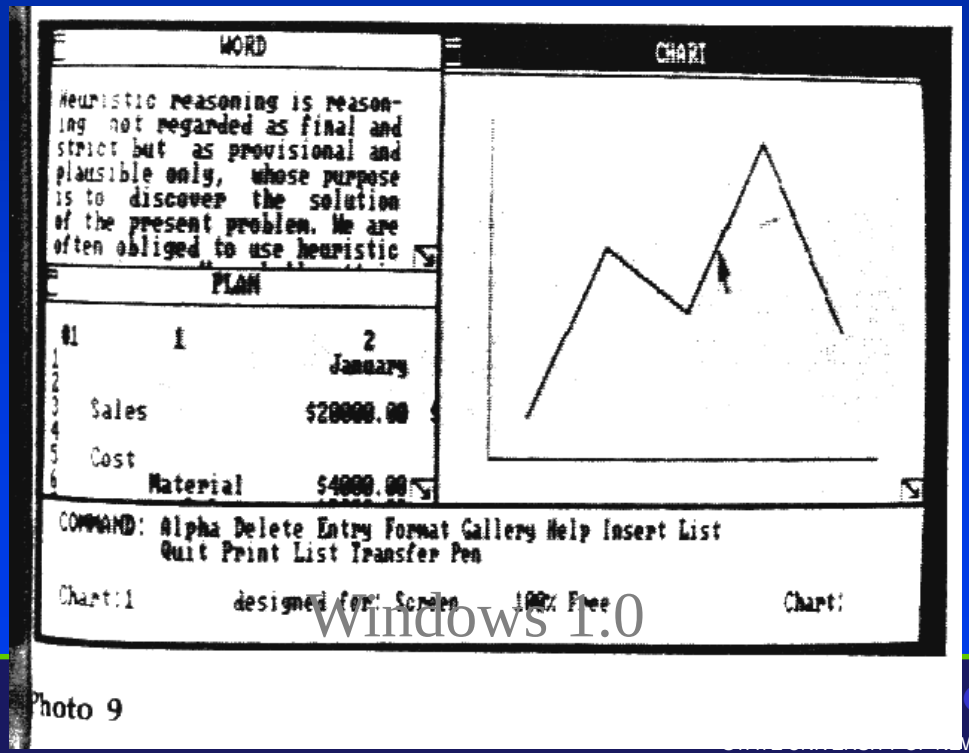


From Text to GUIs

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



Xerox Star

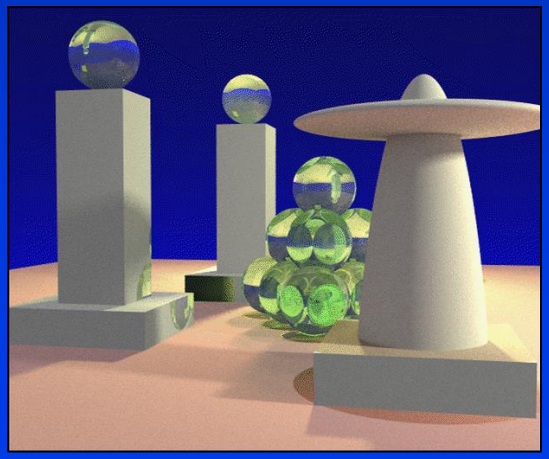


Windows 1.0

Photo 9

History

- Brief history of significant developments in compugter graphics field
- Couple of animated shorts for fun
- Towards end of course: movie, history of CG



Ivan Sutherland (1963) - SKETCHPAD

- Pop-up menus
- Constraint-based drawing
- Hierarchical modeling

Display Hardware

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

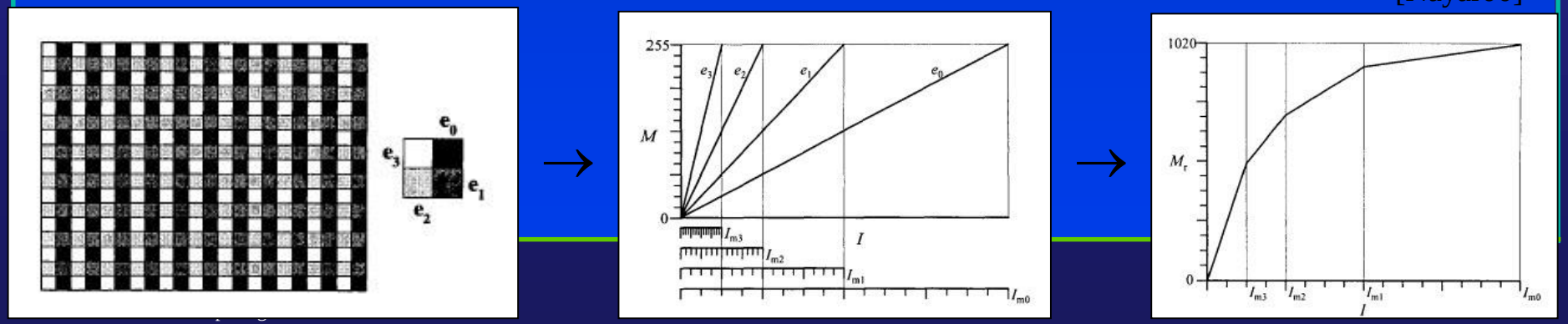
Display Hardware

- 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
  - auto-stereoscopic displays
  - tactile, haptic, sound

Input Hardware

- 2D
  - light pen, tablet, mouse, joystick, track ball, touch panel, etc.
  - 1970s & 80s - CCD analog image sensor + frame grabber → high-X imaging (dynamic range, resolution, depth of field,…)
  - 1990s & 2000's - CMOS digital sensor + in-camera processing

[Nayar00]



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    → high-X imaging (dynamic range, resolution, depth of field,….)

