

# Introduction to Computer Graphics



Overview

# Goals of the course

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- ▶ **Systems:** Write 3D graphics programs (real-time, interactive, in WebGL)
- ▶ **Theory:** Mathematical aspects and algorithms underlying modern 3D graphics systems. Physical illumination models
- ▶ **Applications:** A bit of Blender and Unity 3D modeling and animation.



# What is Computer Graphics?

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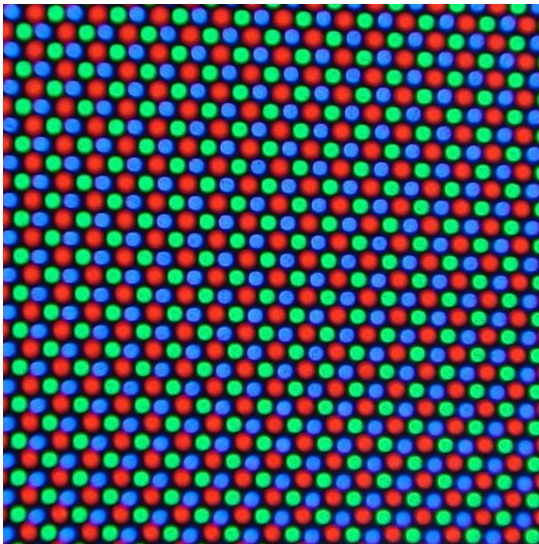
- ▶ Making, manipulating and storing of geometry objects (MODELING)
- ▶ Displaying objects (scenes) as images (RENDERING)
- ▶ Additionally:
  - ▶ Using various display hardware
  - ▶ Image processing
  - ▶ Other: devices for human-computer communication,...



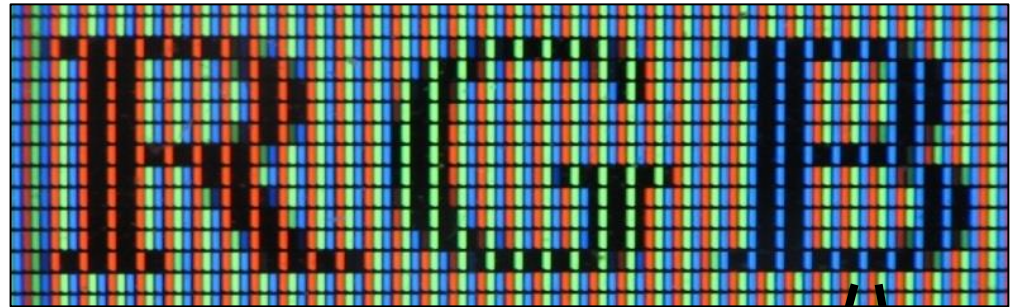
# Computer Graphics in a nutshell

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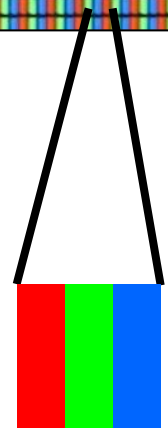
## ► What we see on a display



Close-up of a CRT screen



Close-up of an LCD screen



## ► 2D raster graphics





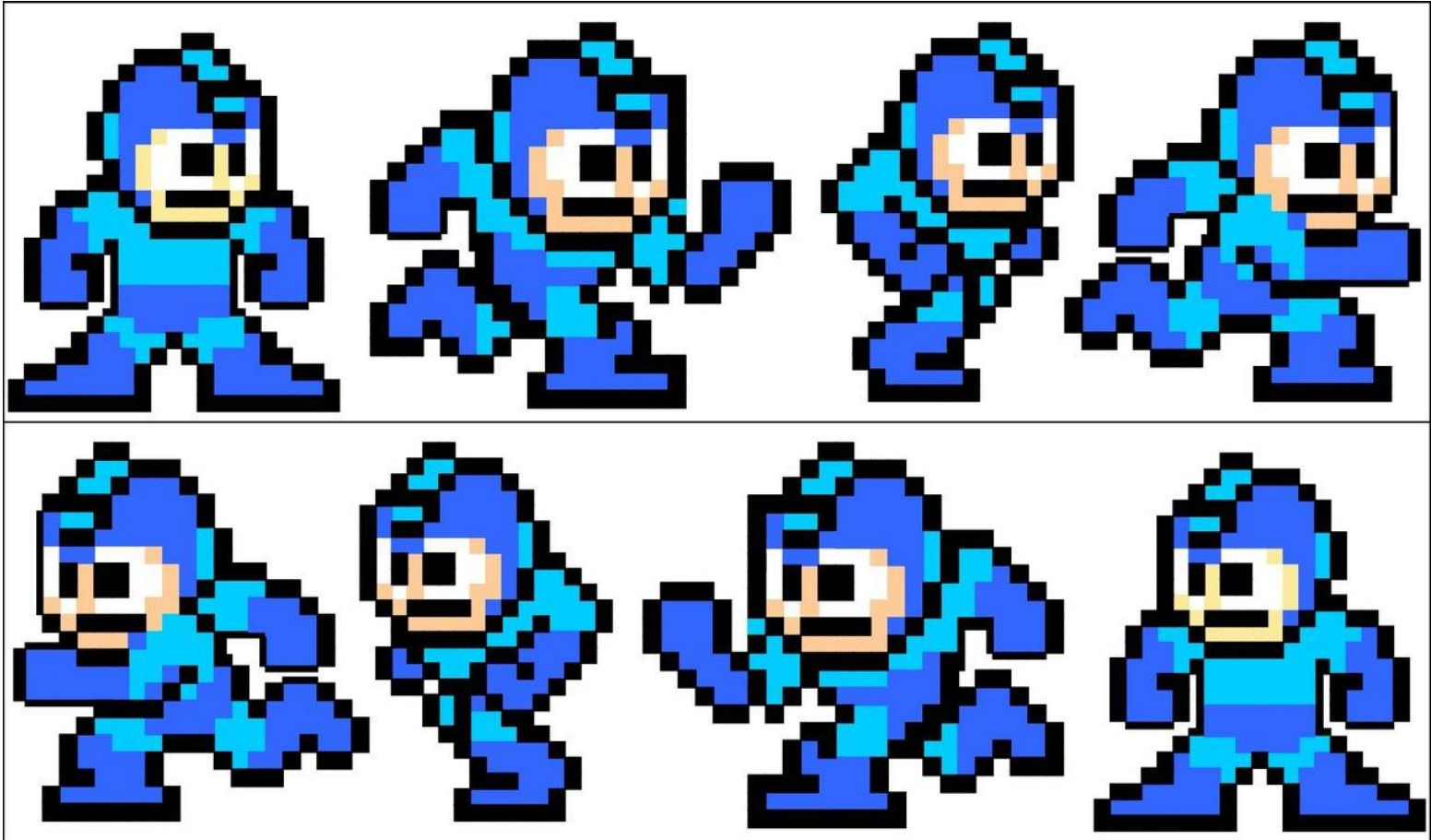
# Raster objects





# Raster objects

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# 3D vector graphics

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- ▶ Based on analytical geometry
- ▶ Coordinate system
- ▶ Basic geometry elements:
  - ▶ Points
  - ▶ Intervals
  - ▶ Triangles
- ▶ Used in objects as: vertices, edges, walls



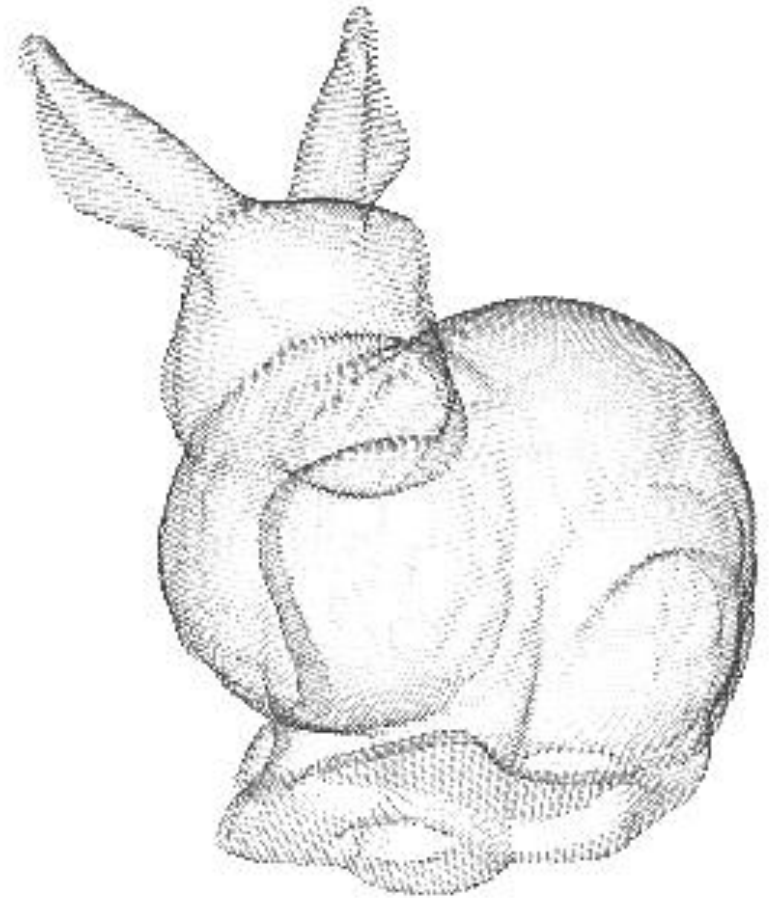


# Vertices

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We can build geometry objects using vertices only...

