

# Computer Graphics 2019

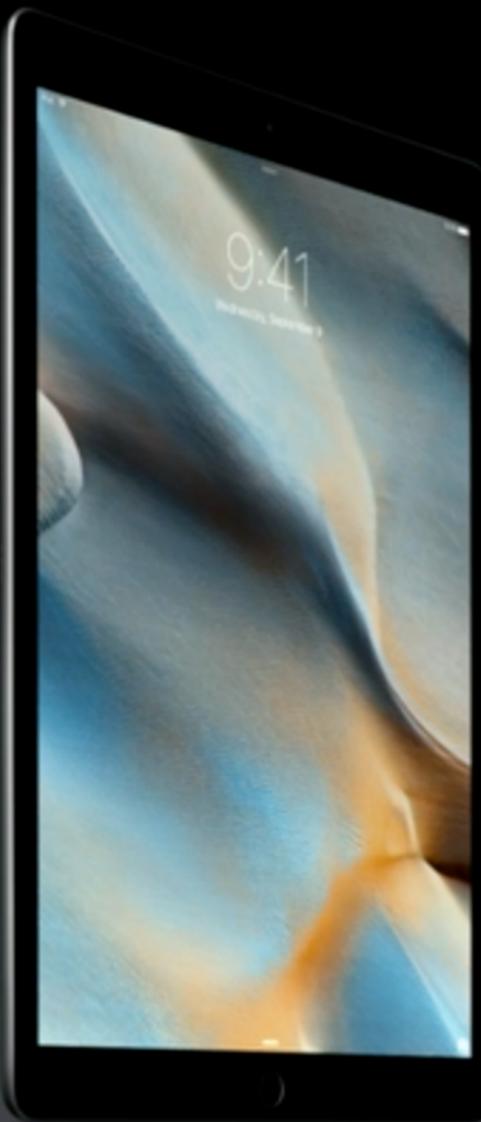
## 1. INTRODUCTION

Hongxin Zhang

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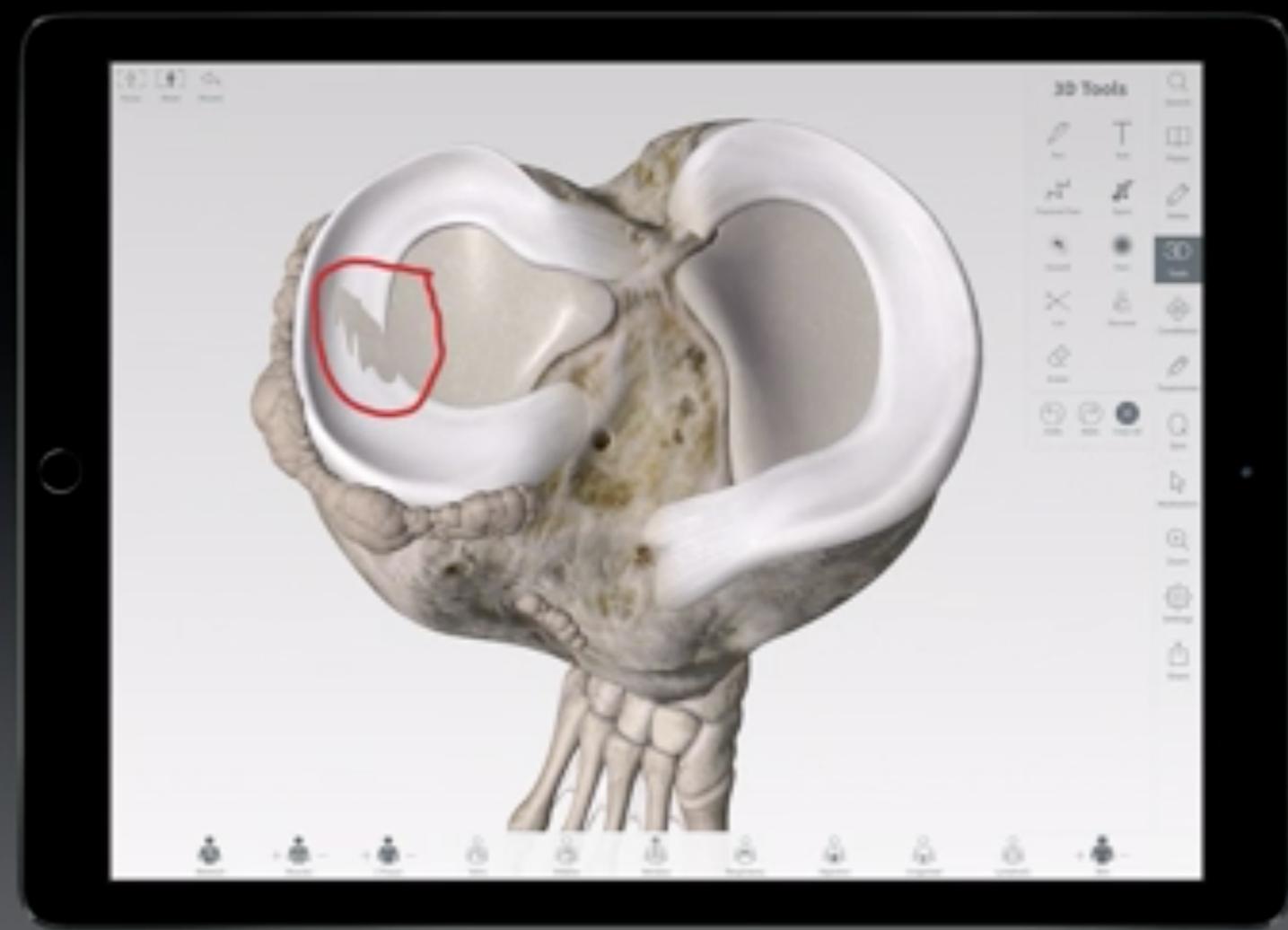
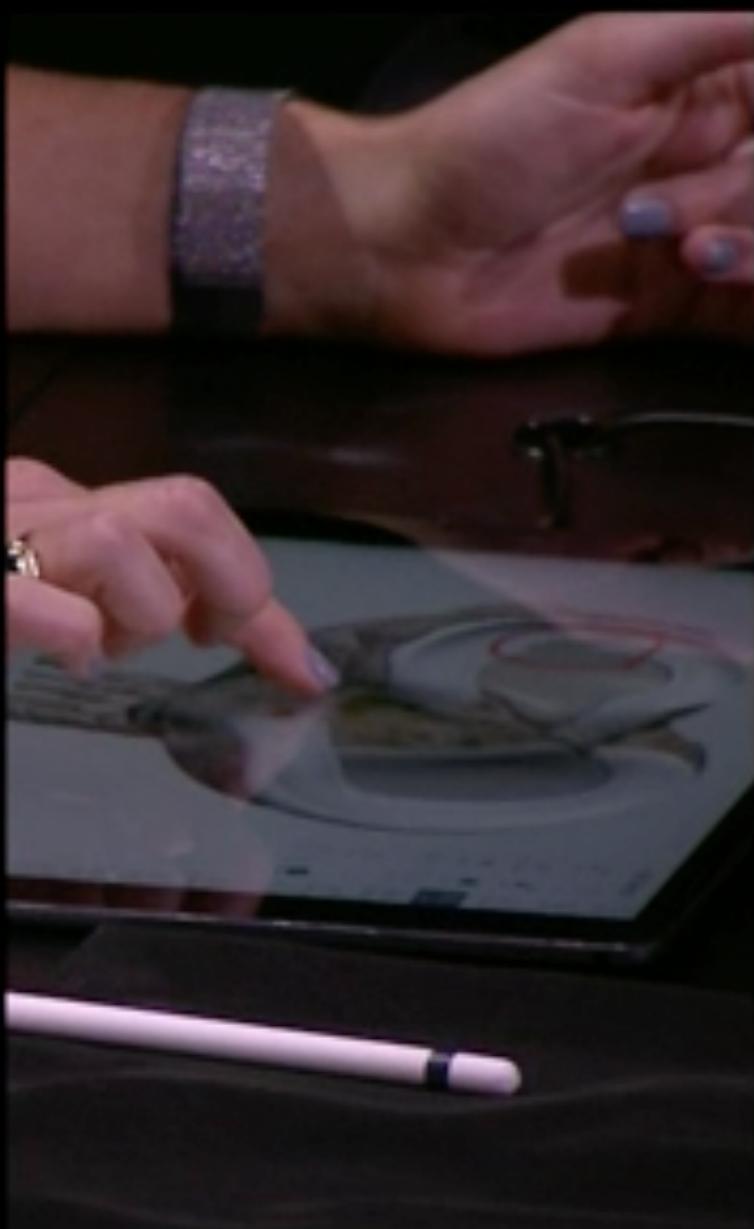
2019-09-11

Why study  
computer graphics?



- 12.9-inch Retina display
- 3rd-generation 64-bit A9X chip
- Four speaker audio
- 10-hour battery
- 8MP iSight camera
- 802.11ac with MIMO
- Up to 150 Mbps LTE
- Touch ID





# Entertainment

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**Movies**  
**Toy Story 3**  
**Pixar**



Spore-Monsters.com

**Games**  
**Spore**  
**W. Wright, Elec. Arts**

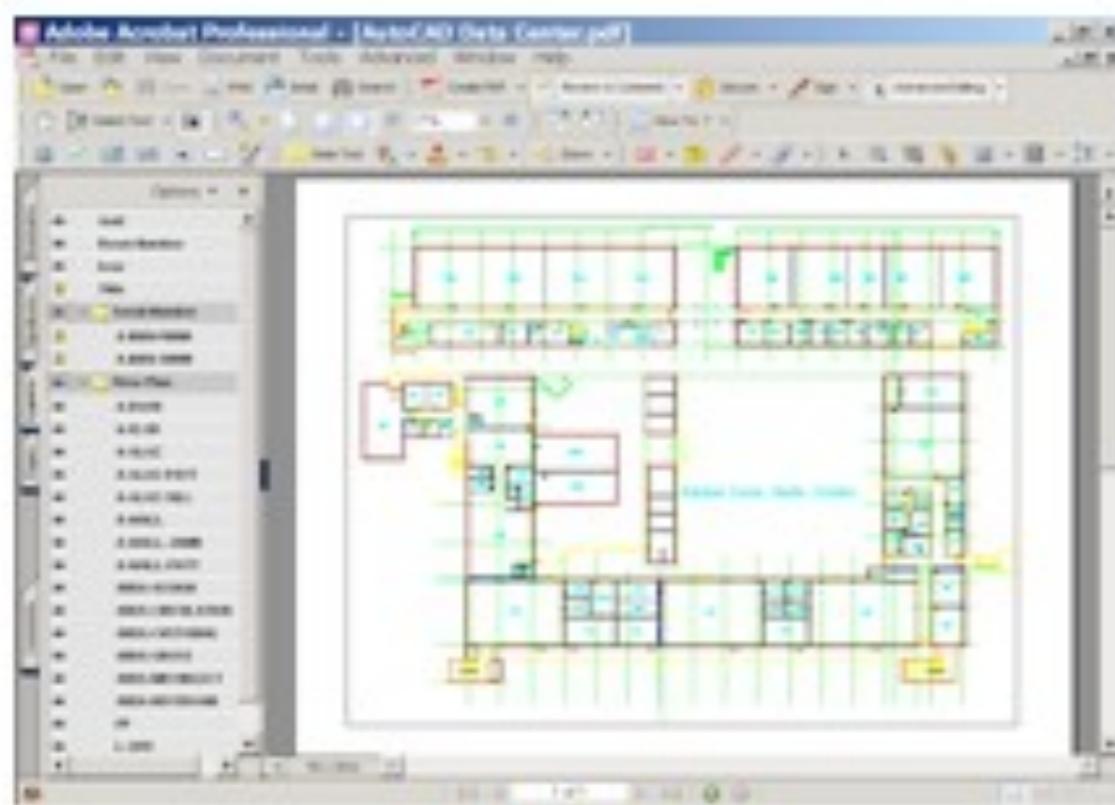
# Computer-Aided Design

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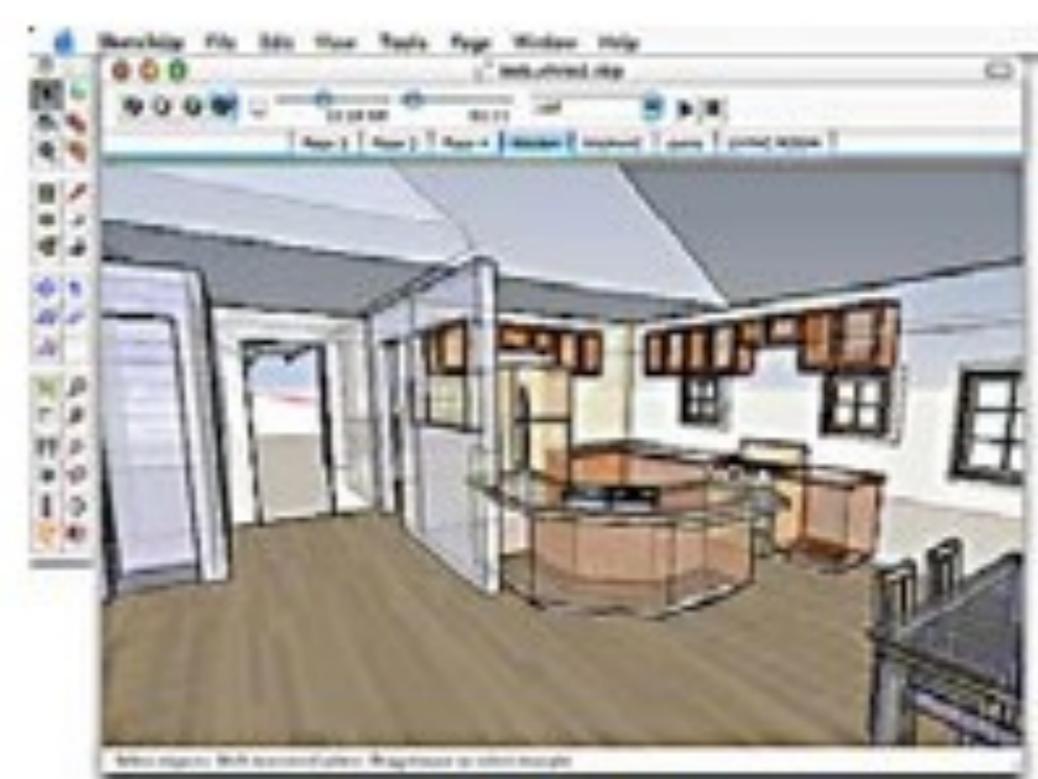
**Mechanical CAD**

**Architectural CAD**

**Electronic CAD**



**AutoCAD**



**Sketchup**

# Visualization

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## Science, engineering and medicine



**The Virtual Human**  
**Karl-Heinz Hoehne**



**Outside-In**  
**The Geometry Center**

# **Visual Simulation and Training**

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**Apollo spacecraft  
Flight simulators  
Driving simulators  
Surgical simulation**



**davinci surgical robot  
Intuitive Surgical**



**Boeing 747 flight simulator  
NASA**

# Digital Media Technologies

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**Convert traditional analog media to digital media**