Input Hardware

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

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, ….)

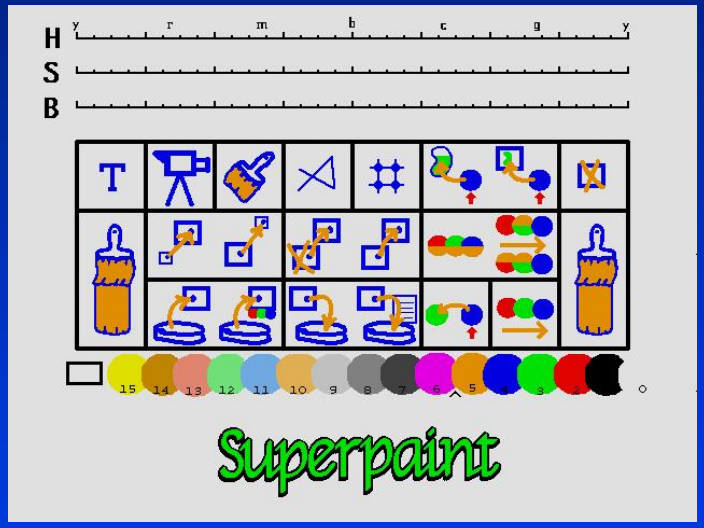
Drawing: Sketchpad (1963)

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

Sketchpad System
1964 MIT Archive Footage

Paint Systems

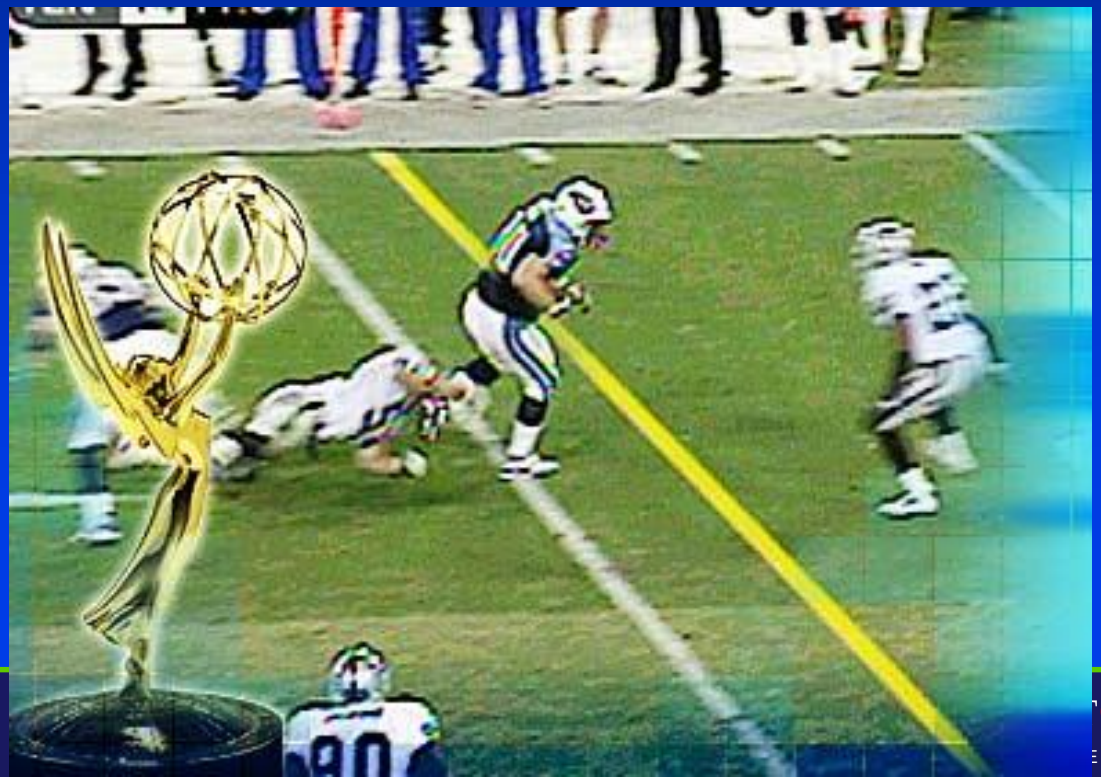
- SuperPaint system: Richard Shoup, Alvy Ray Smith (PARC, 1973-79)



- 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)