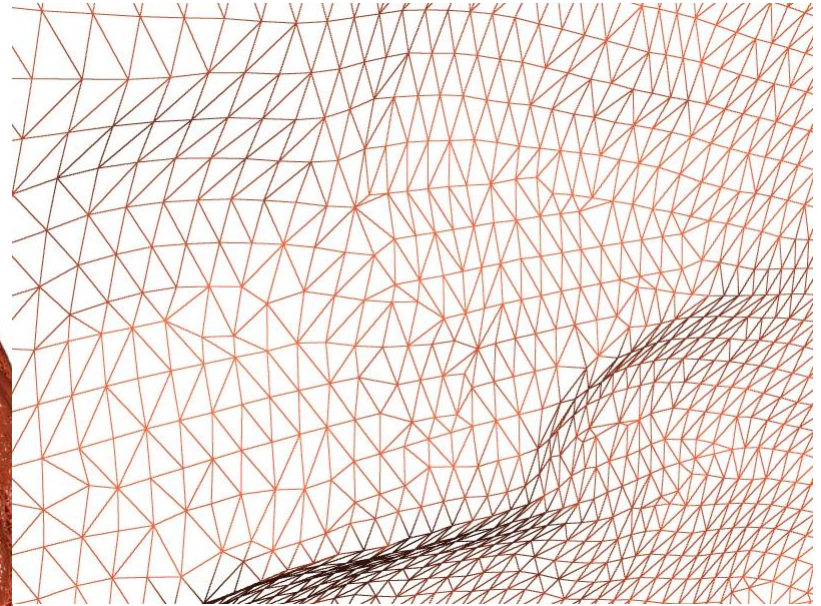
Sometimes useful, but rare



# Mesh

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- ▶ Using mesh of triangles is much more common



# Graphics pipeline (simplified)

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# 3D Graphics Pipeline (very much simplified) with animation effect added

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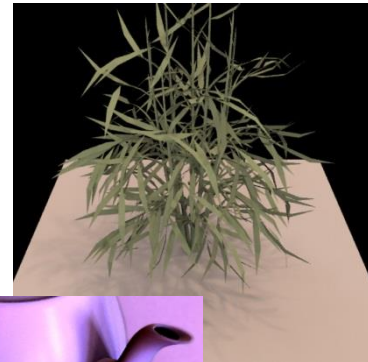
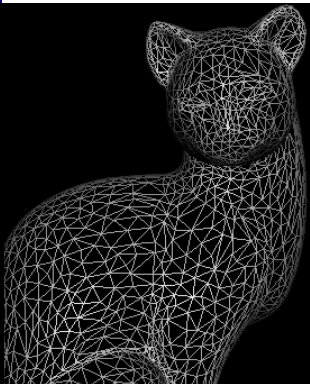
Modeling



Animation

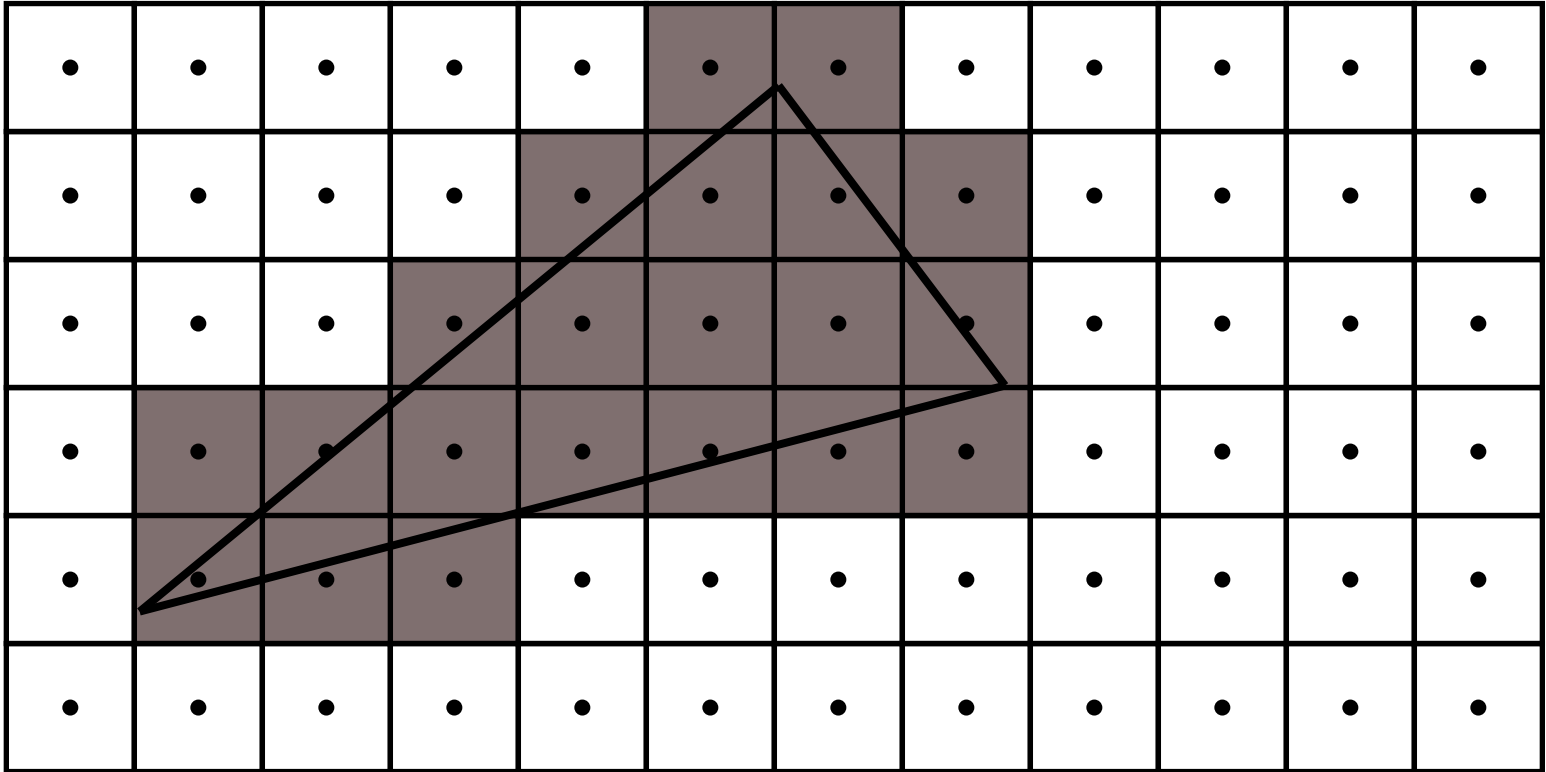


Rendering



# Rasterization

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# Why Study 3D Computer Graphics?