- Desktop publishing and printing
- Digital photography
- Digital video and HDTV



# Digital Media Technologies

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## Emergence of media

- Multimedia computer and media servers
- Networked graphics and the WWW
- Electronic books, magazines and newspapers
- Sharing photos (flickr) and videos (youtube)
- Virtual worlds (Google Earth, Second Life)

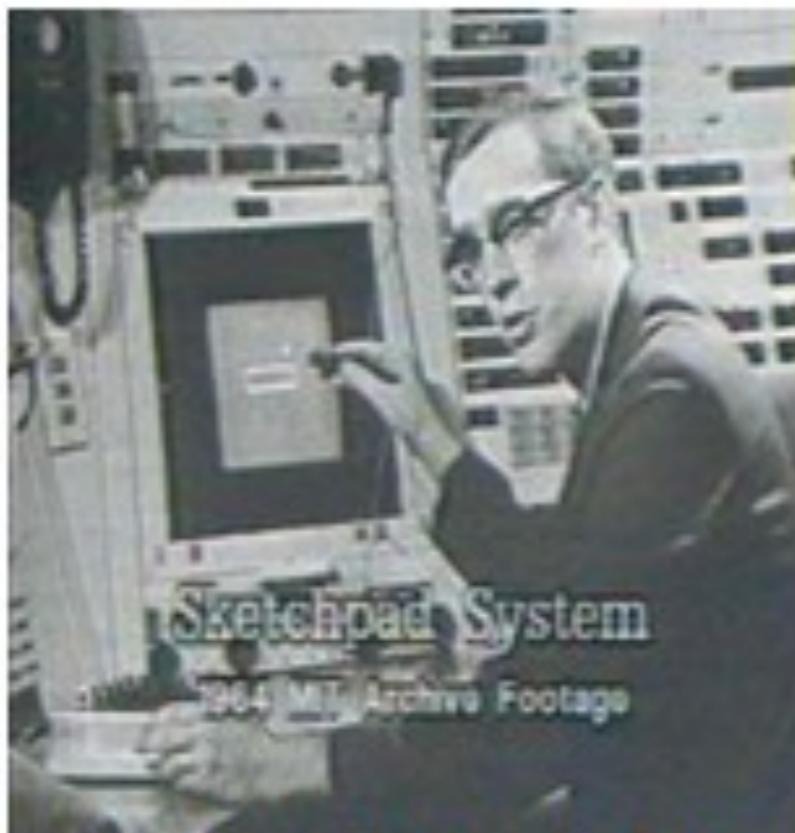
With new possibilities for creating and mixing  
content from different sources

# Graphical User Interfaces

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## Desktop metaphor

- Input: Keyboard, mouse
- Output: Cathode-ray tube



Ivan Sutherland, Sketchpad  
Light-pen, oscilloscope

Douglas Engelbart  
Mouse



Pat Hanrahan, Fall 2010

# **Emerging User Interfaces**

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**Different scales: Small and large**

**Emerging sensors: Multi-touch, accelerometers, ...**



**Apple iPad**



**Microsoft Surface**

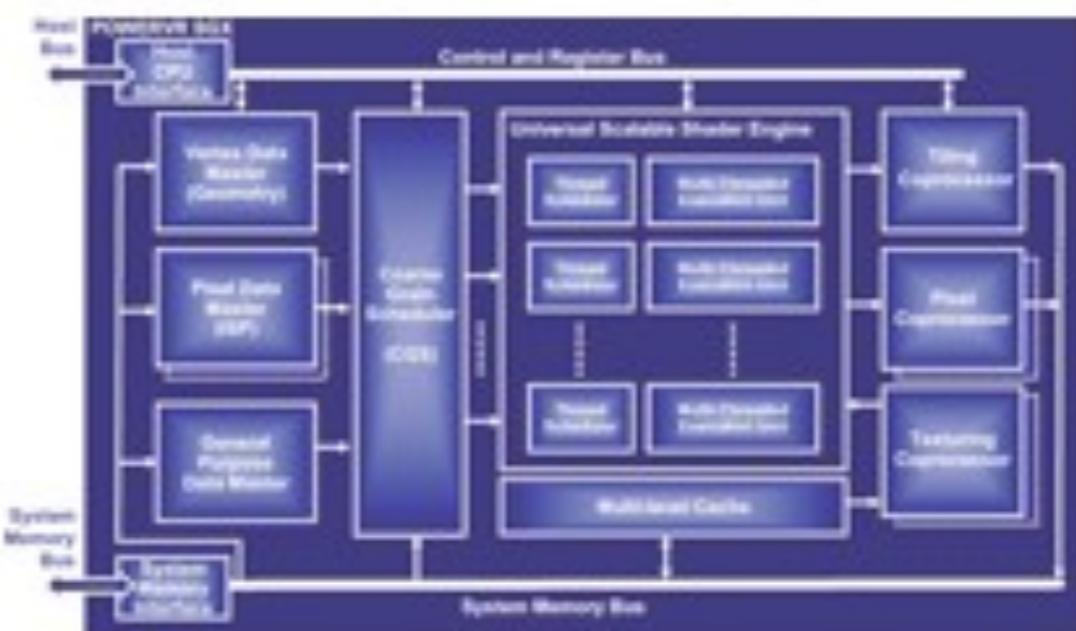
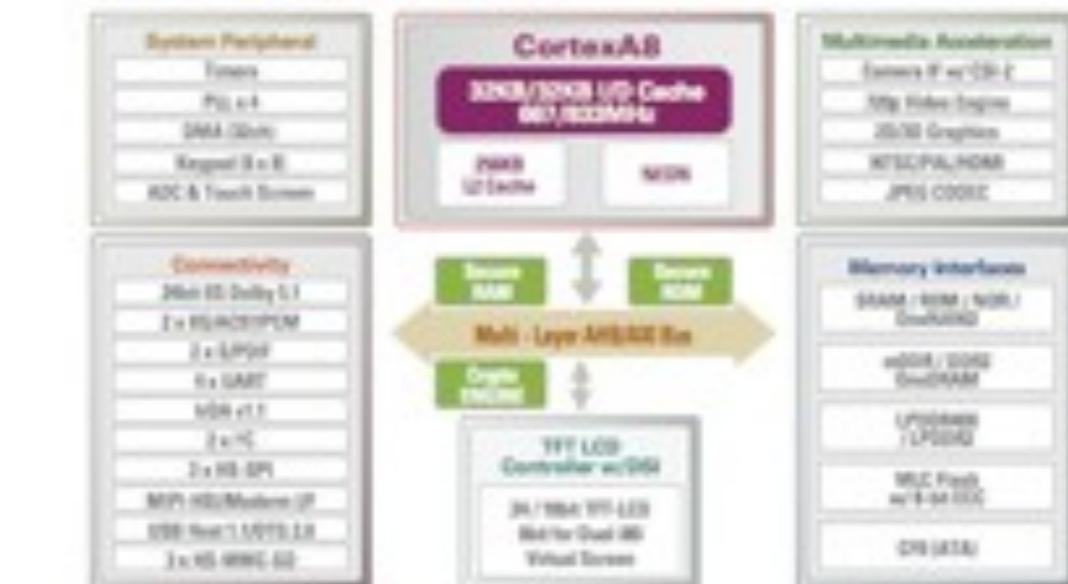
# Innovation in Hardware & Software

## iPhone and iPad



**Apple A4 = CPU+GPU**

S5PC100 Block Diagram

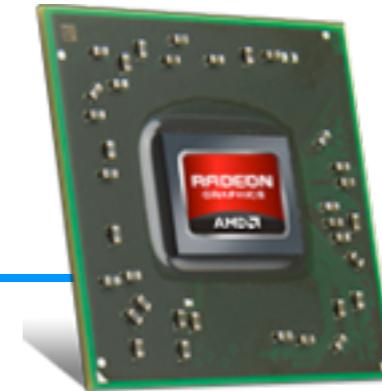


# New Era

# Big Screens



# Mobile Graphics



# **Ultimate Display: Virtual Reality**

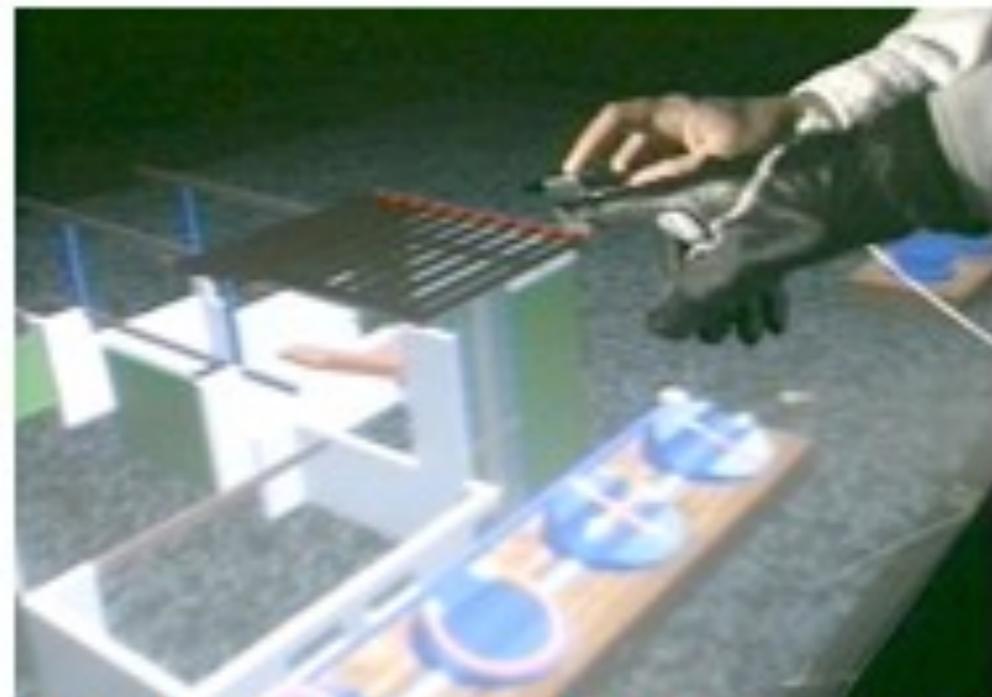
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## **Immersive interfaces**

- Input: 3D 6-DOF tracking, gloves**
- Output: Head-mounted and projection displays**

**Ivan Sutherland**

**Head-mounted displays,  
mechanical tracker**



**Wolfgang Krueger, Pat Hanrahan**  
**Responsive Workbench**  
**Projection display, magnetic tracker**

# New Devices in Home

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# New Personal Devices

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## ROKID GLASS

[See More](#)



# 早晨，若琪的一天

# Theory and Practice

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## Science and Mathematics

- Physics of light, color and appearance
- Geometry and perspective
- Mathematics of curves and surfaces

## Engineering

- Hardware: Graphics processors, sensors
- Software: Graphics libraries, window systems

## Art and Psychology

- Perception: Color, displays, ...
- Art and design: Composition, form, lighting, ...

# Great Ideas in Computer Graphics

- Computers (with suitable output devices) can draw geometric stuff, not just manipulate numbers.
- Computers can draw images of 3D worlds with realistic shapes and light and animate them as well.
- People can create 2D and 3D models.
- People can interact with them in 2D and 3D through innate visual and kinesthetic senses.
- Computers can be fun (games).
- Computers can make the virtual appear real (special effects).
- Computer graphics can sell computers.
- All that can fit on a low cost PC graphics board.
- All that can fit into a mobile phone.

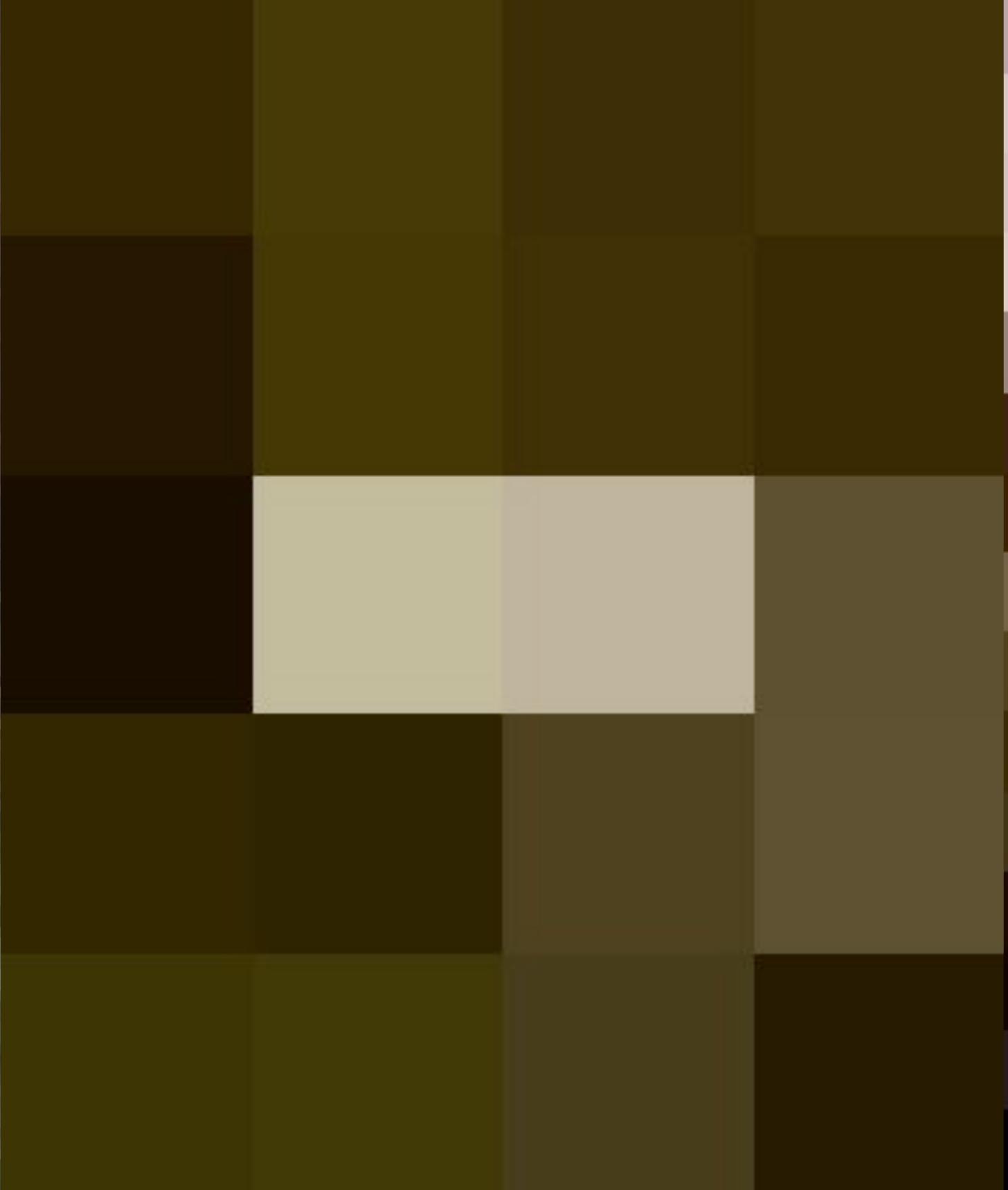
Can we give a definition  
for computer graphics?

# Computer Graphics

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One of many different descriptions

- The science and technology of imaging the world in pixels, such that it provides the real experience (**looks real**, sounds real, feels real)



And last ...