Rendering

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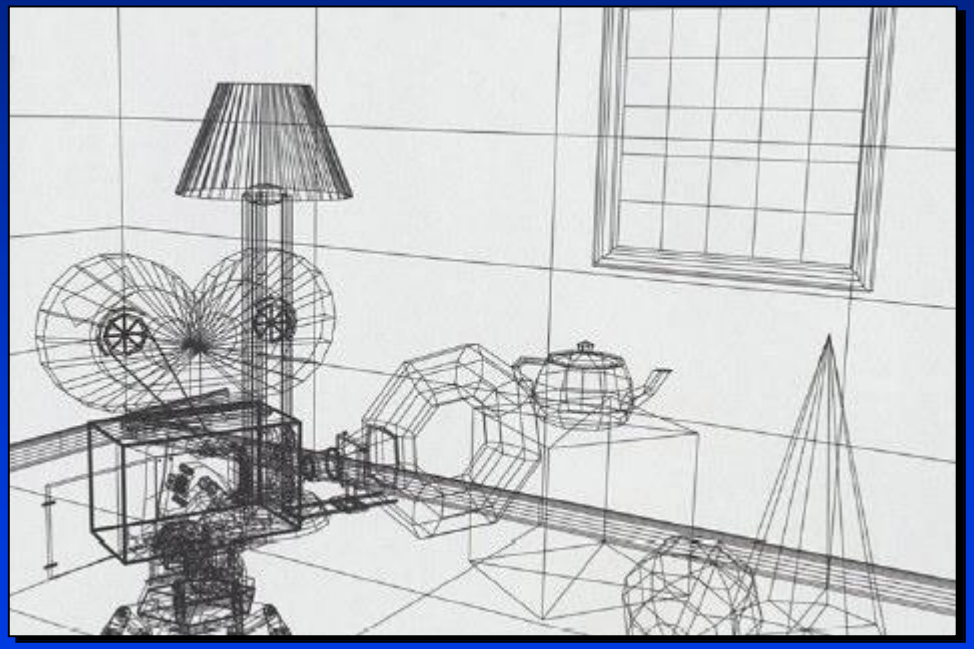