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- ▶ Applications (next slides)
- ▶ Fundamental Intellectual Challenges
  - ▶ Create and interact with realistic virtual world
  - ▶ Requires understanding of all aspects of physical world
  - ▶ New computing methods, displays, technologies
- ▶ Technical Challenges
  - ▶ Math of (perspective) projections, curves, surfaces
  - ▶ Physics of lighting and shading
  - ▶ 3D graphics software programming and hardware



# Entertainment: Movies

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Movies: Brave, Pixar 2012

# Entertainment: Video Games

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Games: Halo 3, Bungie 2007



# Photorealistic Scenes: Lighting Simulation

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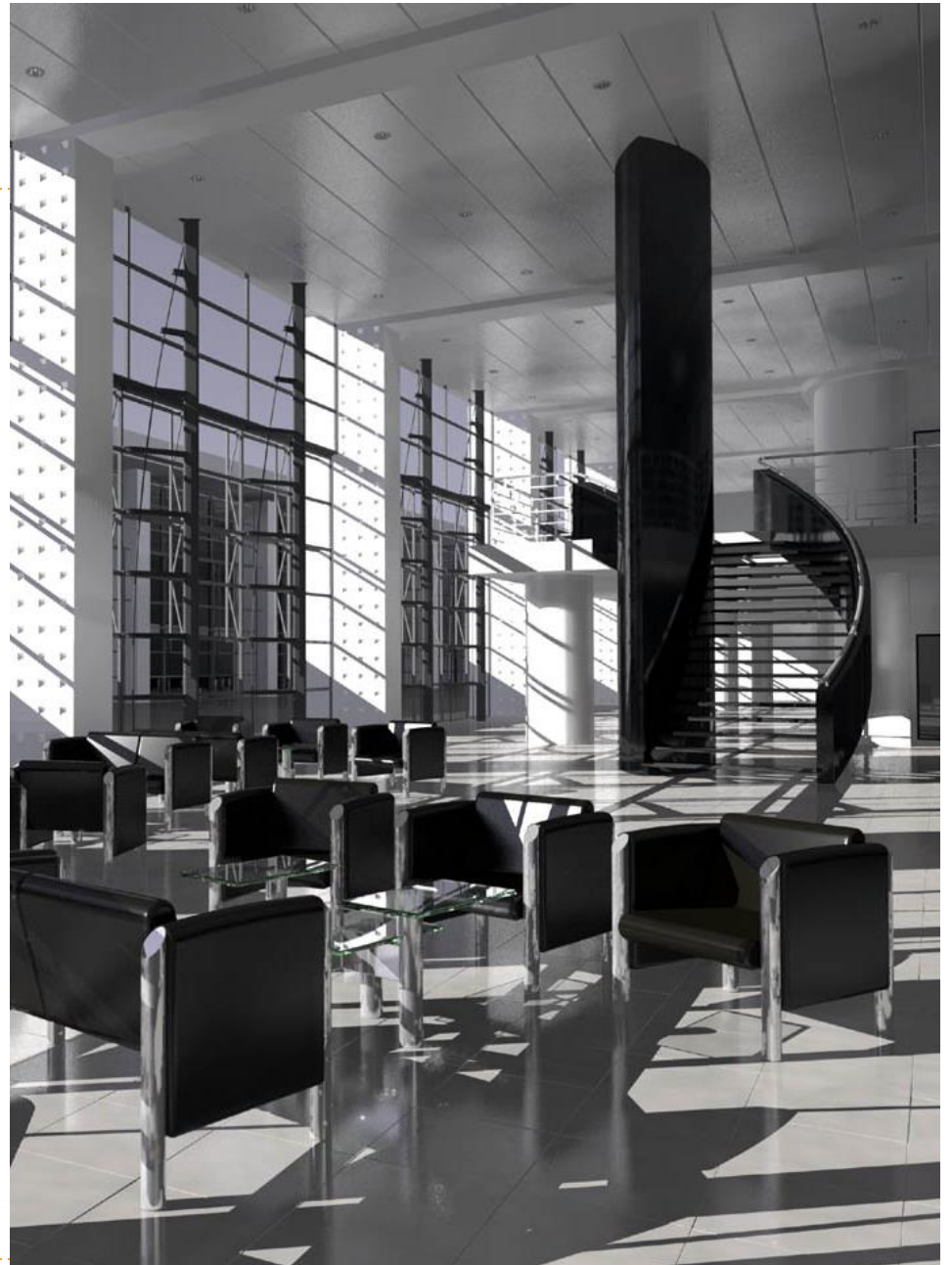


Interior Design

Automobile Visualization



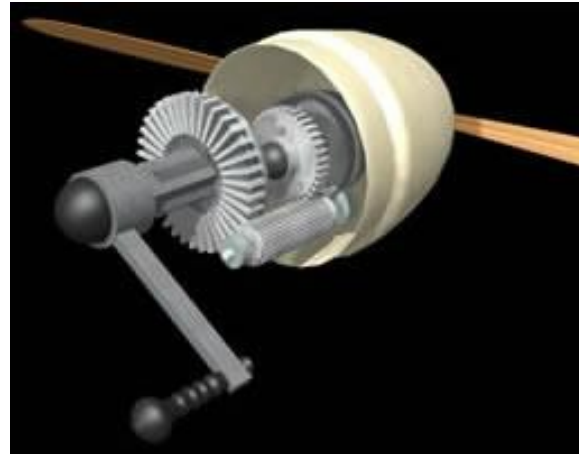
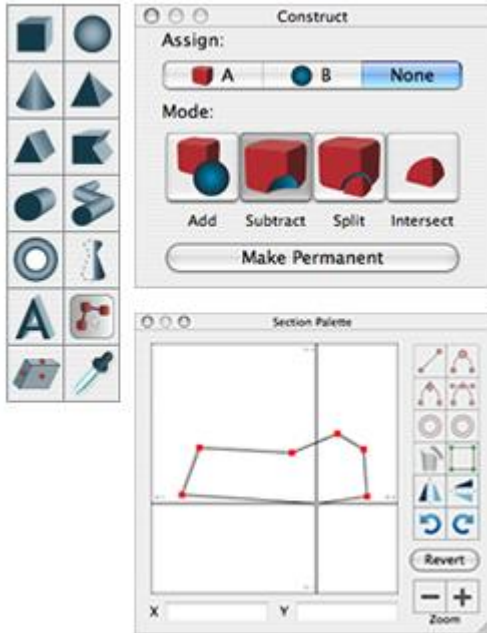
# Architecture





# Computer Aided Design

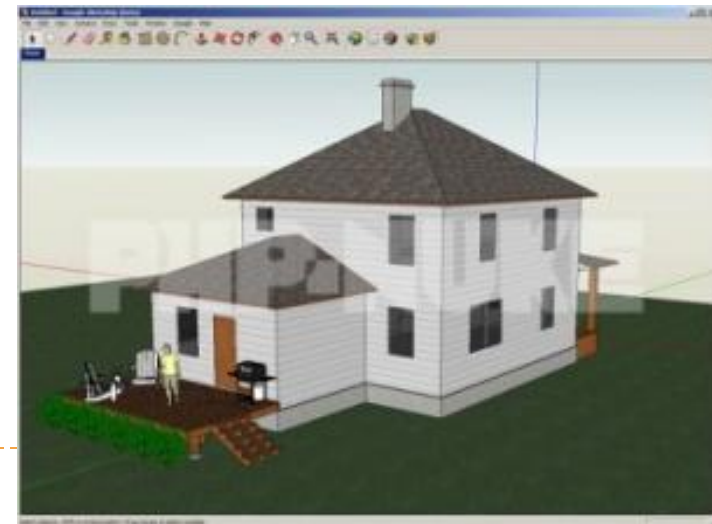
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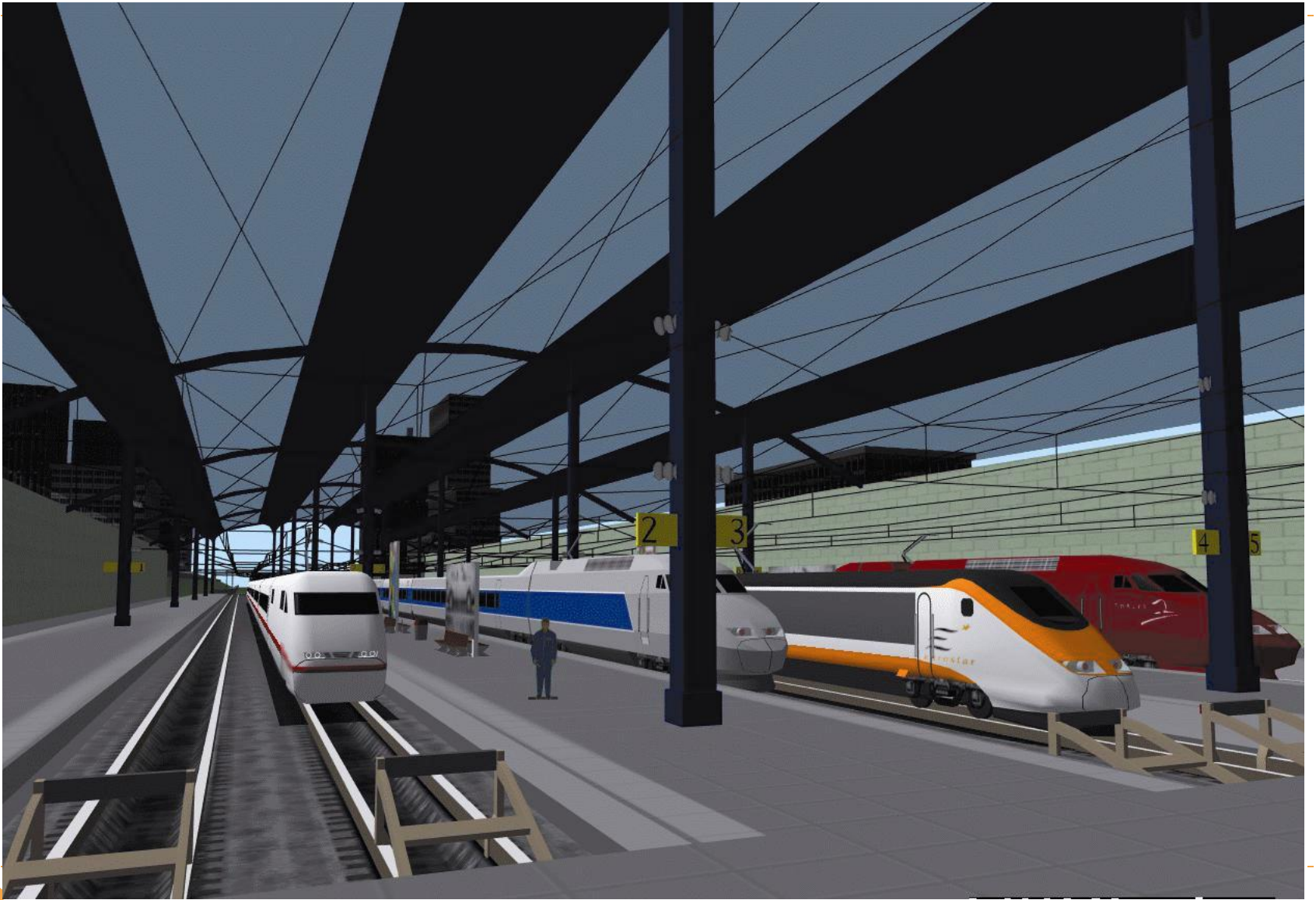
Interiors Professional