# Pixel Representation Problem

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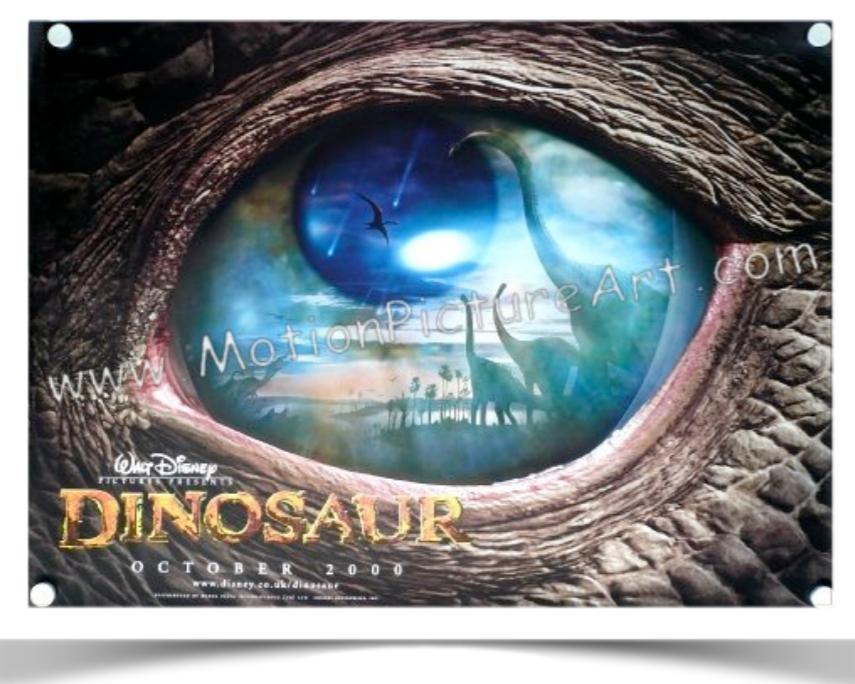
- The pixel has only two properties:
  - area of the pixel is fixed
  - color of the pixel is set under program control
- Image: array of pixels

# Computer Graphics

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recommended description

- The science and technology of modeling , processing and displaying objects in the world in a computer



# Three Fundamental Tasks

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## Computer Graphics

- Modeling
- Animation (simulating)
- Rendering (displaying)



# Three Fundamental Tasks

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- Modeling the World (World Representation)
  - Simulating the behavior of objects in the world
  - Displaying the World
- 
- Geometry and Physics are the traditional tools

# Different Digital Representations of the World

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- Digital Images
  - 3D Geometric Objects (Graphics)
  - Symbolic Descriptions
- 
- Question:
    - Advantages and disadvantages ?

# Different Digital Representations of the World

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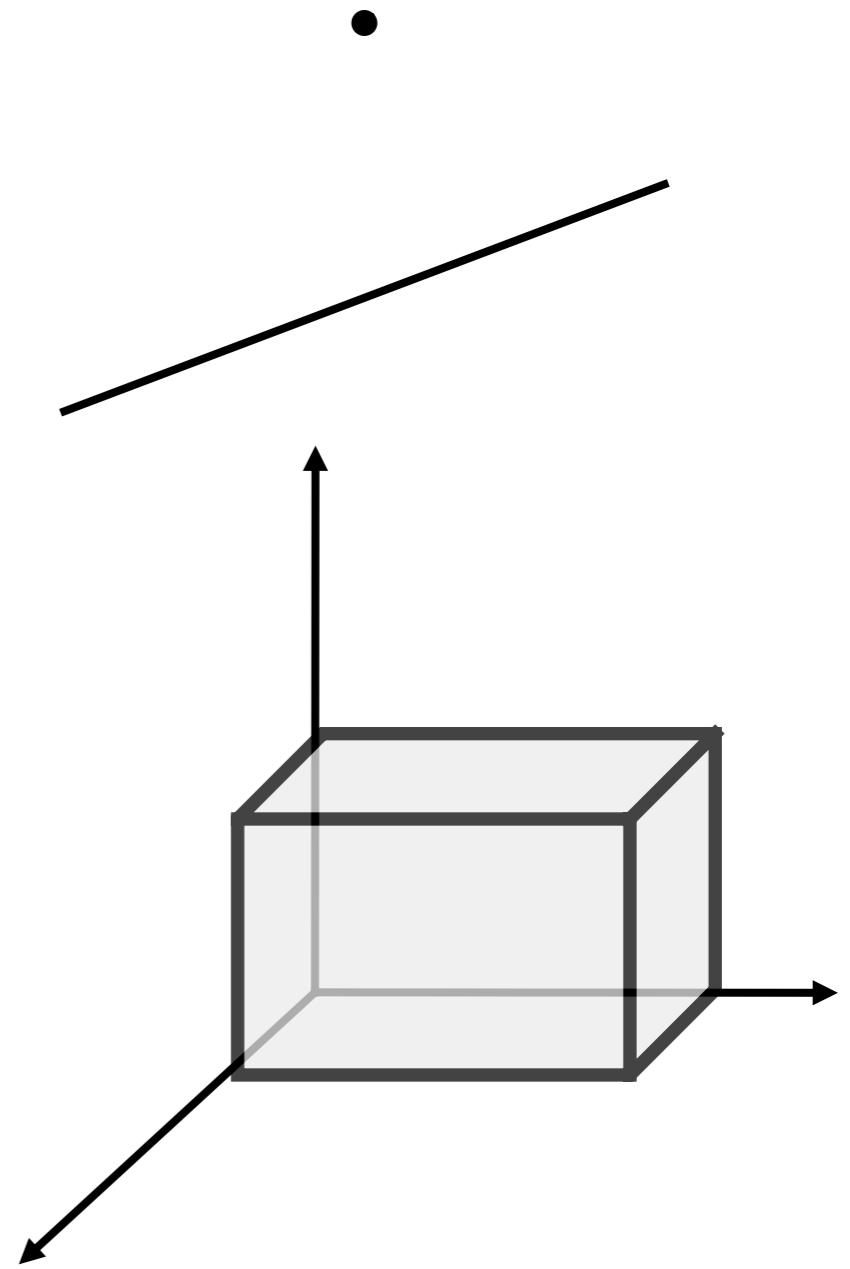
- Digital Images
- 3D Geometric Objects (Graphics)
- Symbolic Descriptions
- Question:
  - Difference?
  - Advantages and disadvantages ?

# Graphics Representation

- find appropriate data structure to represent the object

```
Point3D {  
    double x;  
    double y;  
    double z;  
}
```

```
Cuboid {  
    Point3D location;  
    double x;  
    double y;  
    double z;  
}
```



# World Representation Problem

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- Three very important and rather complex attributes:
  - complex **shape** (desk, tree, water, animal, people)
  - visual look or **appearance** due to lighting effects
  - **dynamic behavior** due to interaction with other elements of the world -- movement, sound, elastic effects, ...

# Three Fundamental Tasks

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- Modeling the World (World Representation)
  - Simulating the behavior of objects in the world
  - Displaying the World
- 
- Geometry and Physics are the traditional tools



# Three Fundamental Tasks

---

- Modeling the World (World Representation)
  - Simulating the behavior of objects in the world
  - **Displaying the World**
- 
- Geometry and Physics are the traditional tools

# Displaying the World

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- I/O of Computer Graphics
  - Input : graphics : object (shape, material,...)
  - Output : image : array of pixels (RGB)



# Different Digital Representations of the World

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- Digital Images
- 3D Geometric Objects (Graphics)
- Symbolic Descriptions
- Region of Object in an Image

# Visual Computing Fields

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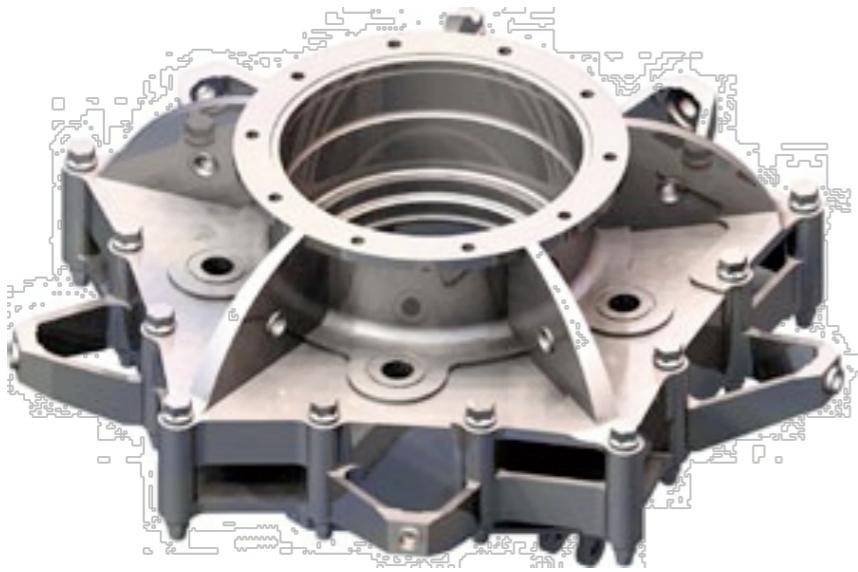
- **Image Processing**
  - Image $\Rightarrow$ image, image $\Rightarrow$ region
- **Pattern Recognition**
  - Image $\Rightarrow$ symbolic descriptions
- **Computer Vision**
  - Image $\Rightarrow$ graphics
- **Computer Graphics**
  - Graphics $\Rightarrow$ image, graphics $\Rightarrow$ graphics

# Computer Graphics Applications

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- Use is all pervasive (No computer application domain untouched by Computer Graphics)
  - CAD
  - GIS
  - Movie, Animation
  - Game
  - Scientific visualization
  - Virtual Reality
  - User interface

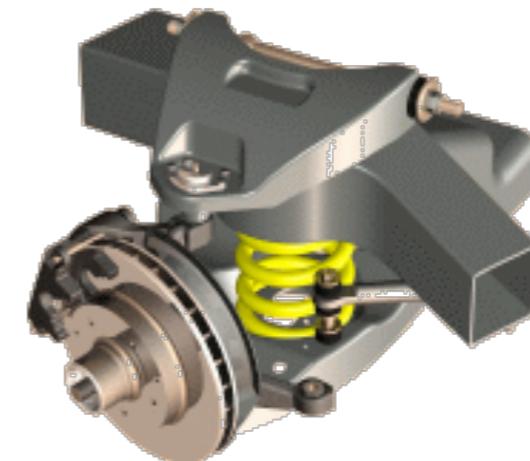
# Computer Graphics Applications



2D Drawing  
(AutoCAD)

3D modeling  
(Pro/E, UG, CATIA)