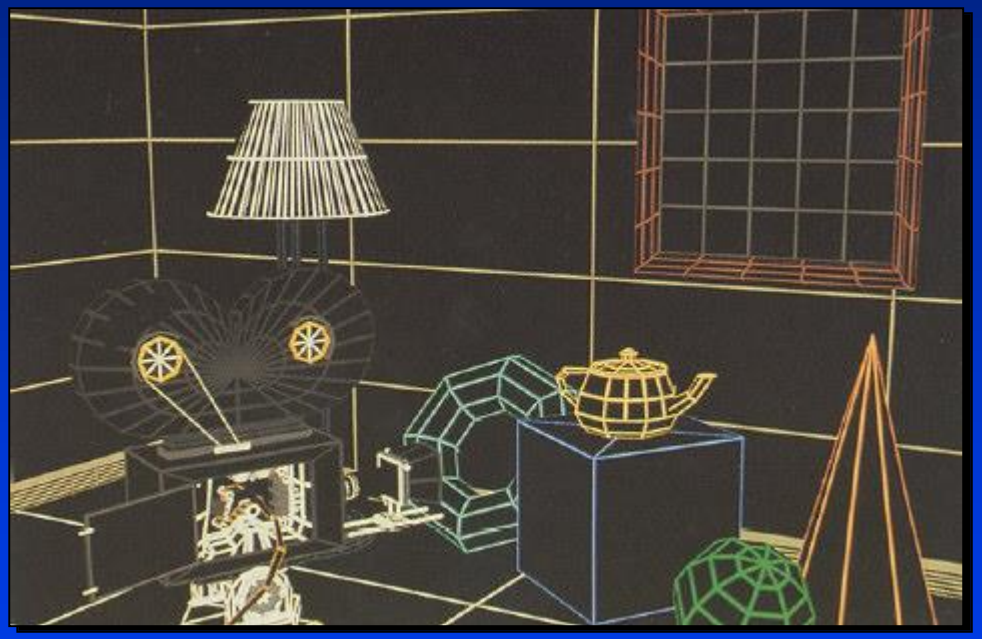

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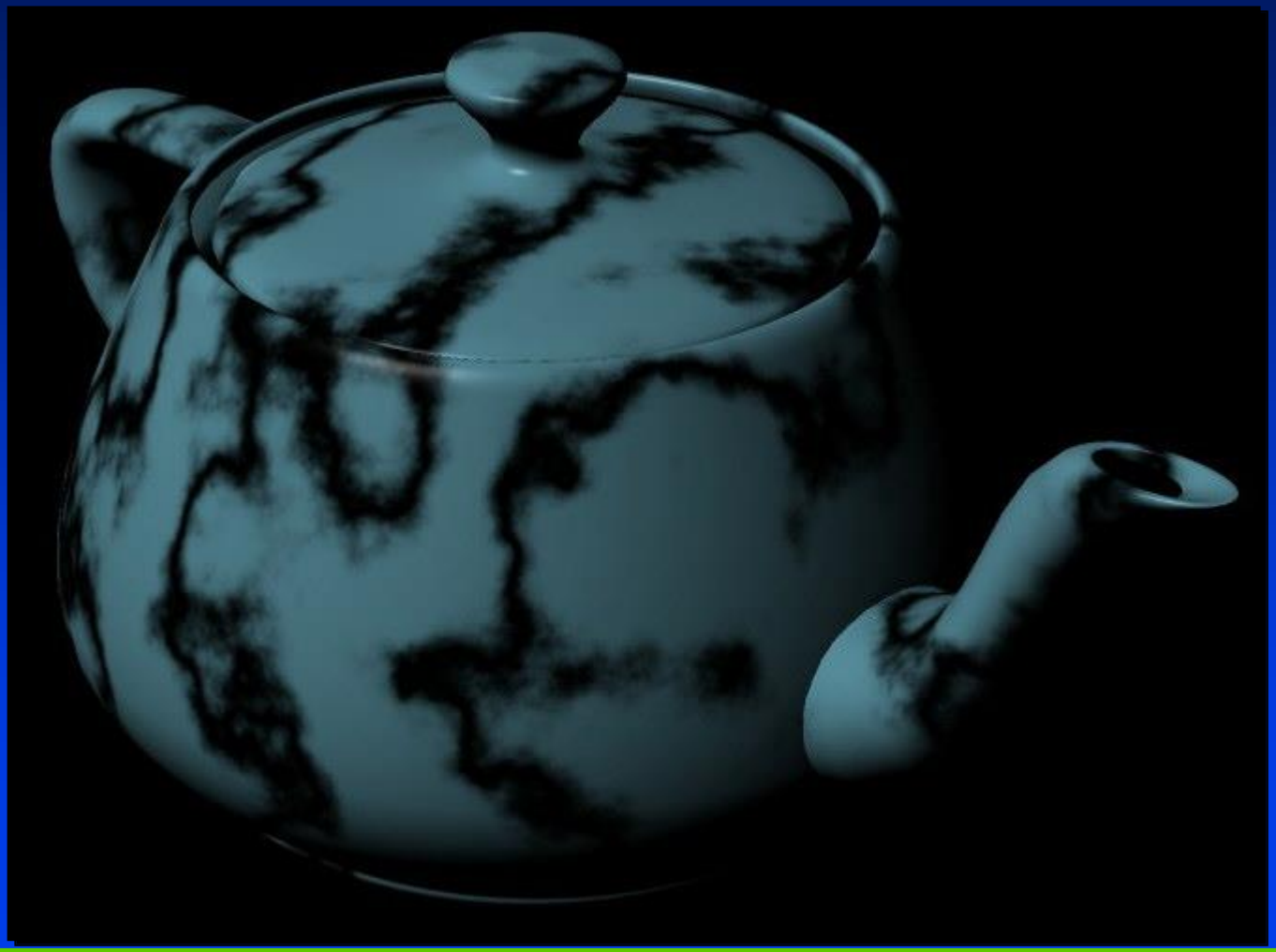
- Crow (1977) - anti-aliasing



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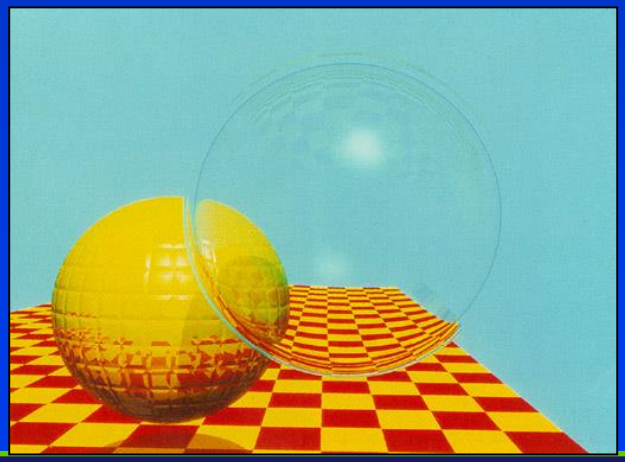