Mechanical CAD  
Architectural CAD  
Electronics CAD  
Casual Users

Google Sketchup

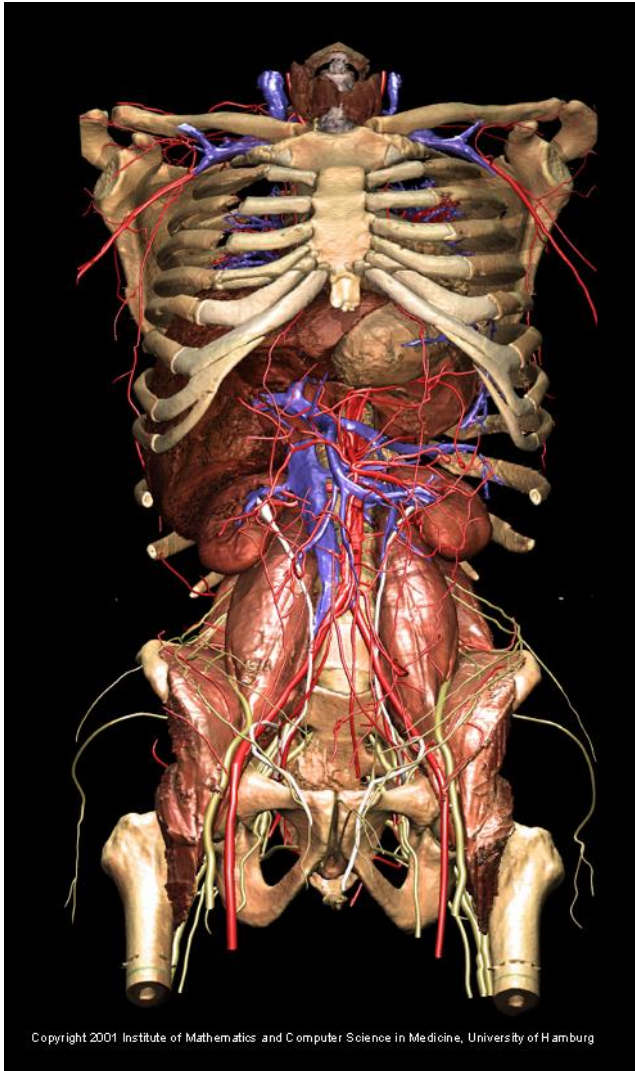


# CAD



# Visualization: Science and Medicine

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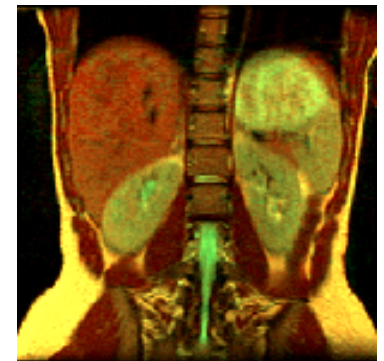
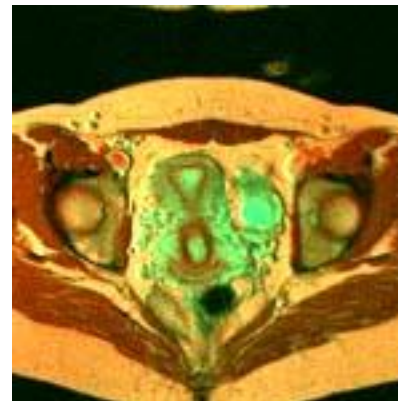
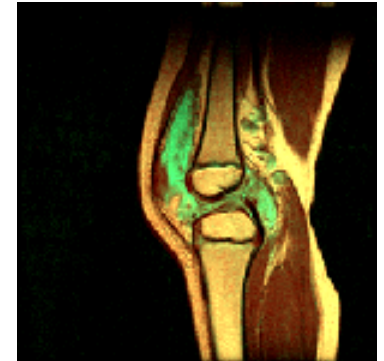
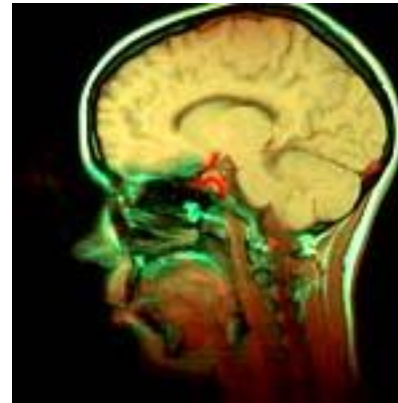
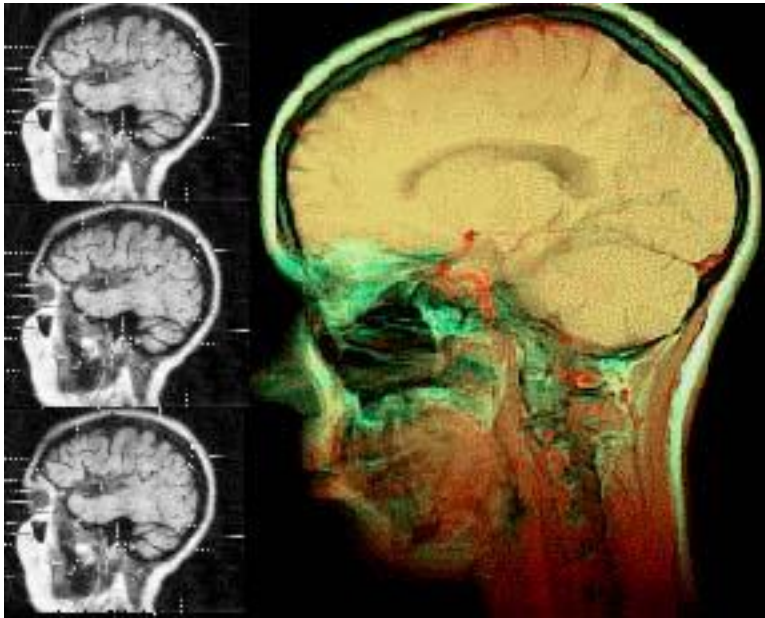