Computer Aided  
Design

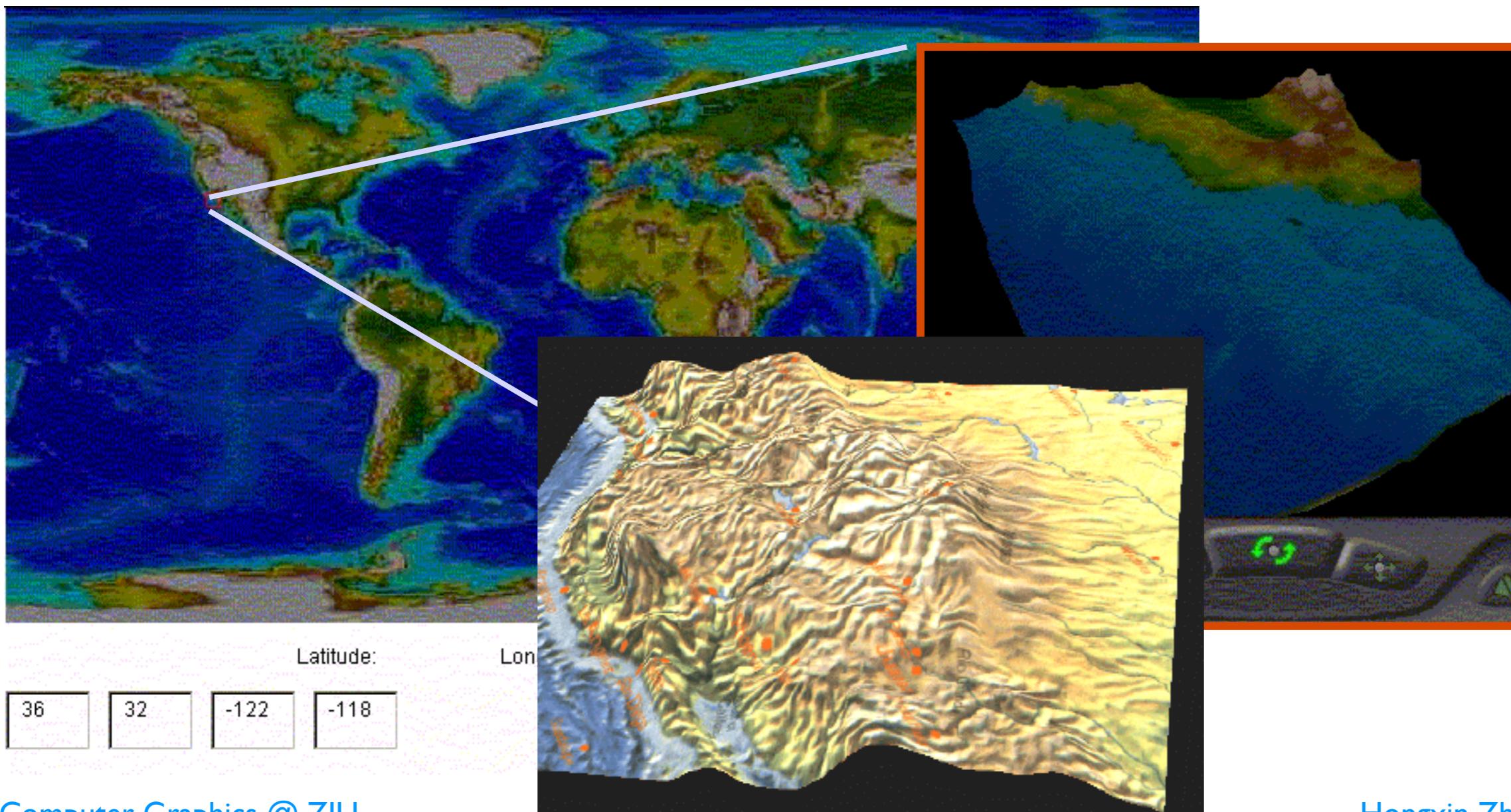


CAE

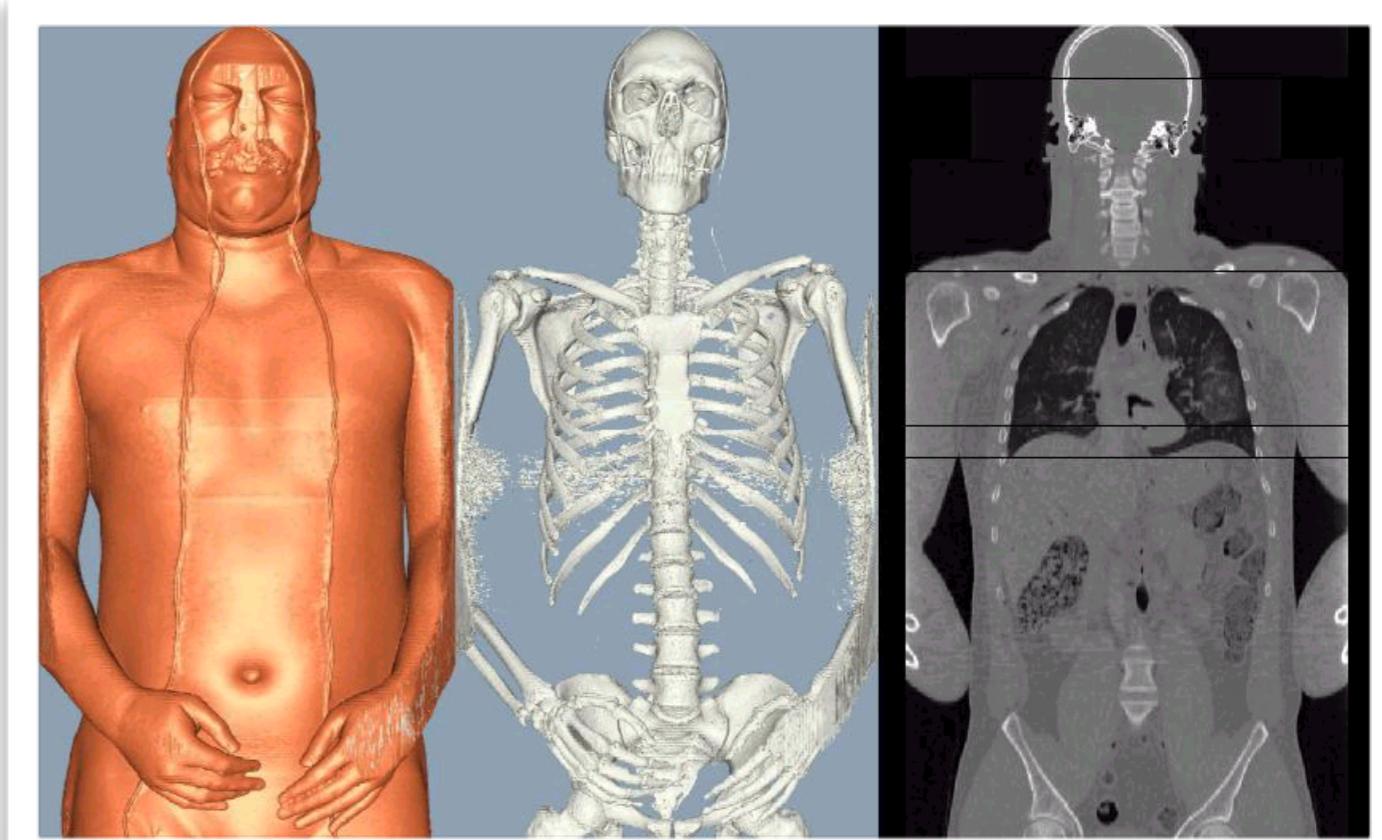
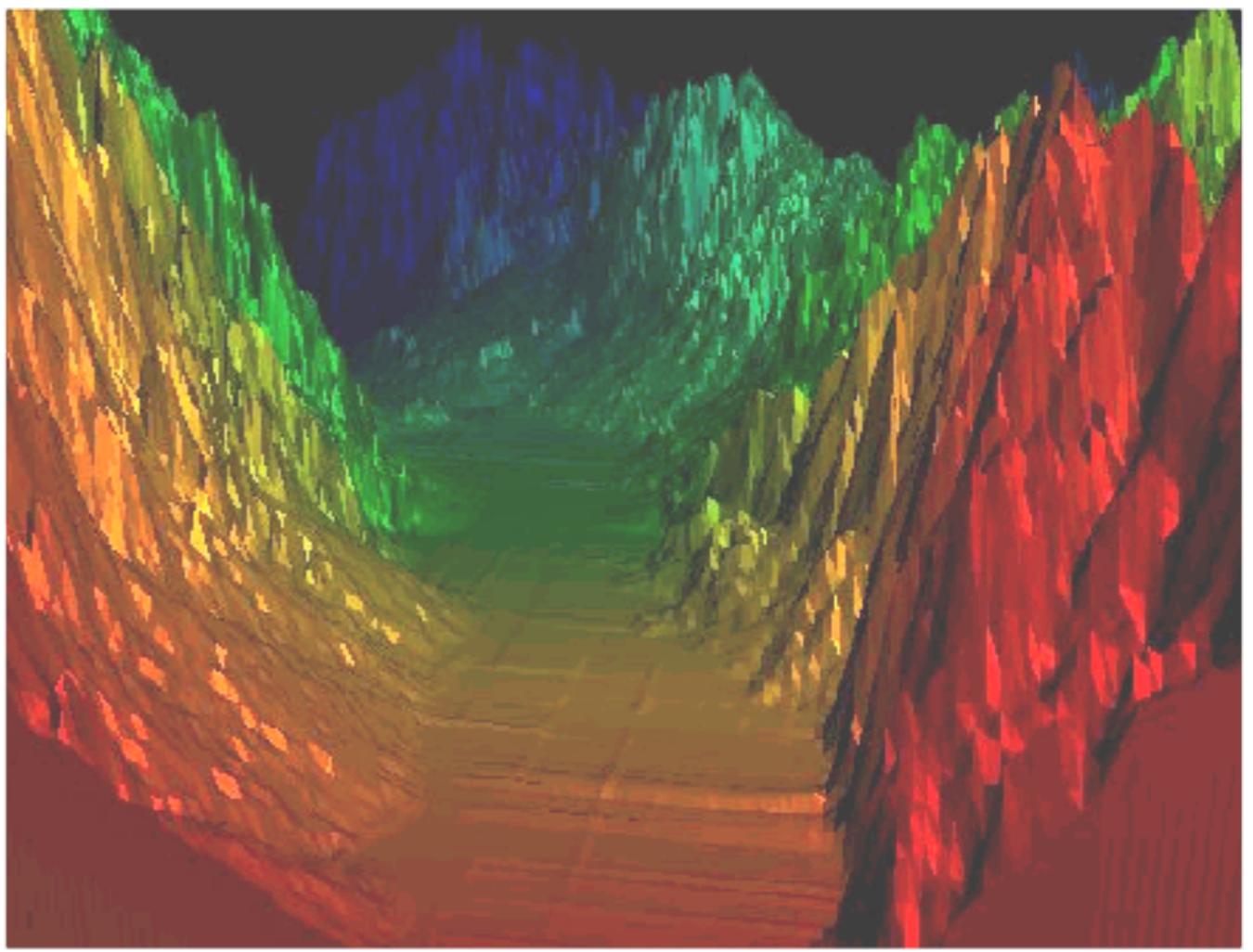
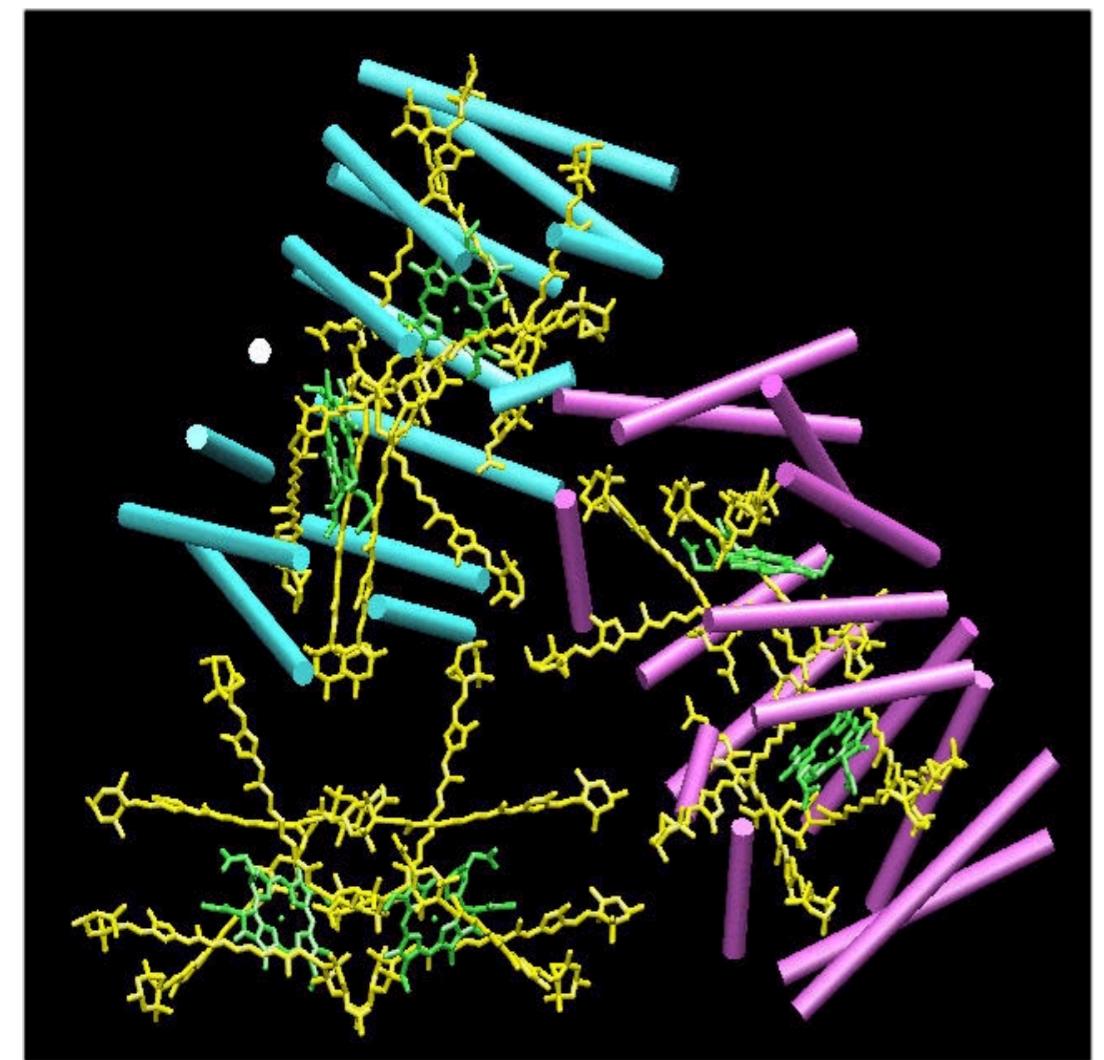
CAM

# Computer Graphics Applications

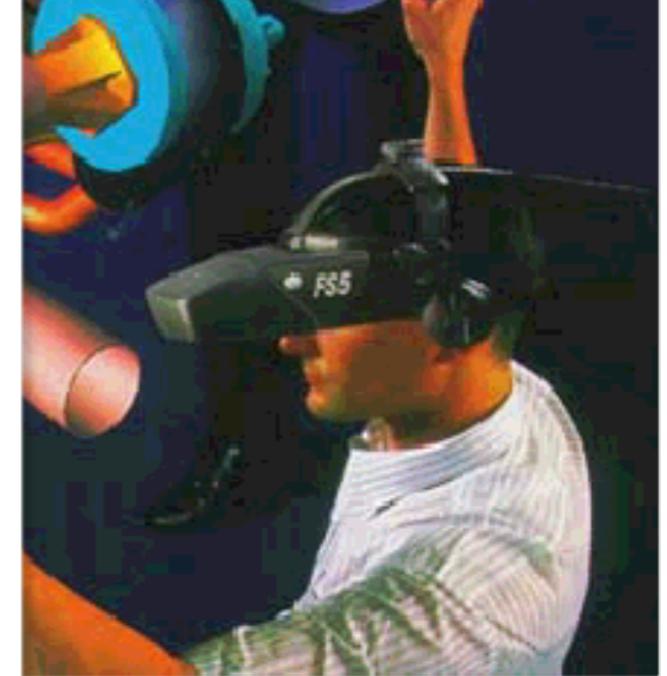
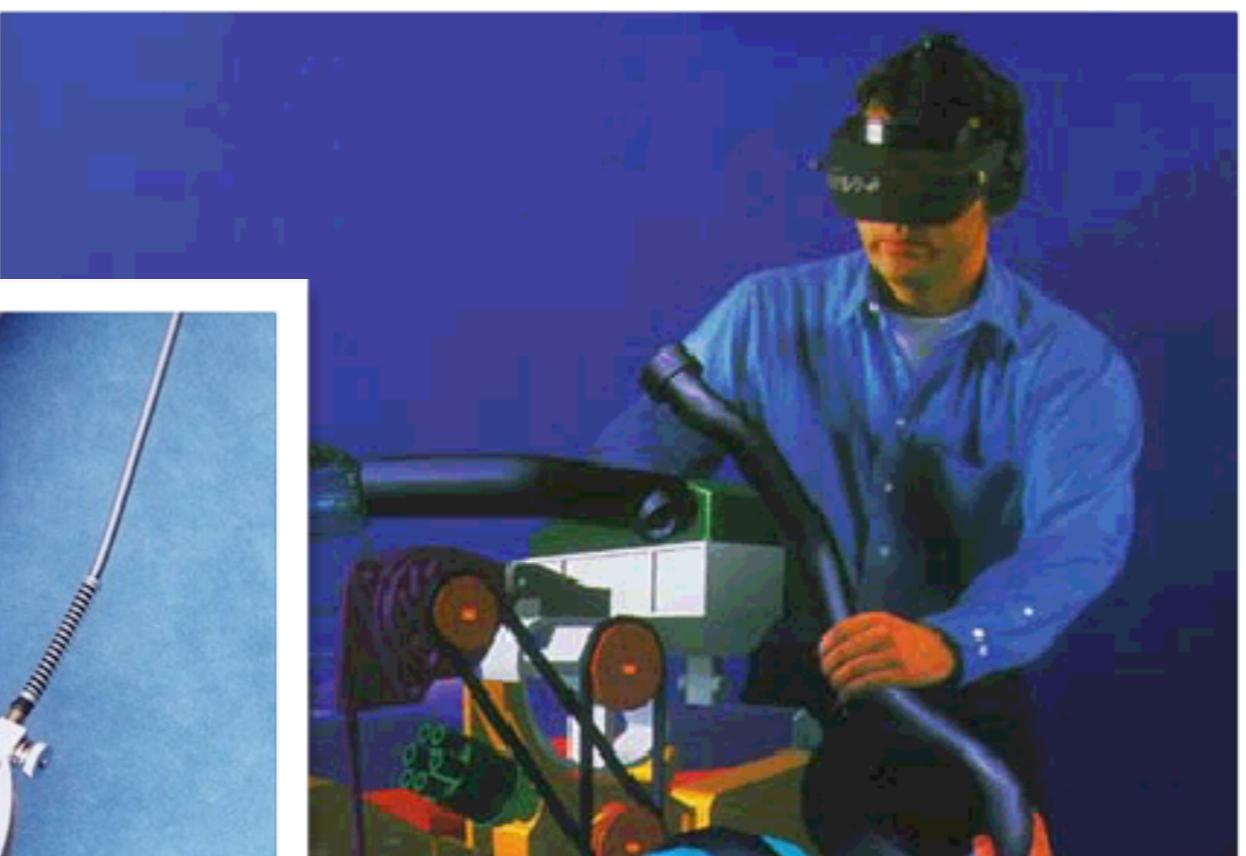
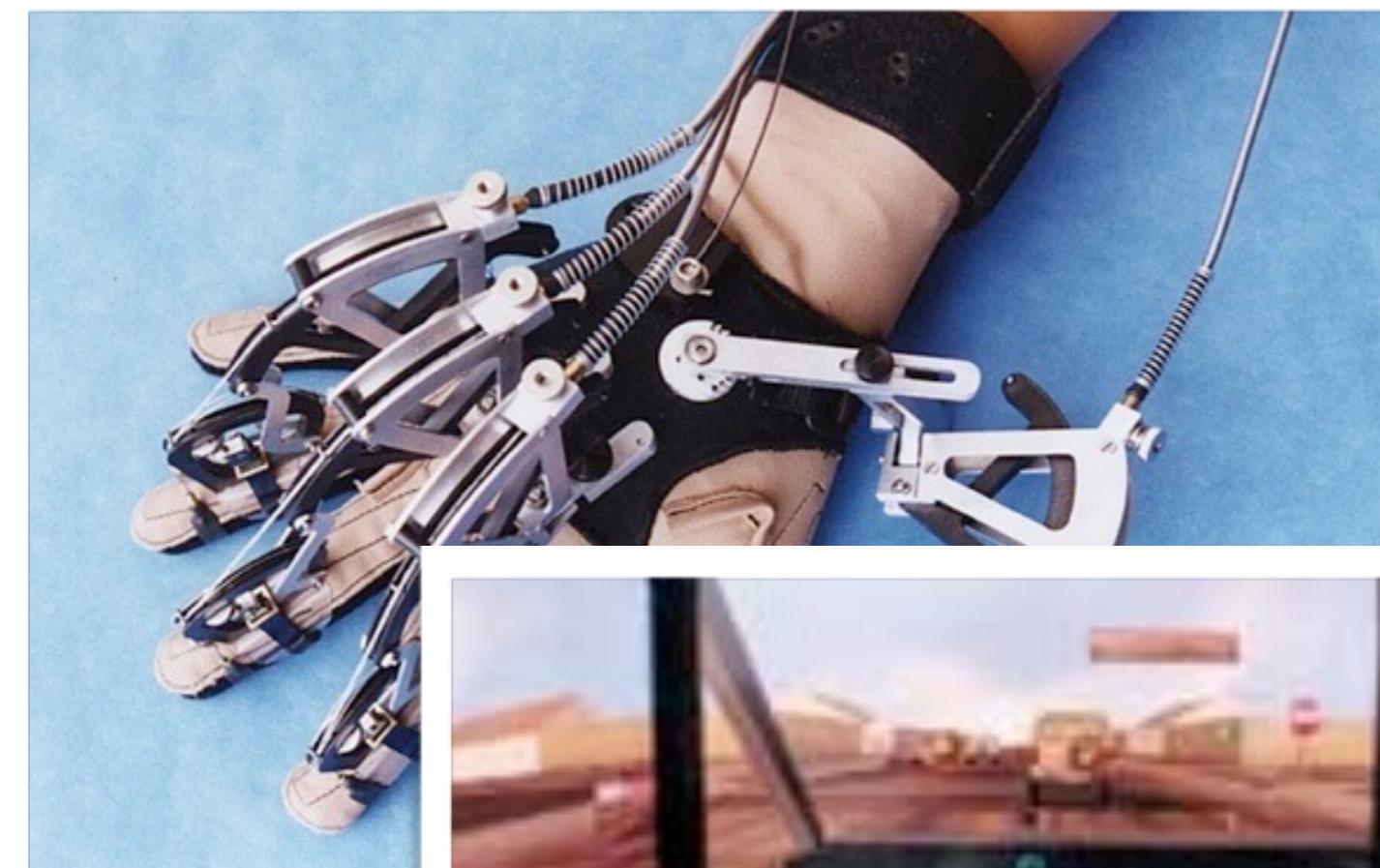
## GIS: Geography information system