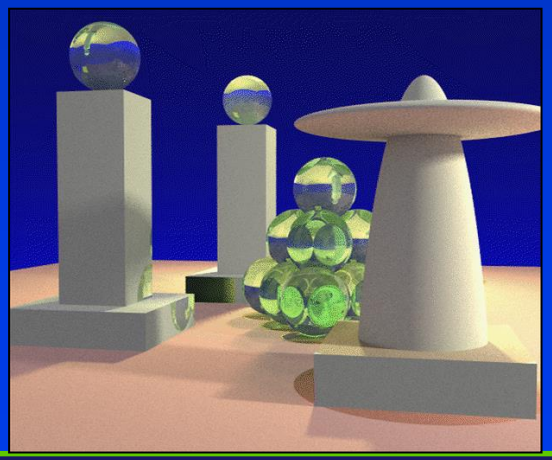

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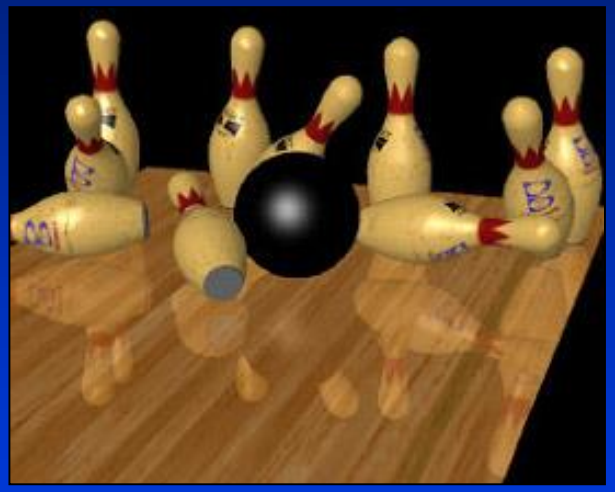
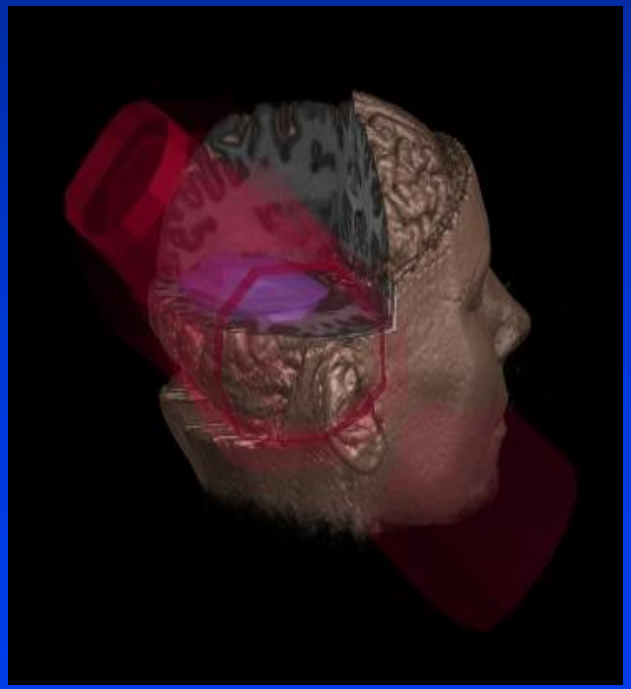
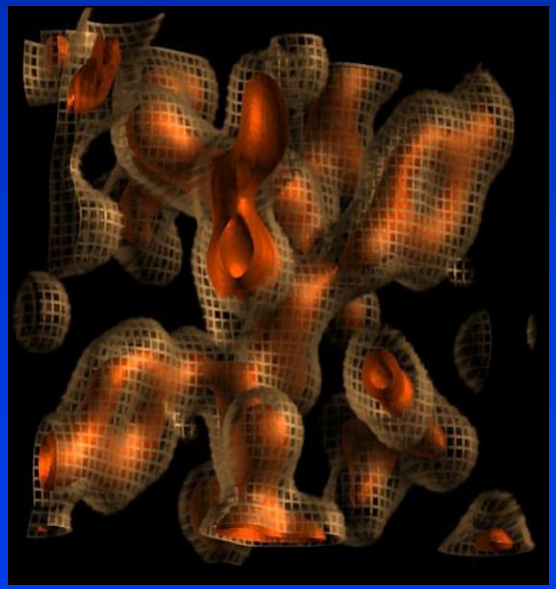
- Late 1980s - Photorealism
  - Cook (1984) - shade trees
  - Perlin (1985) - shading languages
  - Hanrahan and Lawson (1990) - RenderMan



- 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





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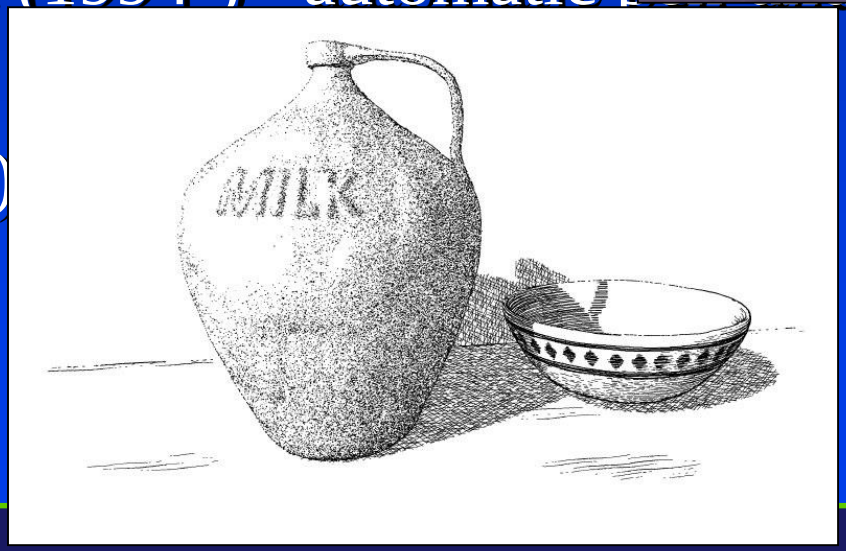


Photorealism

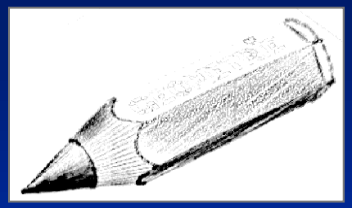
- **Driving force behind computer graphics for many years**
- **Quality of image is judged by how closely they resemble a photograph**
- **Images are rendered by running a physics-simulation which emulates the behavior of light inside the modeled scene**

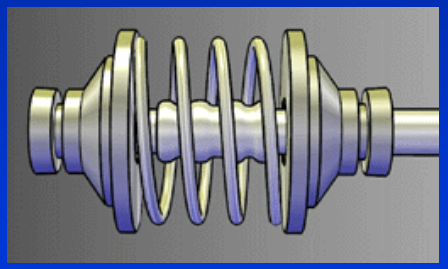
Effects needed for Photorealism

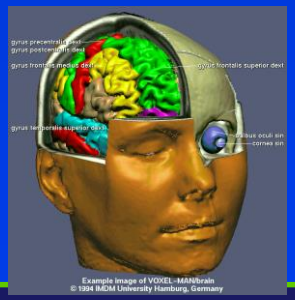
- **Shadows**
- **Reflections (Mirrors)**
- **Transparency**
- **Inter-reflections**
- **Detail (Textures etc.)**
- **Complex Illumination**
- **Realistic Materials**
- **And many more**