Visible Human Project: University of Hamburg



# Medical Visualization

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MRI

H. Keith Brown, Ph.D. [Brenau University](http://www.colormri.com/)

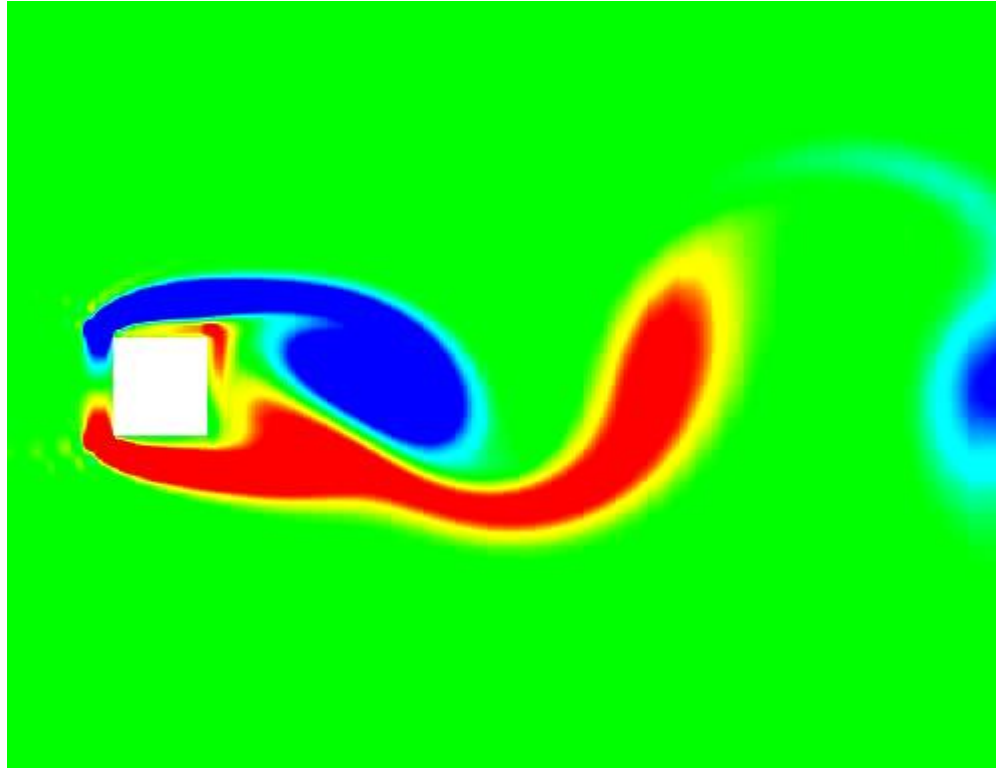
<http://www.colormri.com/>

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# Scientific visualization

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Vorticity visualization  $Re=200$ .

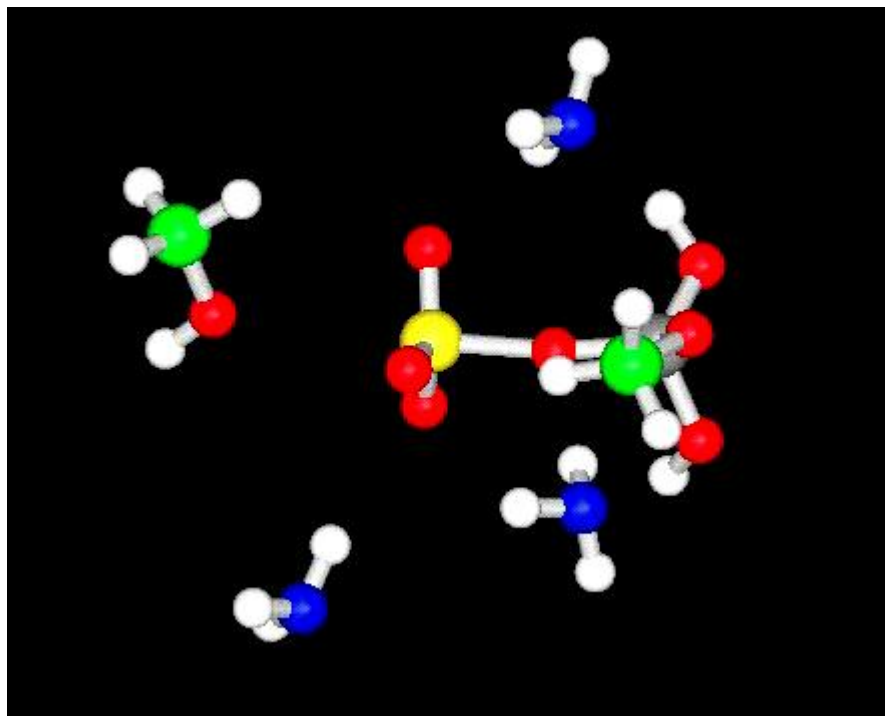
This movie appears courtesy of J. Wissink Department of Mathematics, University of Groningen.





# Scientific visualization

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Chemical reaction

Lee Bartolotti from North Carolina Supercomputing Center

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# Virtual Reality

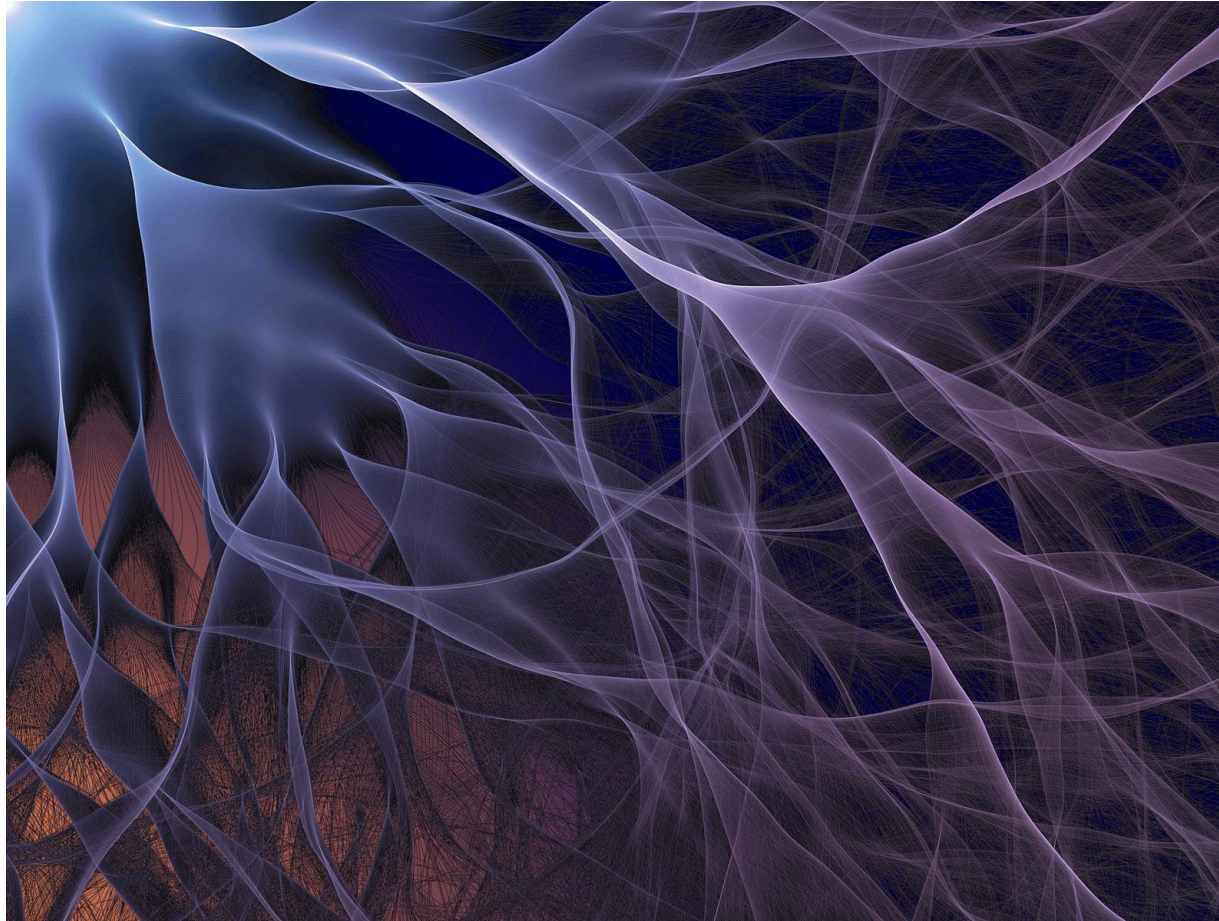
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- ▶ VR for design and entertainment
- ▶ Simulators: Surgical, Flight, Driving, Spacecraft