# Visualization



# Virtual Reality



# Technology Developments

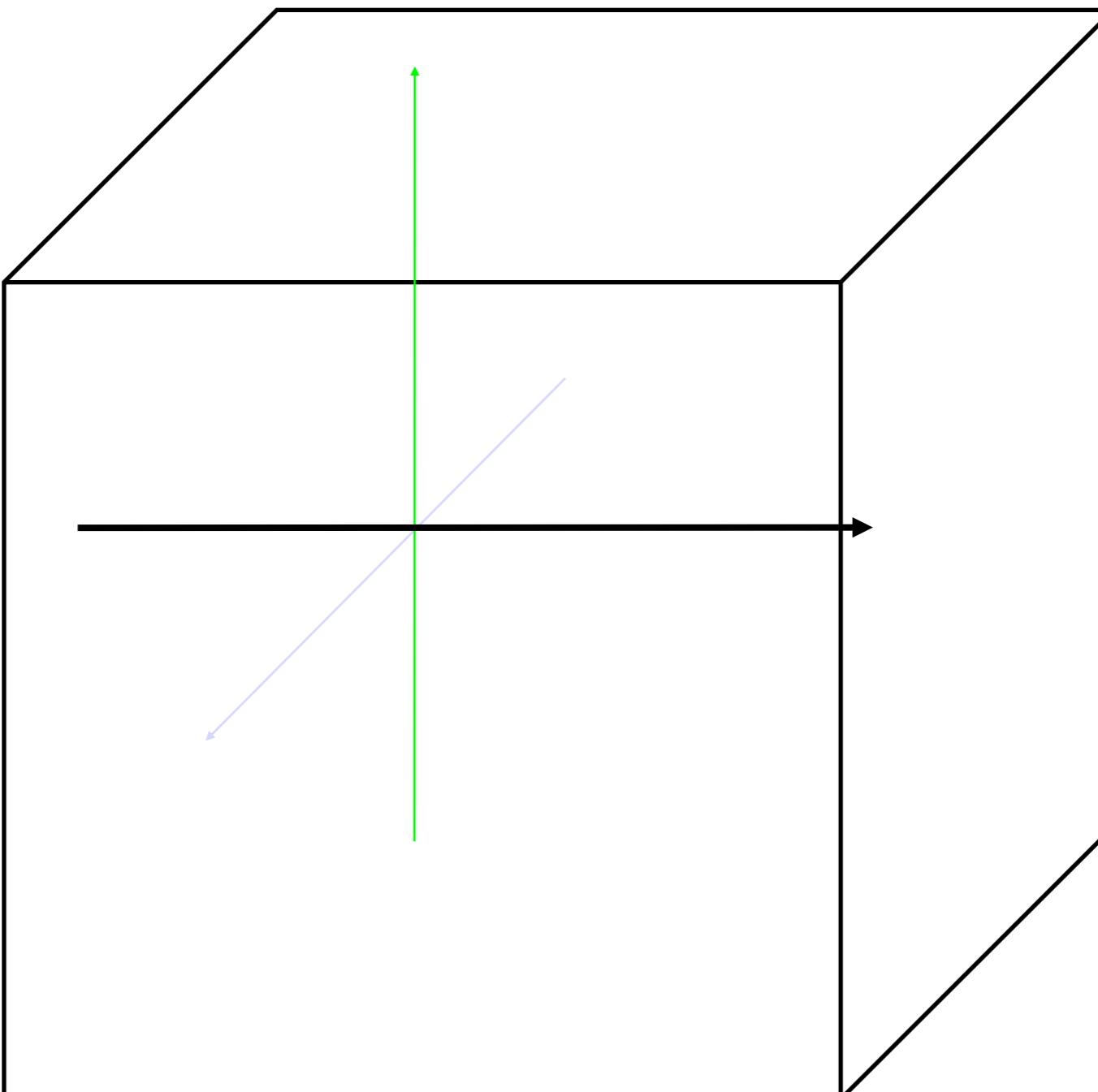
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- 1962 : Sutherland's Sketchpad
- 1970s: Special Hardware
- 1980s: Raster Graphics
- 1990s: Reality Engines
- 2000s: 3D acceleration
- 2010s: Mobile graphics
- 2020s: ??? Intelligence ???

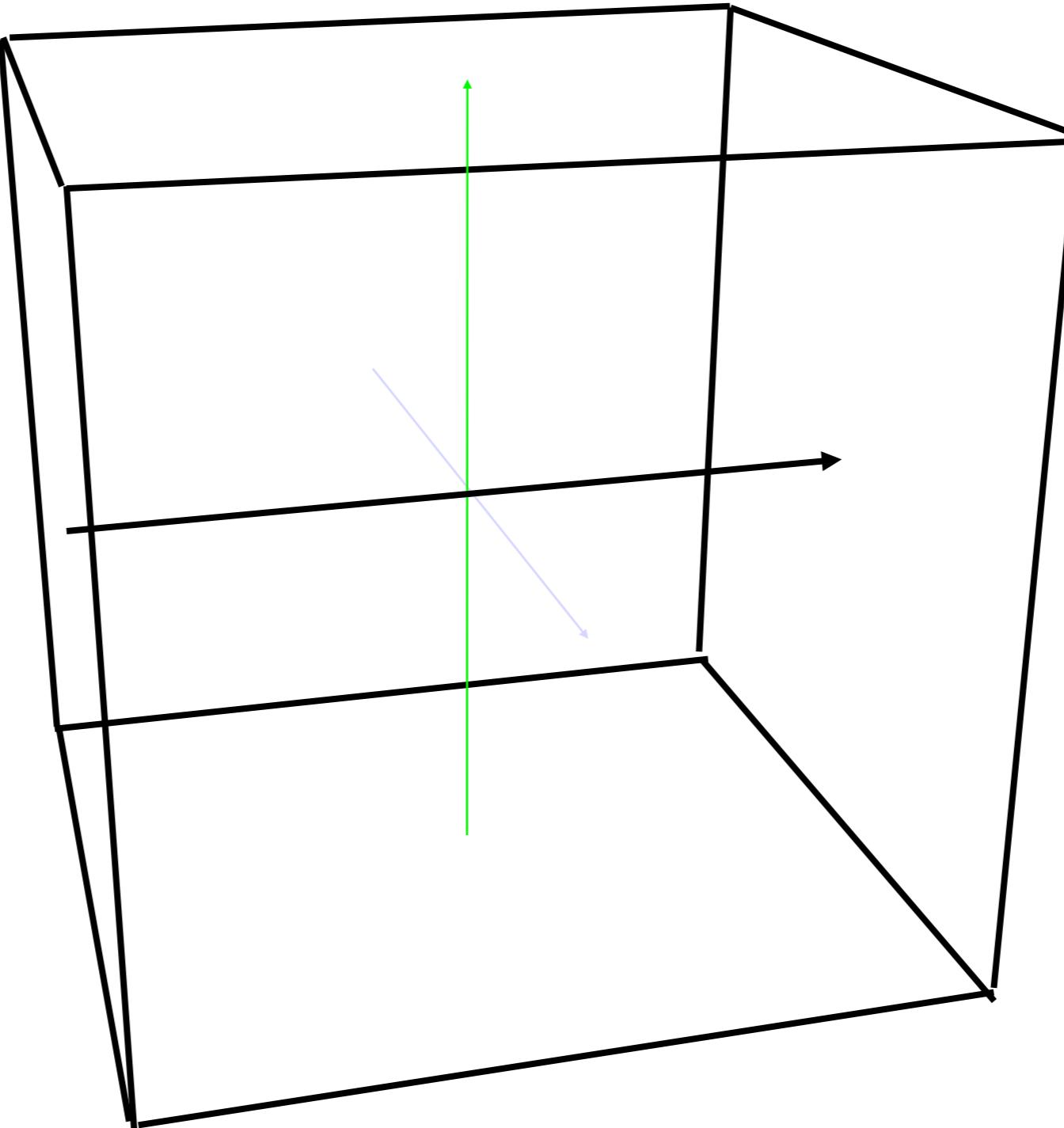
# Topics Addressed in this Class

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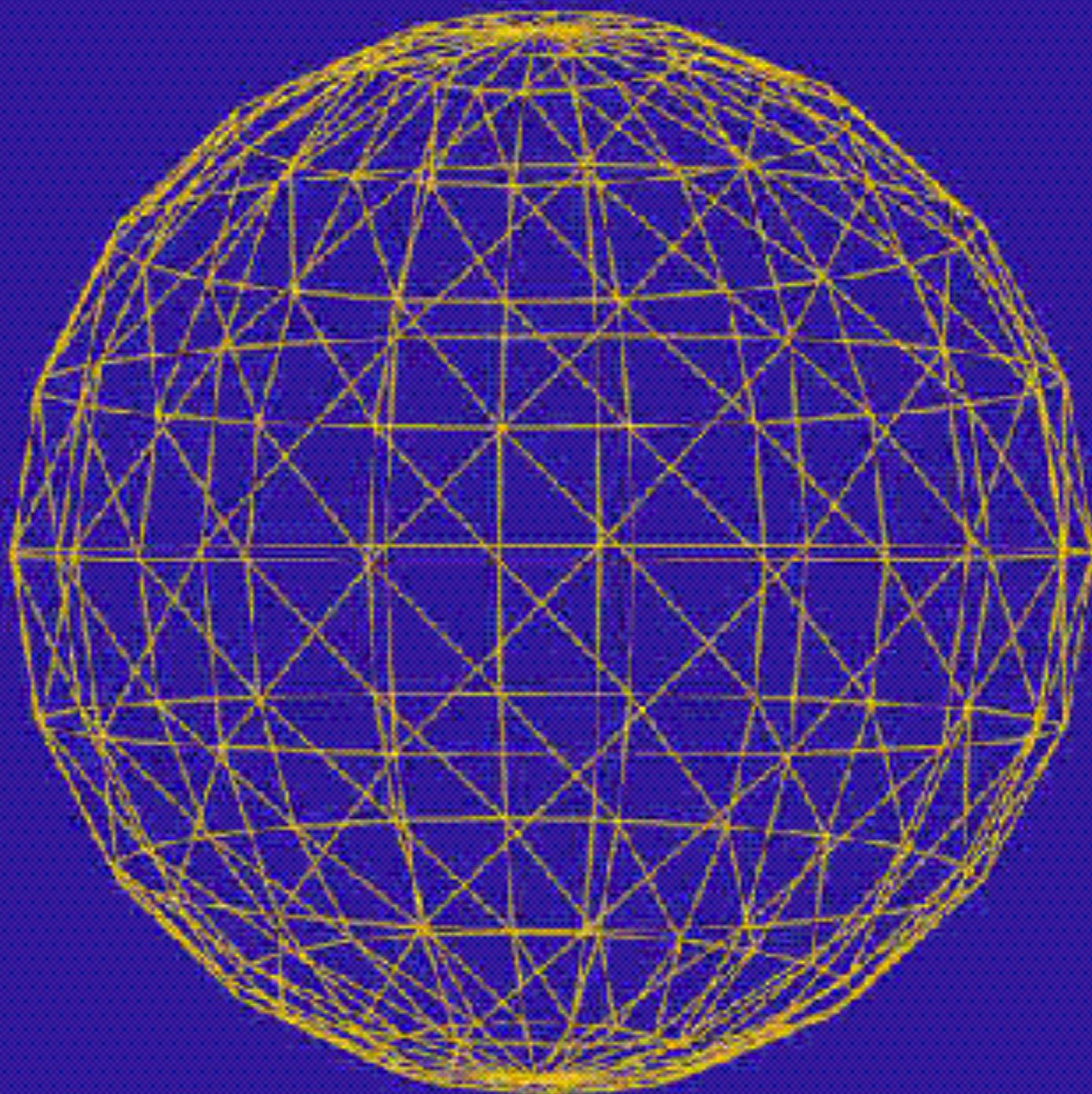
- Basics - Transformations and Synthetic Camera for Viewing the World
- Modeling techniques and tools - Meshes, Surfaces and Solid Objects