Non-Photorealistic Rendering (NPR)

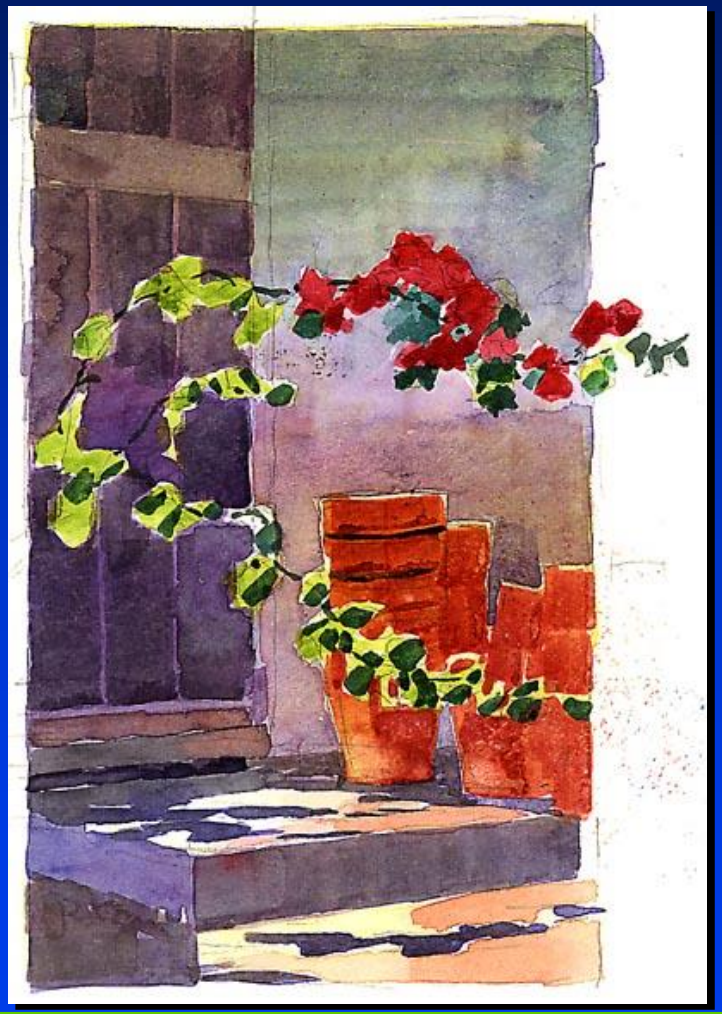
- **Images are judged by how effectively they communicate**
- **Involves stylization and communication, usually driven by human perception**
- **Knowledge and techniques long used by artists and illustrators**
- **Emphasis on specific features of a scene, expose subtle attributes, omit extraneous information**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