# Art

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Transport VI ©2000

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Eric Heller

# Digital Visual Media

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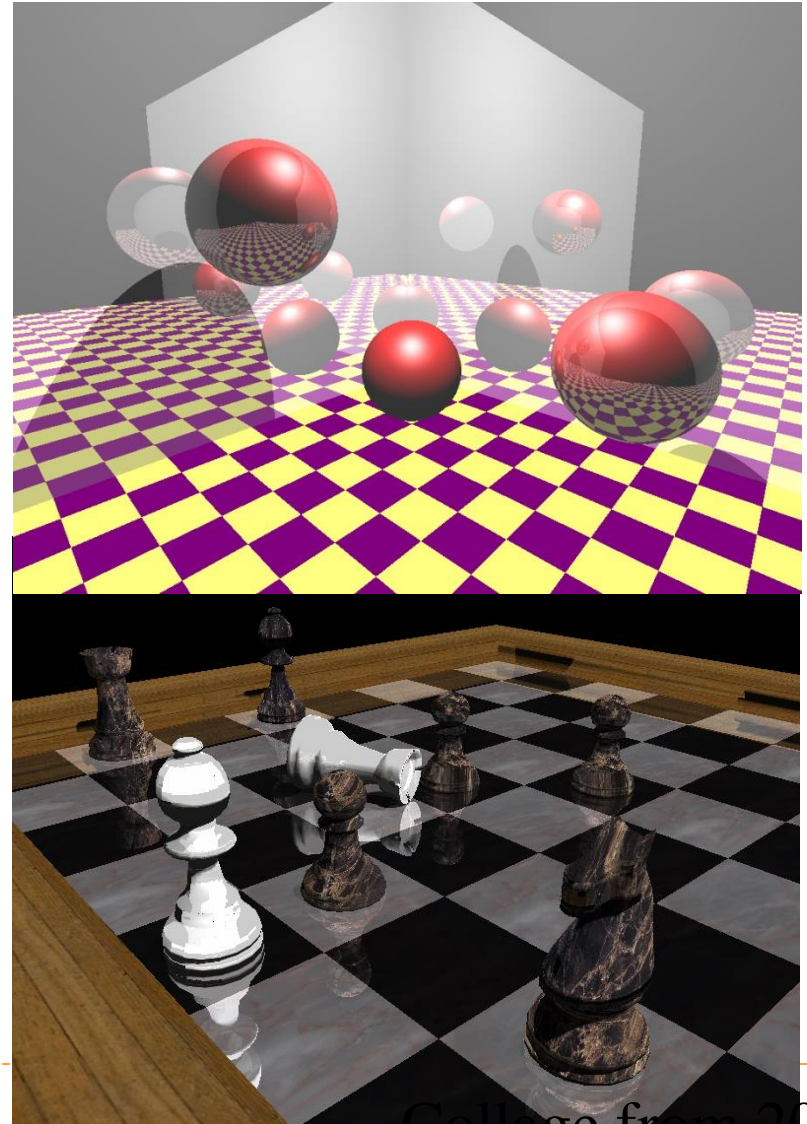
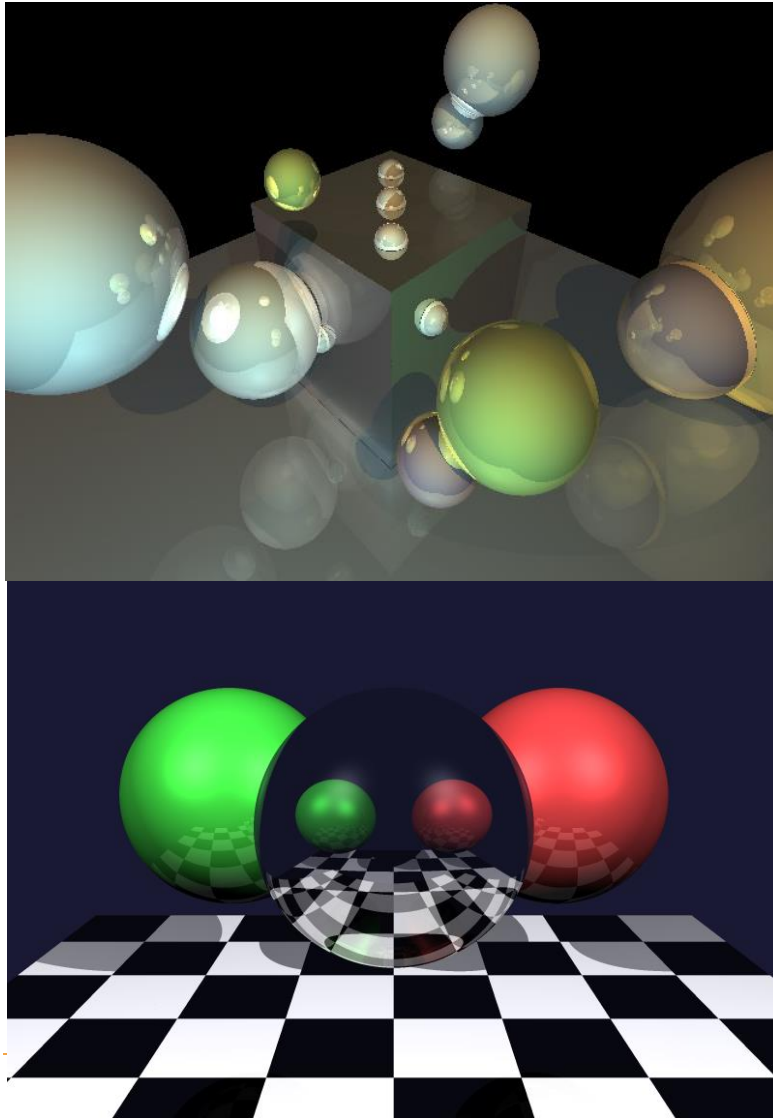
- ▶ From text to images to video (to 3D?)
- ▶ Image and video processing and photography
- ▶ Multimedia computers, tablets, phones
- ▶ Flickr, YouTube, WebGL
- ▶ Real, Virtual Worlds (Google Earth, Second Life)
- ▶ Electronic publishing
- ▶ Online gaming
- ▶ 3D printers and fabrication





# Image Synthesis Examples

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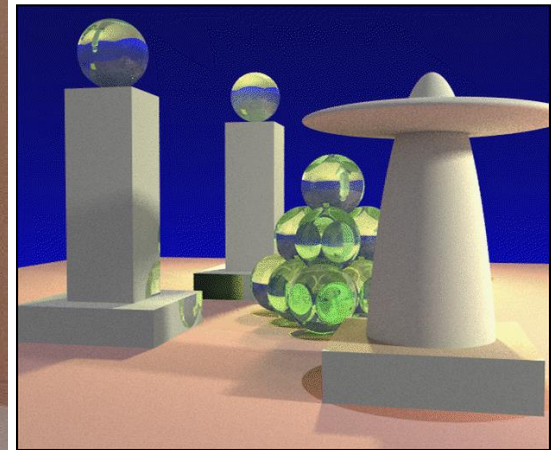
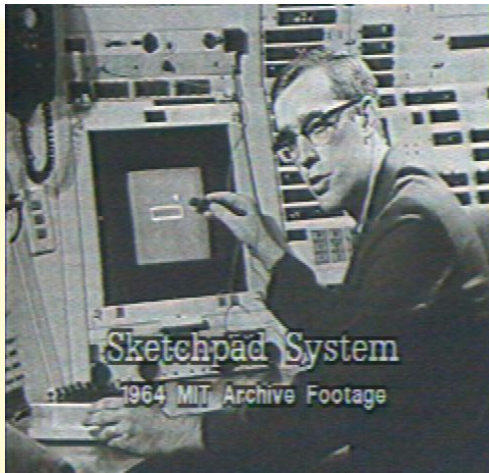
Collage from 2007



# Brief History of CG

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- ▶ Brief history of significant developments in field
- ▶ End with a video showcasing graphics