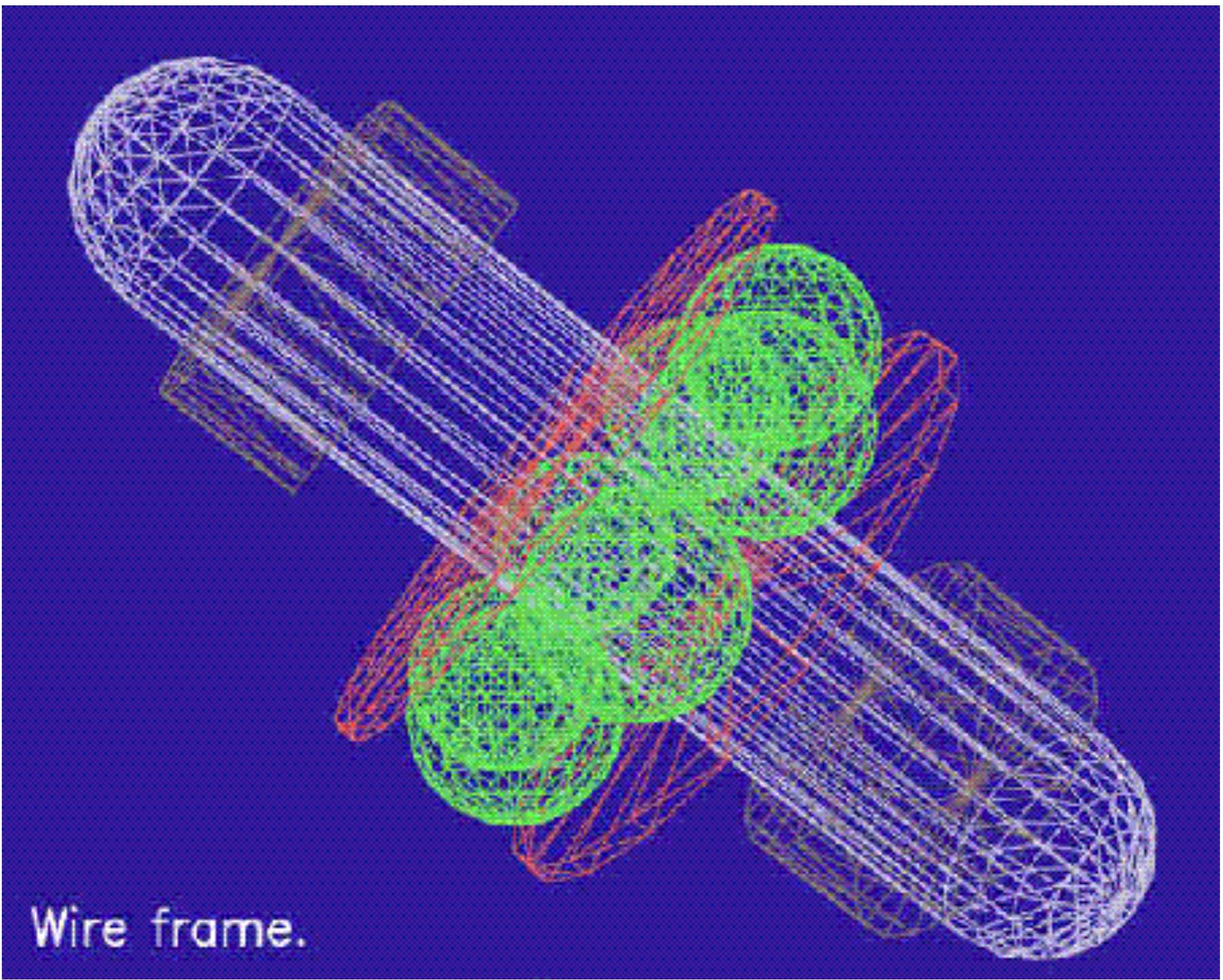
# Parallel Projection



## Perspective Projection



Wire frame.

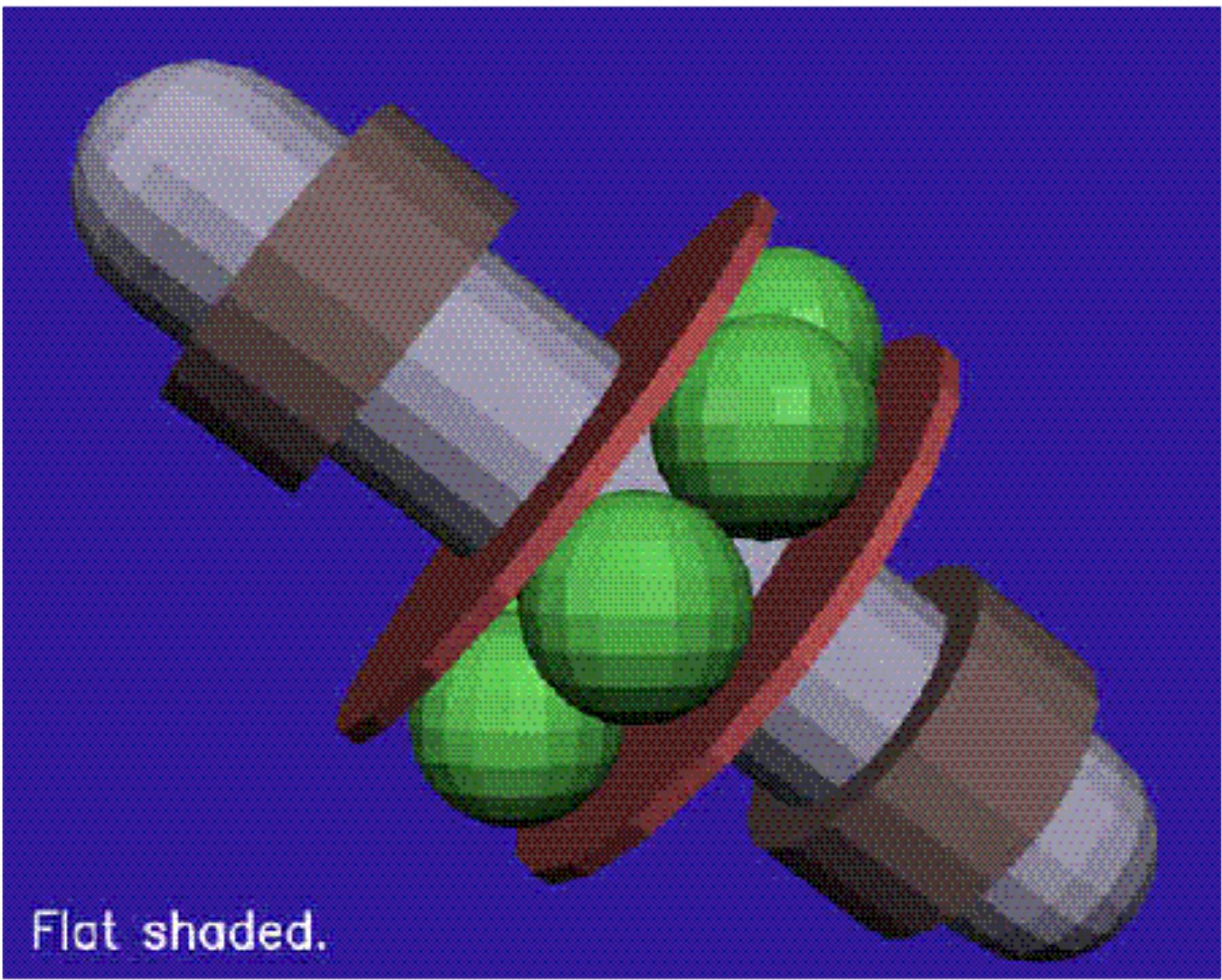


Wire frame.

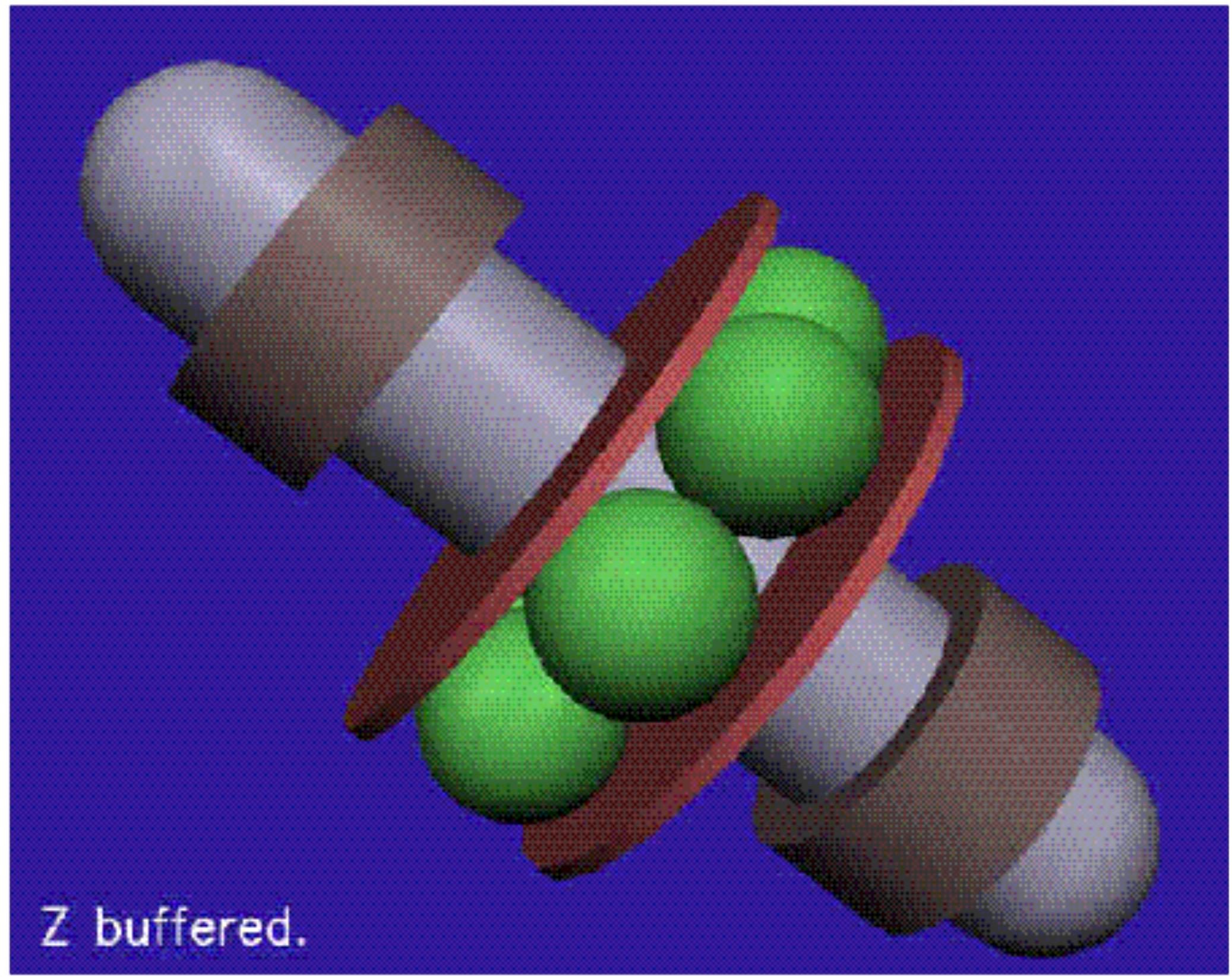
# Topics Addressed (contd)

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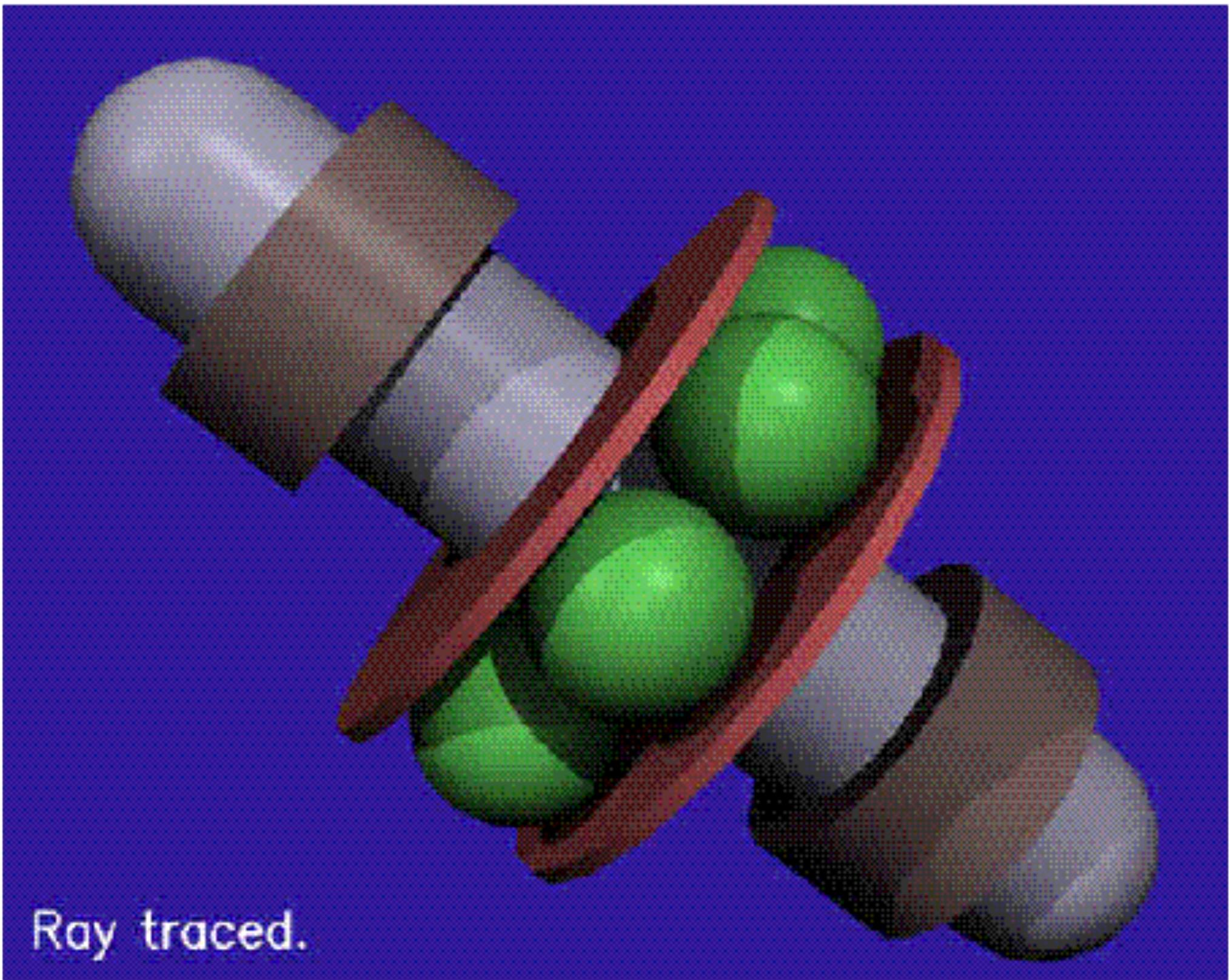
- Rendering techniques - visibility computation, illumination models, realistic imaging algorithms