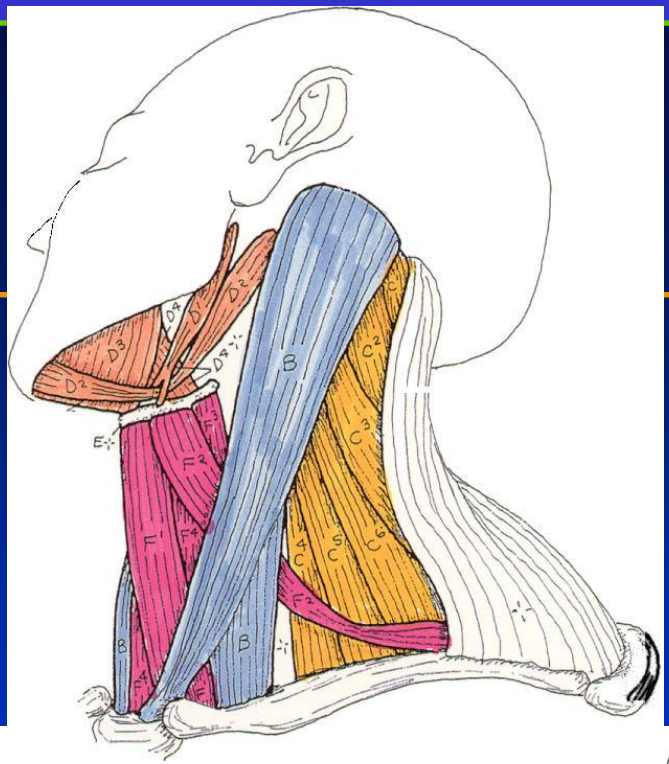


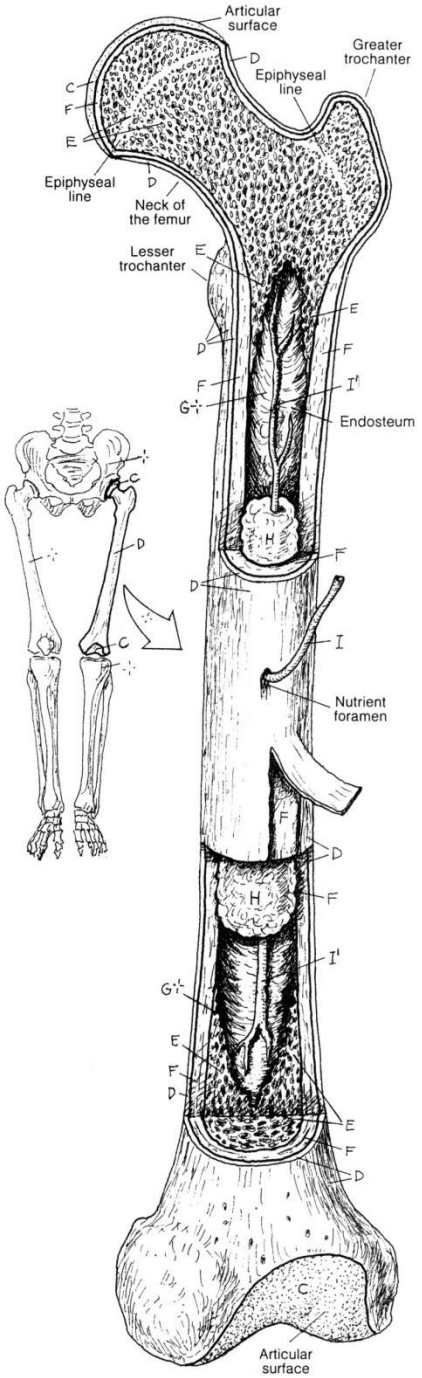


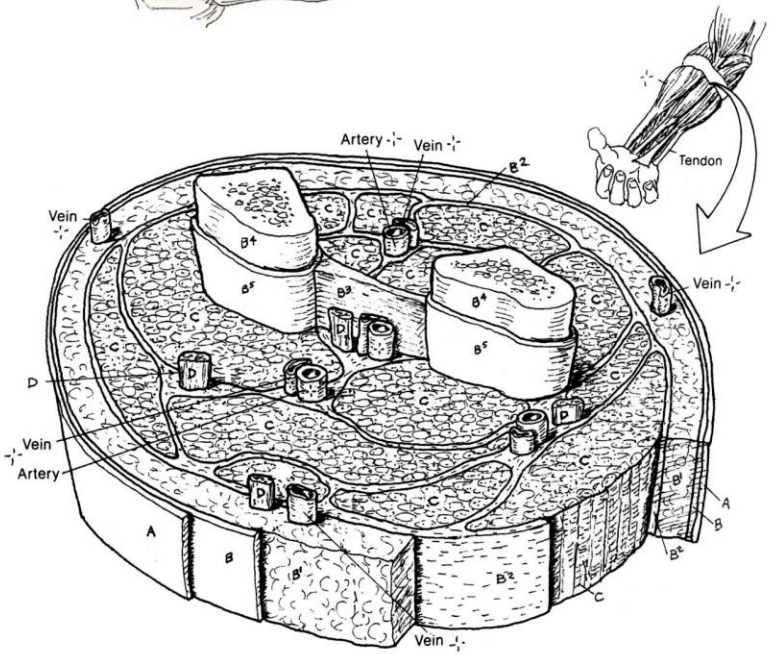

Example image of VOXEL-MAN/brain
© 1994 IMDM University Hamburg, Germany

What Dreams May Come
PB14 Final






Articular surface
Greater trochanter
Epiphyseal line
Epiphyseal line
Neck of the femur
Lesser trochanter
Endosteum
Nutrient foramen
Articular surface