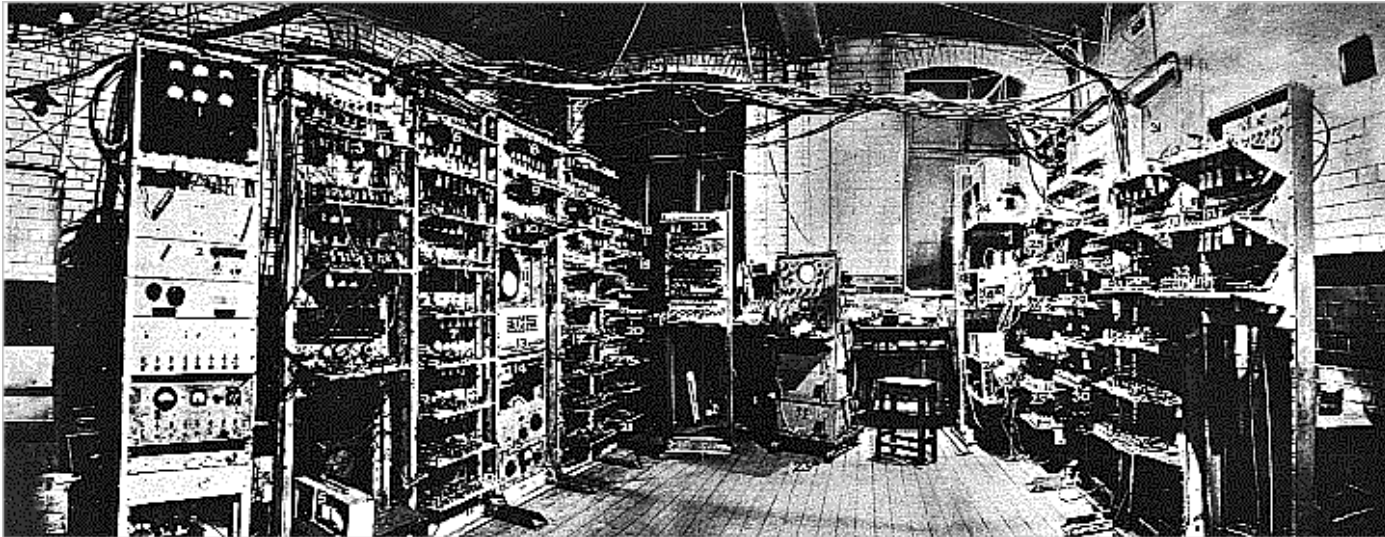


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▶ The term Computer Graphics was coined by William Fetter of Boeing in 1960  
First graphic system in mid 1950s USAF SAGE radar data (developed MIT)

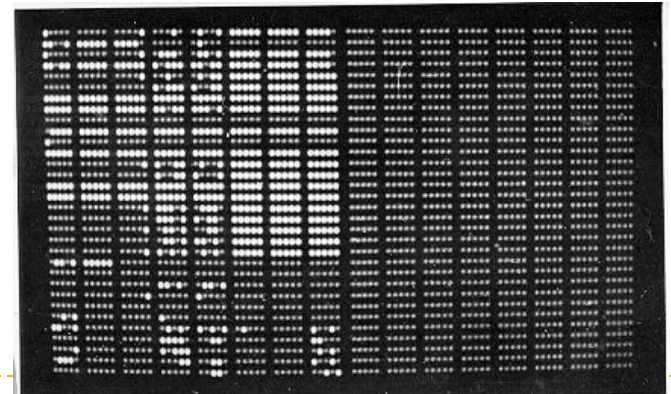
# How far we've come: TEXT

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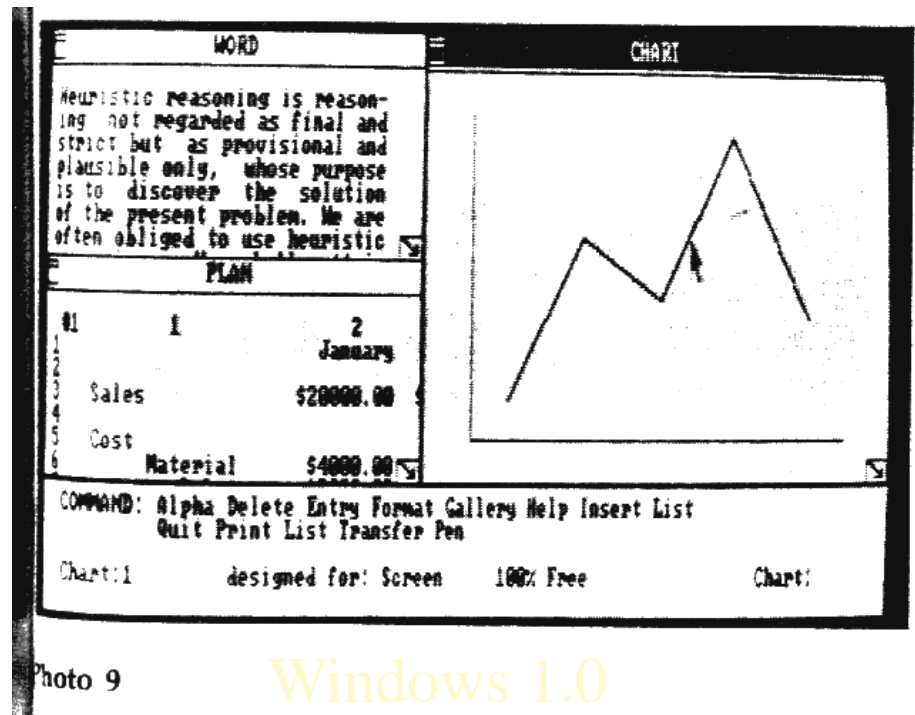
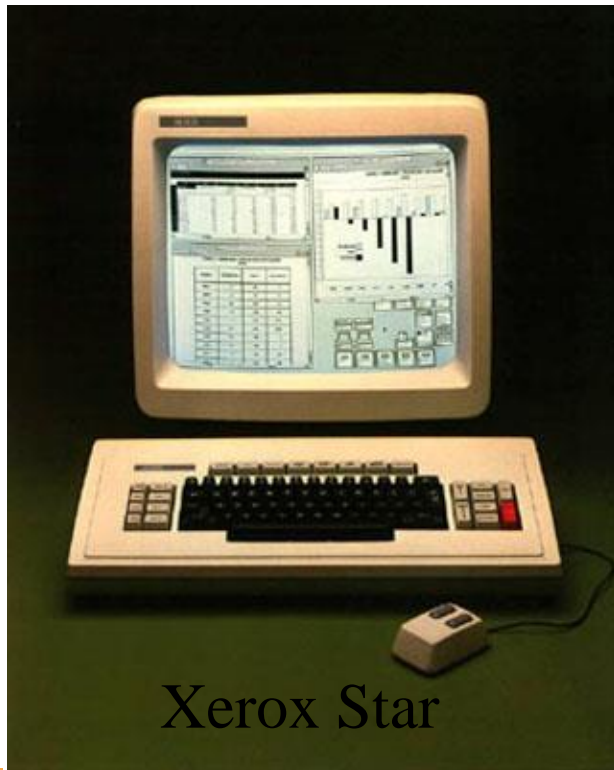
Manchester Mark I

Display →



# From Text to GUIs

- ▶ Invented at PARC (Palo Alto Research Center), formerly Xerox PARC, circa 1975. Used in the Apple Macintosh, and now prevalent everywhere.





# Drawing: Sketchpad (1963)

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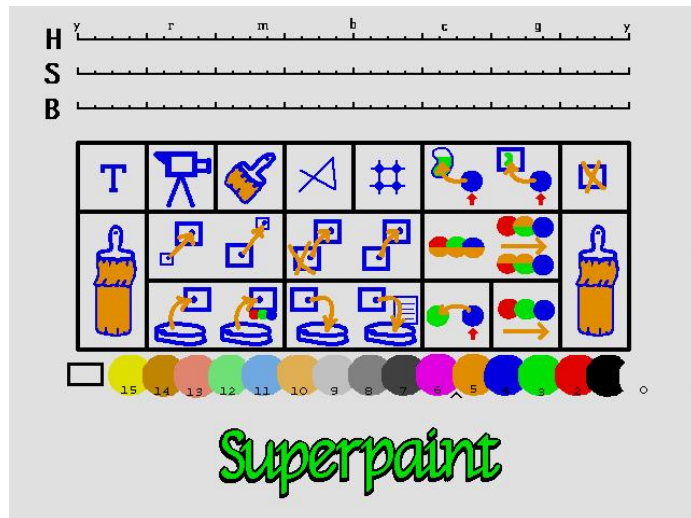
- ▶ Sketchpad (Sutherland, MIT 1963)
- ▶ First interactive graphics system
- ▶ Many of concepts for drawing in current systems
  - ▶ Pop up menus
  - ▶ Constraint-based drawing
  - ▶ Hierarchical Modeling