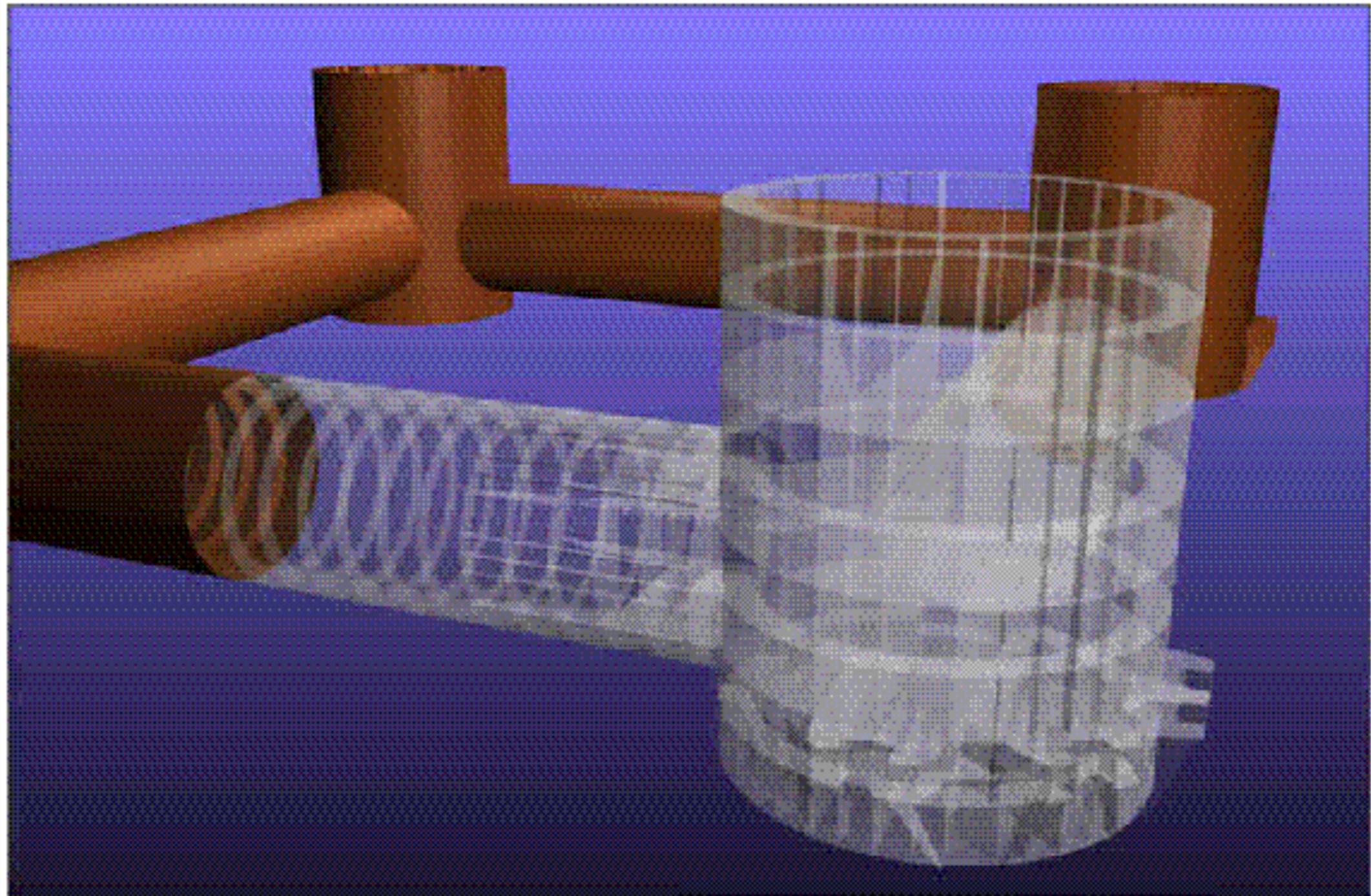
Flat shaded.



Z buffered.



Ray traced.

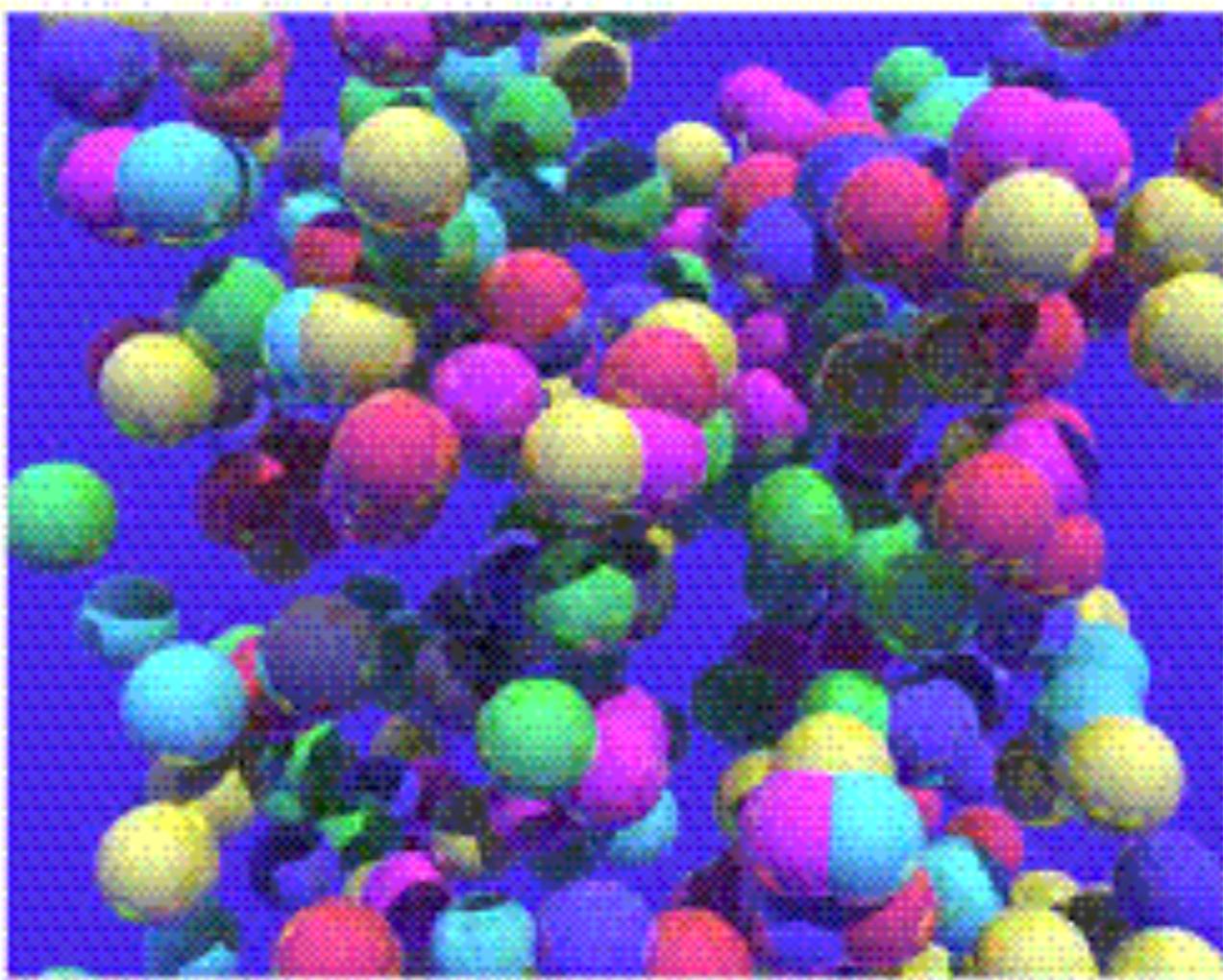




# **Texture Mapping**

## **(Only Brief Overview)**

# SPHEREO's

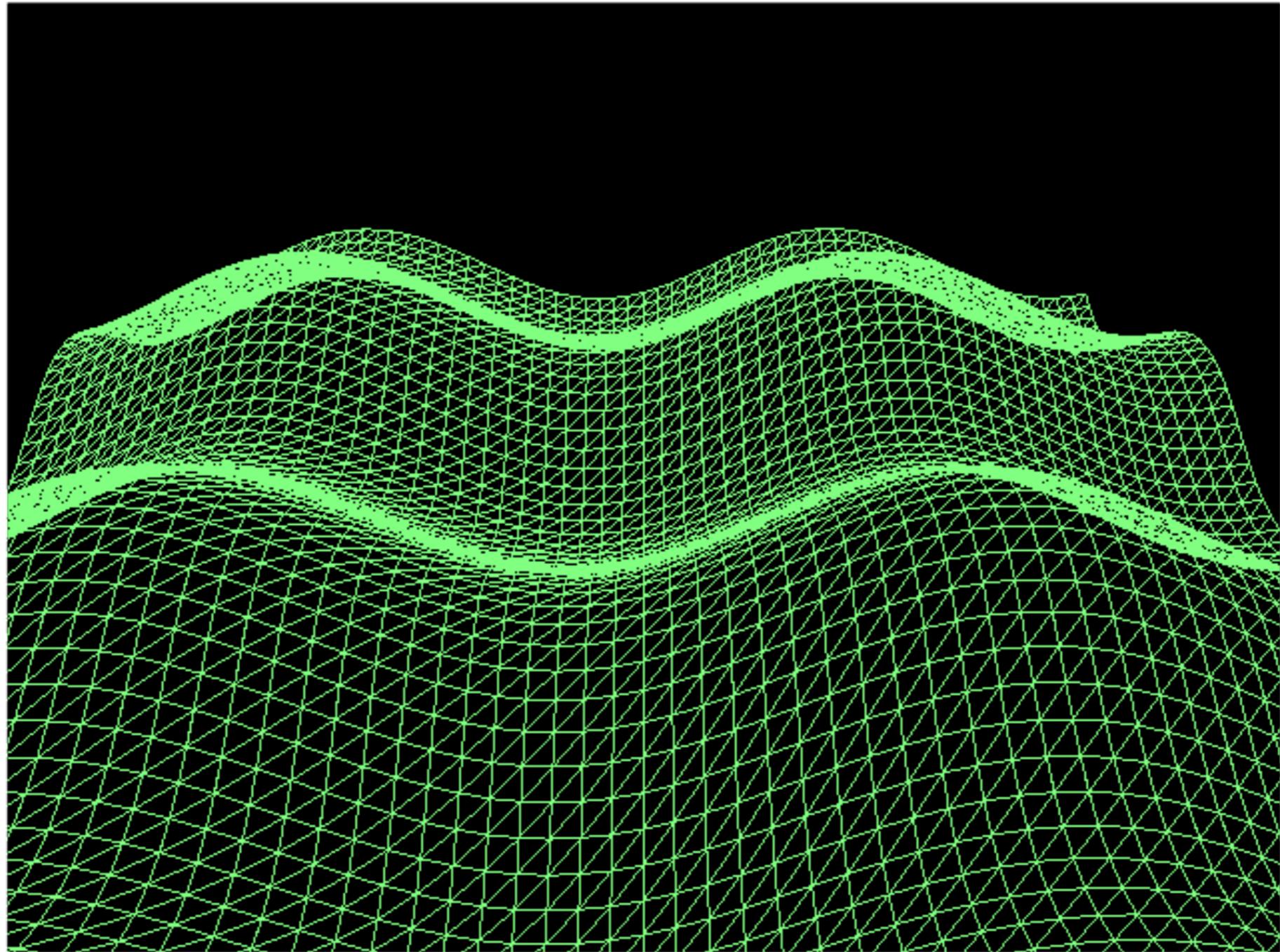


*A different color  
in every byte*

INGREDIENTS: Ray traced spheres, FDD&C blue background, No. 7 directional light sources, contains no more than 1/2 of 1 percent oil-free ramenants, Specular highlights added to preserve freshness.