Tendon
Artery
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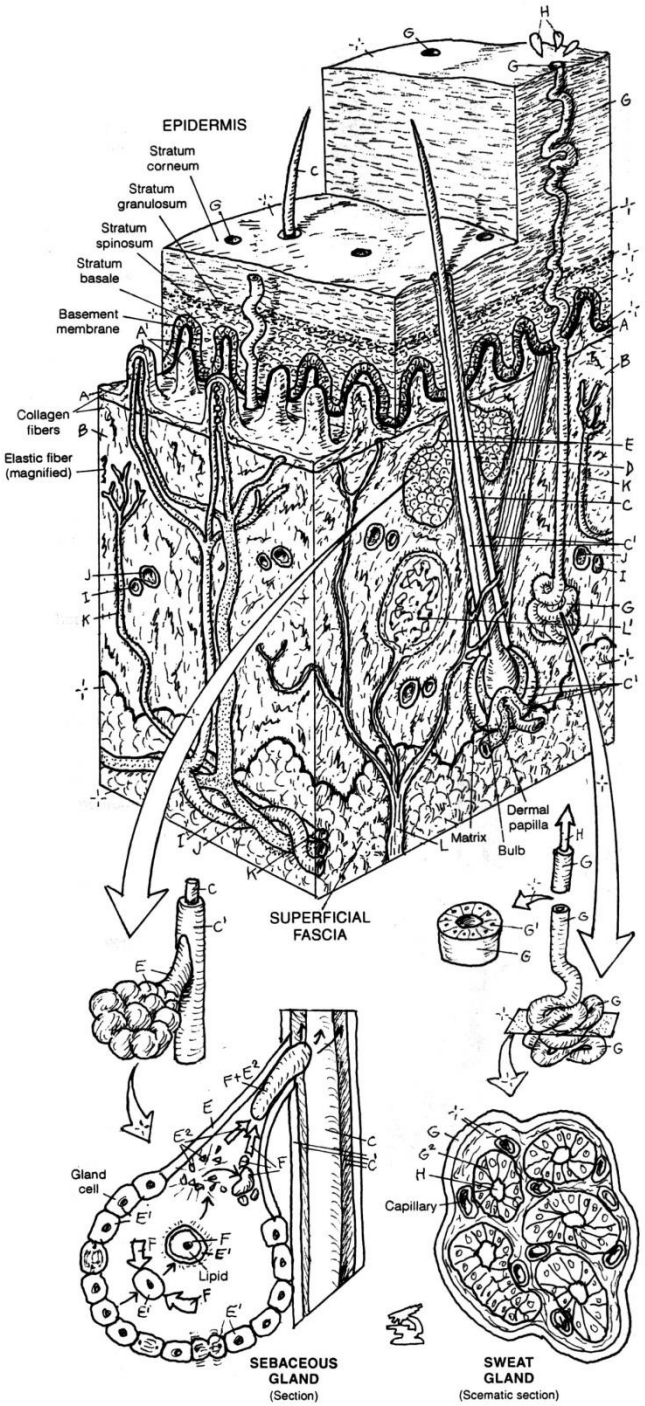
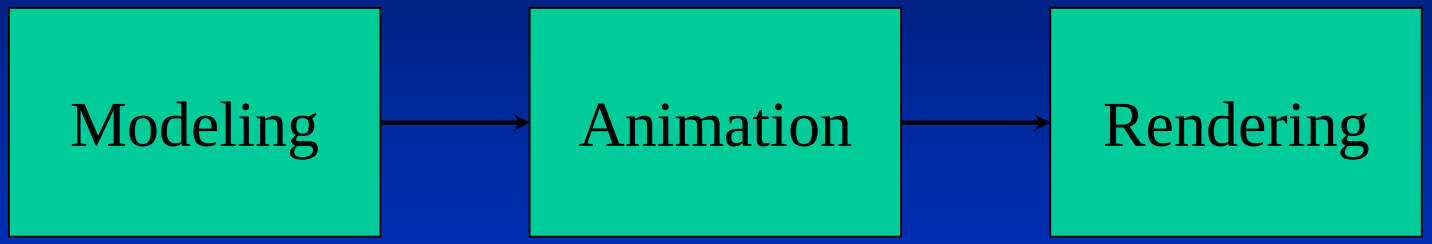

EPIDERMIS
Stratum corneum
Stratum granulosum
Stratum spinosum
Stratum basale
Basement membrane
Collagen fibers
Elastic fiber (magnified)
SUPERFICIAL FASCIA
Dermal papilla
Bulb
Matrix
Gland cell
Lipid
SEBACEOUS GLAND (Section)
Capillary
SWEAT GLAND (Scematic section)

The Graphics Pipeline



Modeling

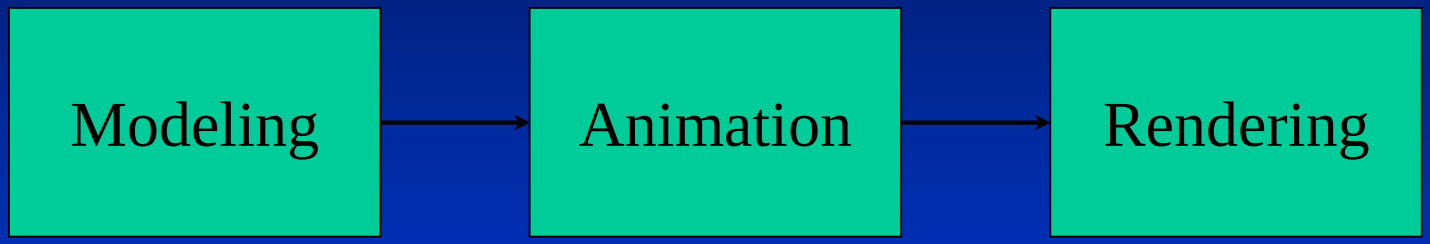
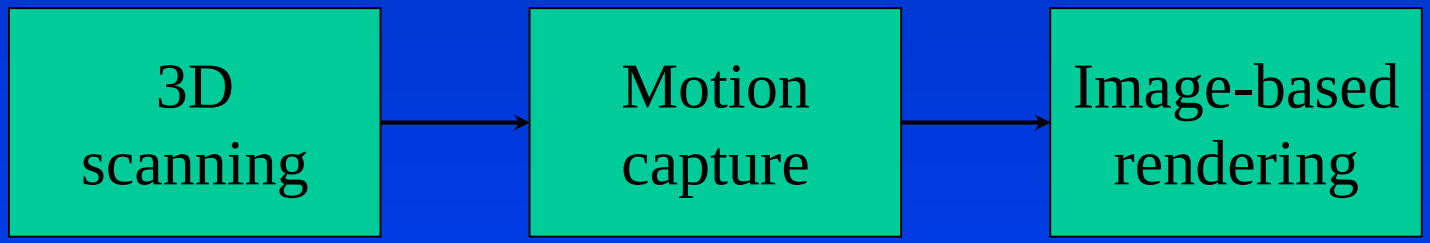
- Polygons
- Constructive solid geometry
- Parametric surfaces
- Implicit surfaces
- Subdivision surfaces
- Particle systems
- Volumes

Animation

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

The Graphics Pipeline

The traditional pipeline



The new pipeline?