# Paint Systems

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



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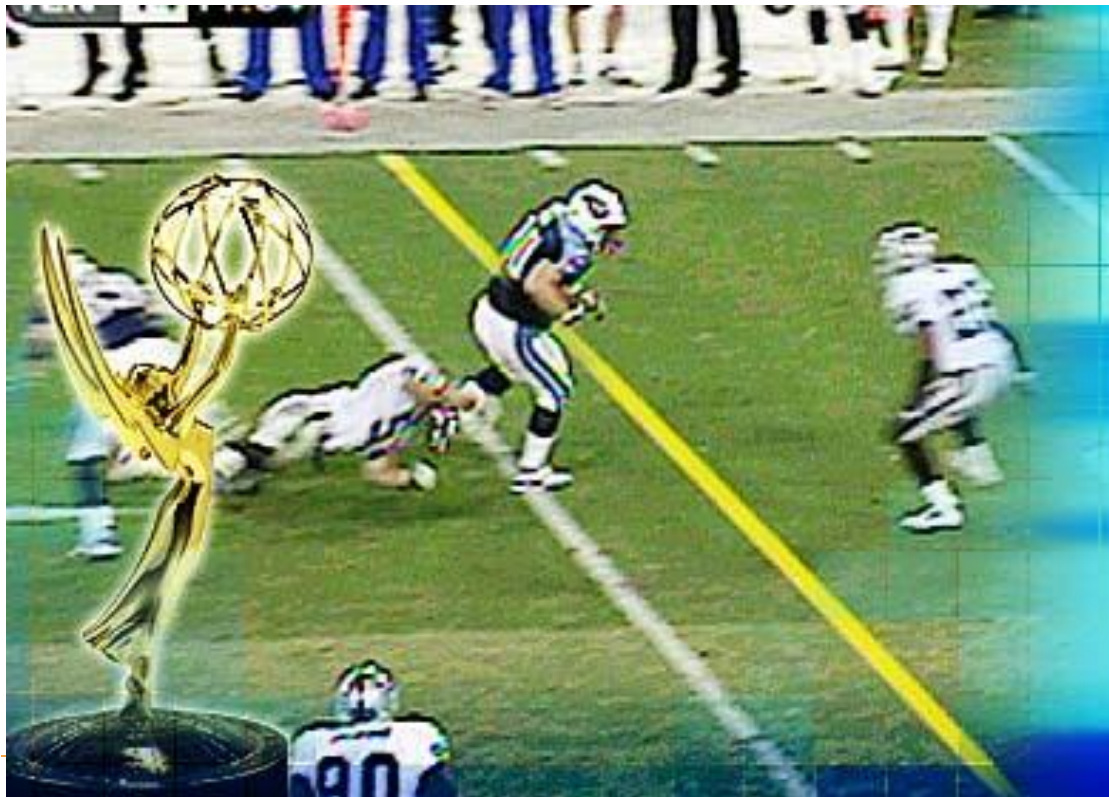




# Image Processing

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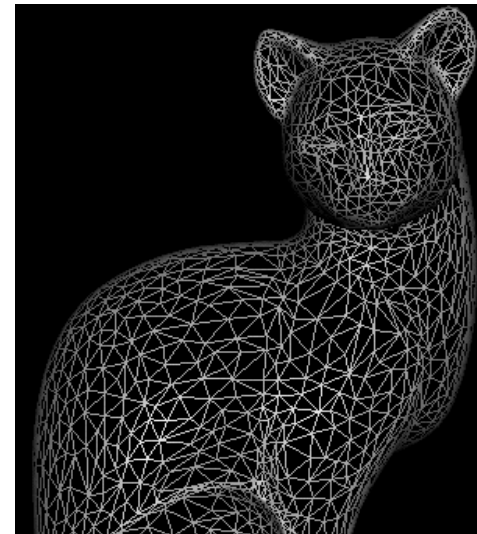
- ▶ Digitally alter images, crop, scale, composite
- ▶ Add or remove objects
- ▶ Sports broadcasts for TV (combine 2D and 3D processing)



# Modeling

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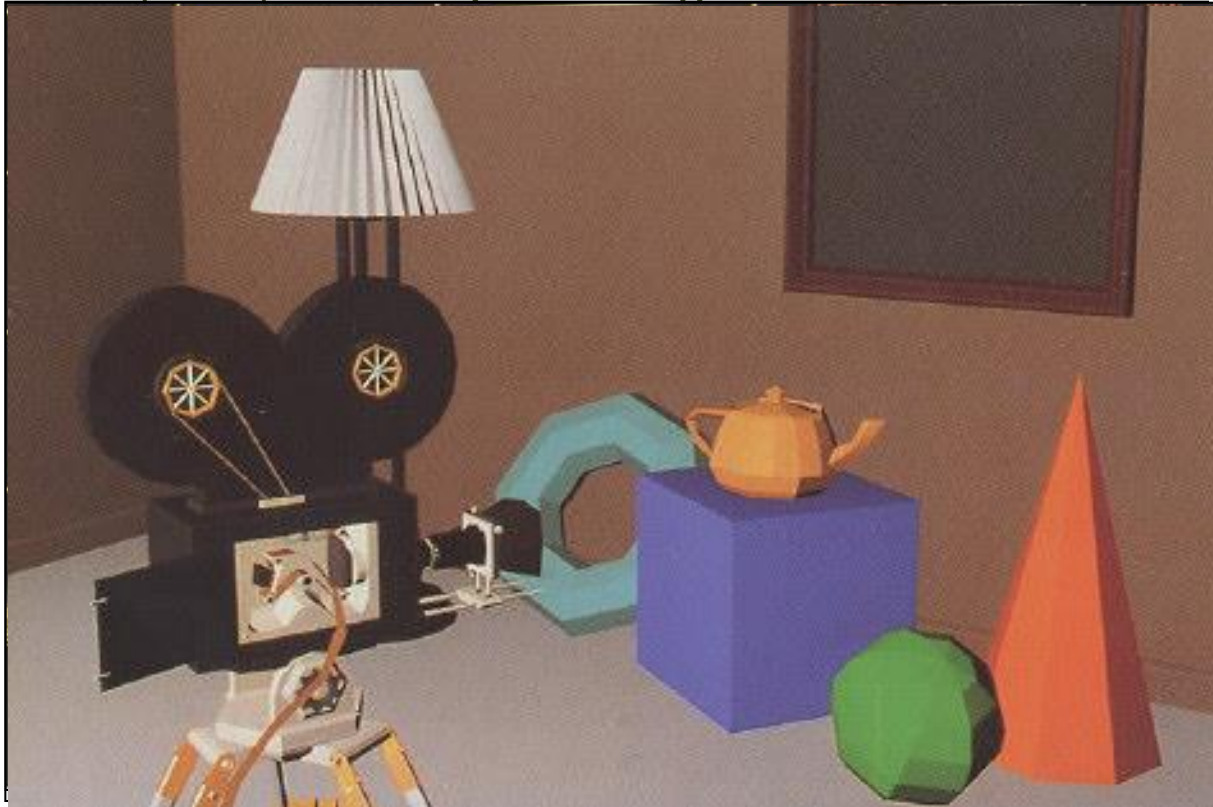
- ▶ Spline curves, surfaces: 70<sup>s</sup> – 80<sup>s</sup>
- ▶ Utah teapot: Famous 3D model
- ▶ More recently: Triangle meshes often acquired from real objects



# Rendering: 1960s (visibility)

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



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Images from FvDFH, Pixar's Shutterbug  
Slide ideas for history of Rendering courtesy Marc Levoy

# Rendering: 1970s (lighting)

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## 1970s - raster graphics

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



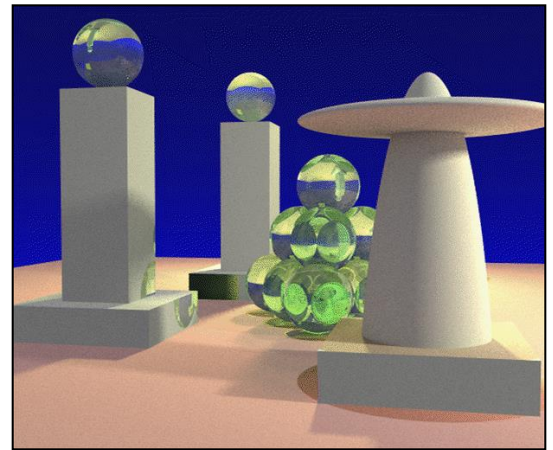
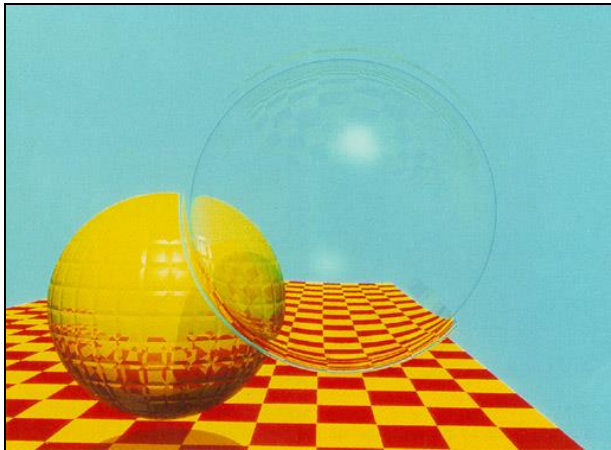


# Rendering (1980s, 90s: Global Illumination)

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## early 1980s - global illumination

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



# History of Computer Animation

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- ▶ 10 min clip from video on history of animation
- ▶ <http://www.youtube.com/watch?v=LzZwiLUVaKg>