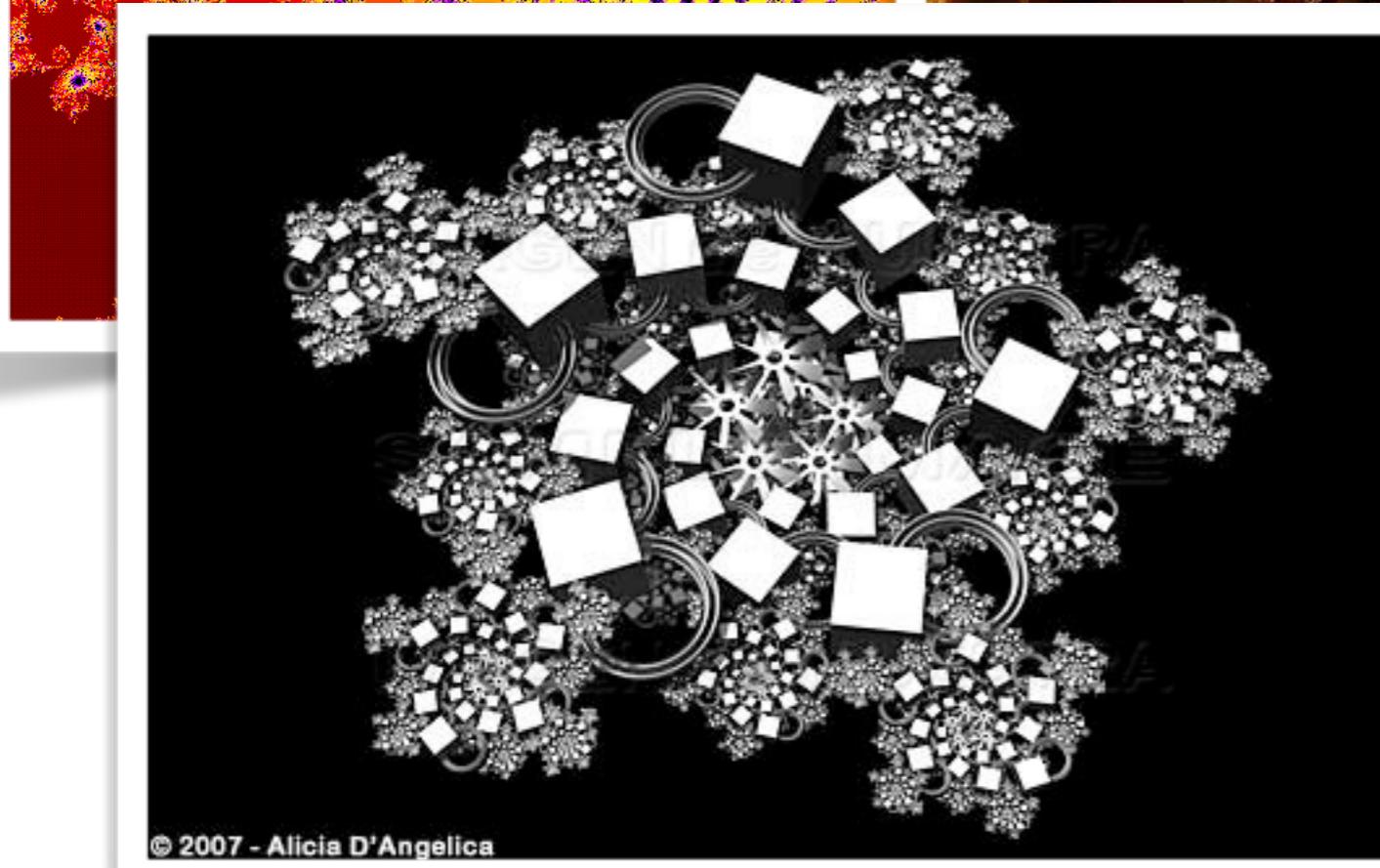
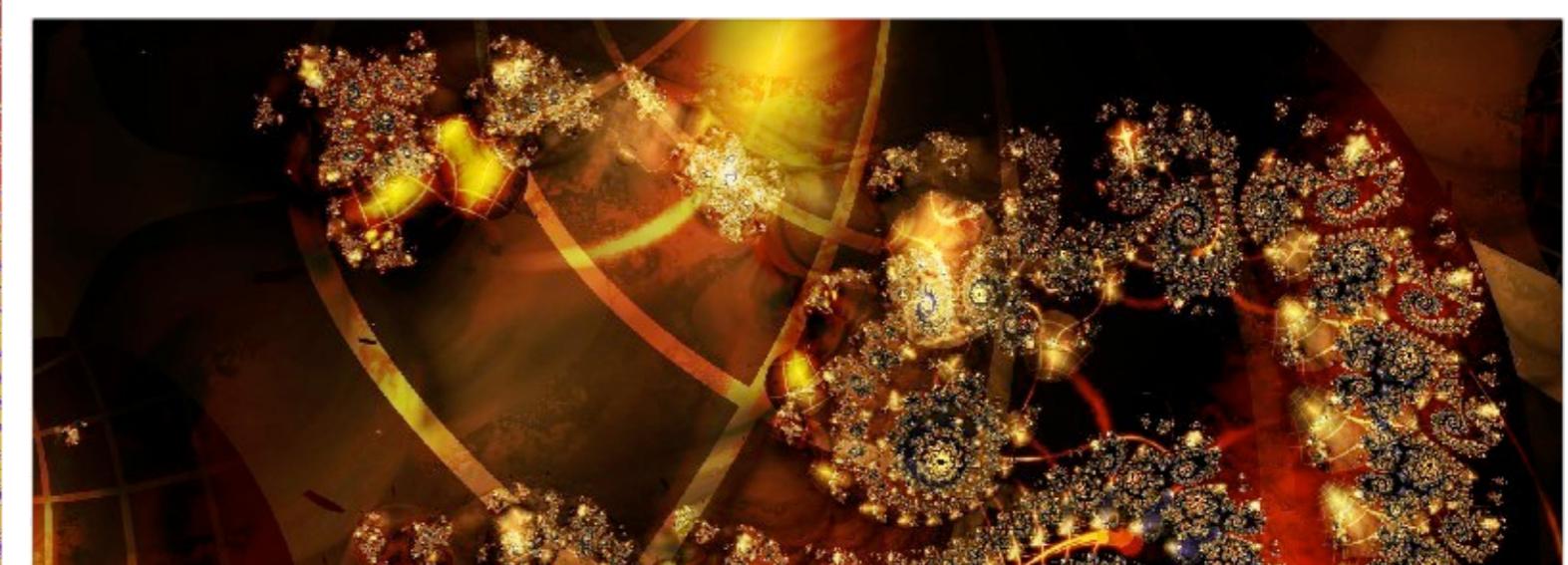
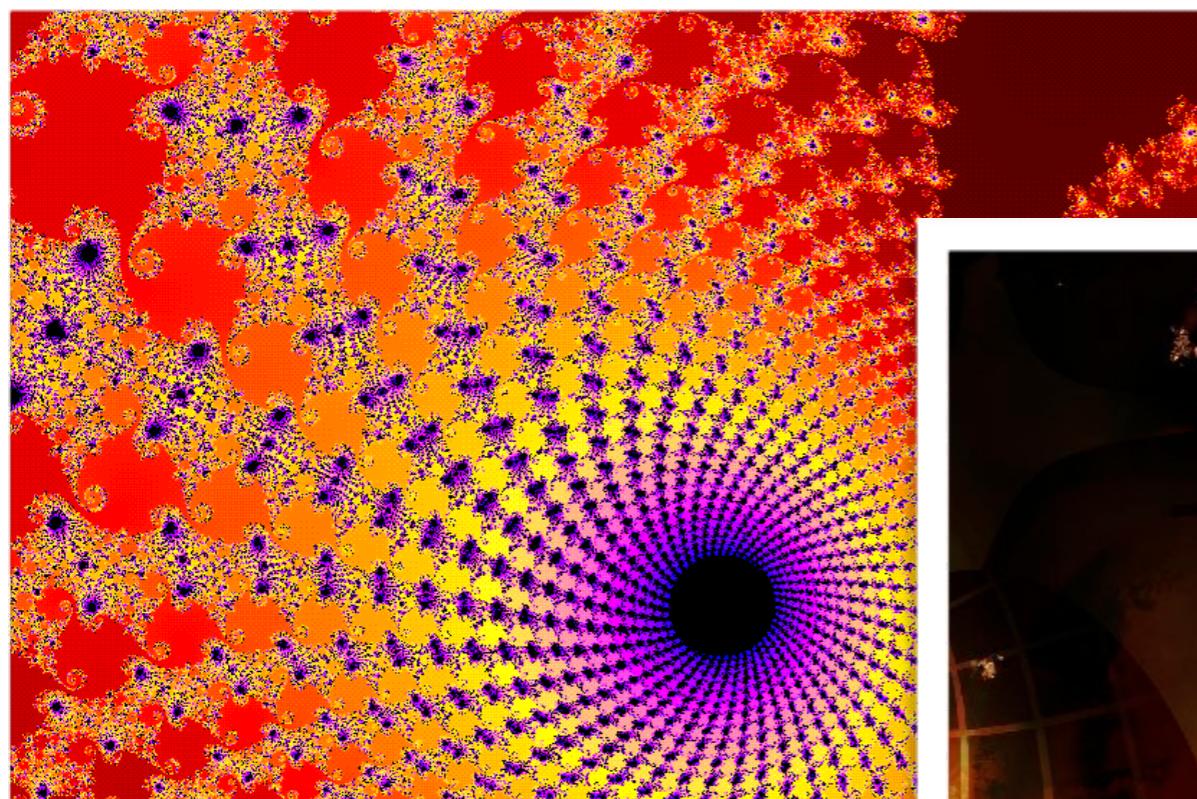
# Topics Not Addressed

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- Advanced modeling and rendering methods
  - complex lighting effects,
  - natural objects (fractals), and
  - volumetric objects
  - non-photorealistic rendering



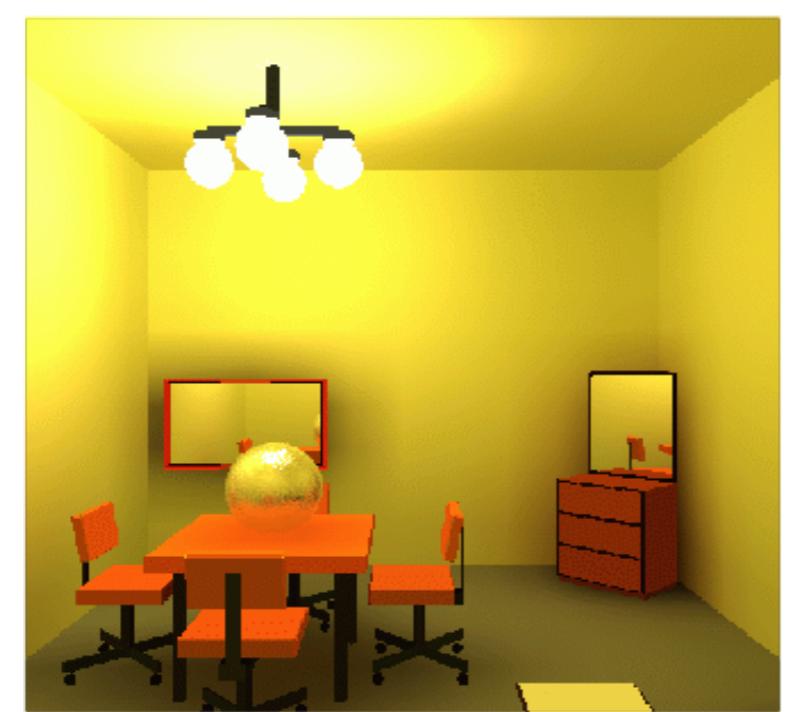
Museum simulation with progressive radiosity  
by Eric Chen, Michael Cohen, 1989



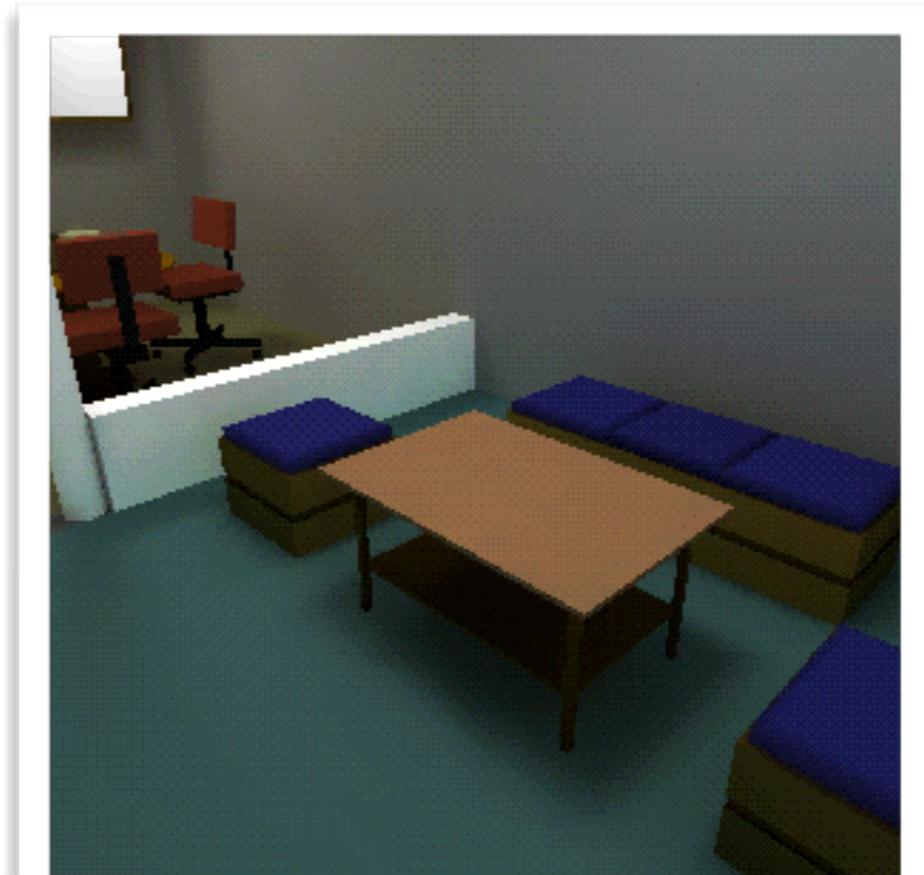
fractal images



© Ken  
Musgrave



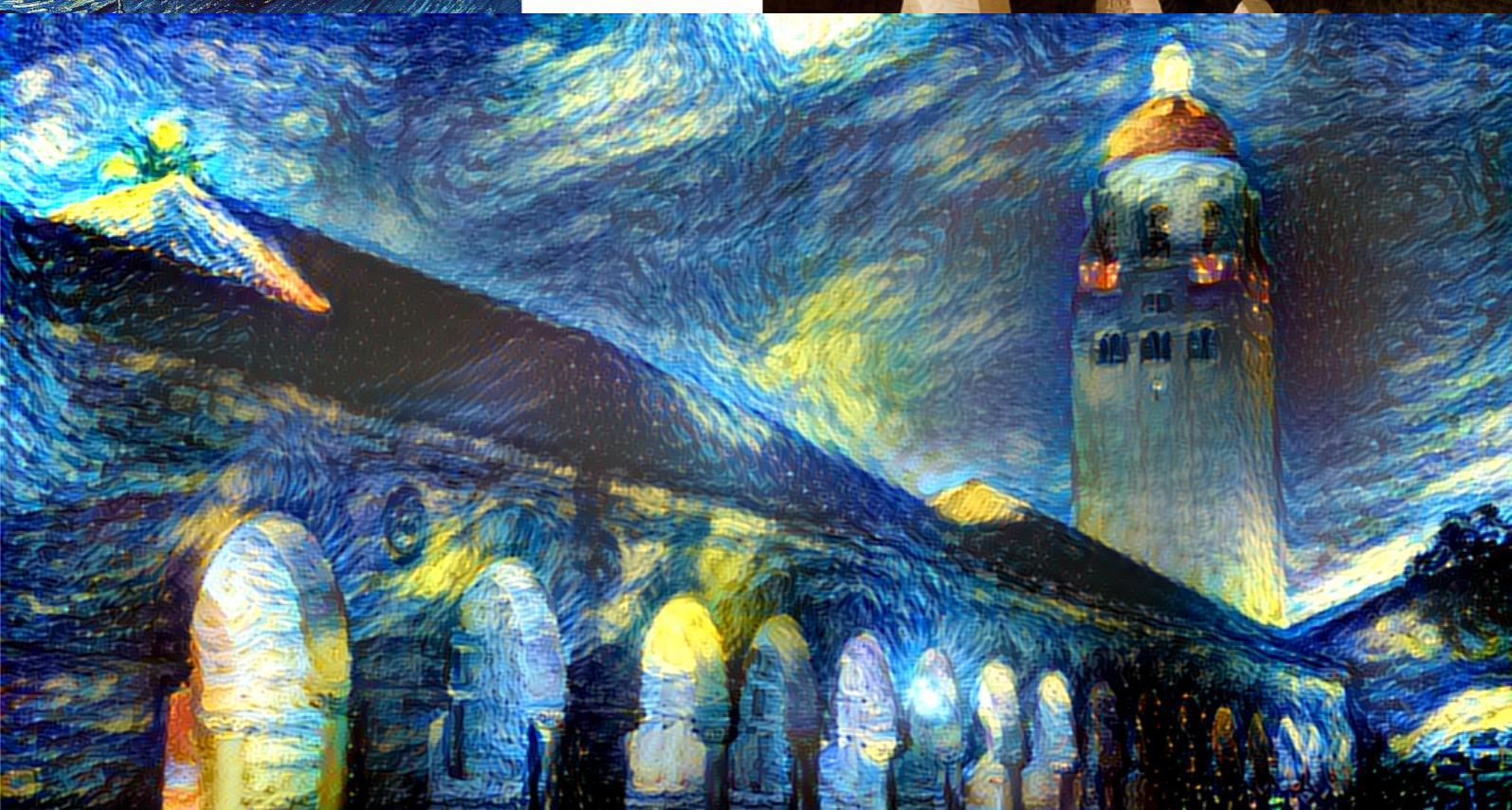
# 3D Graphics and Visualization

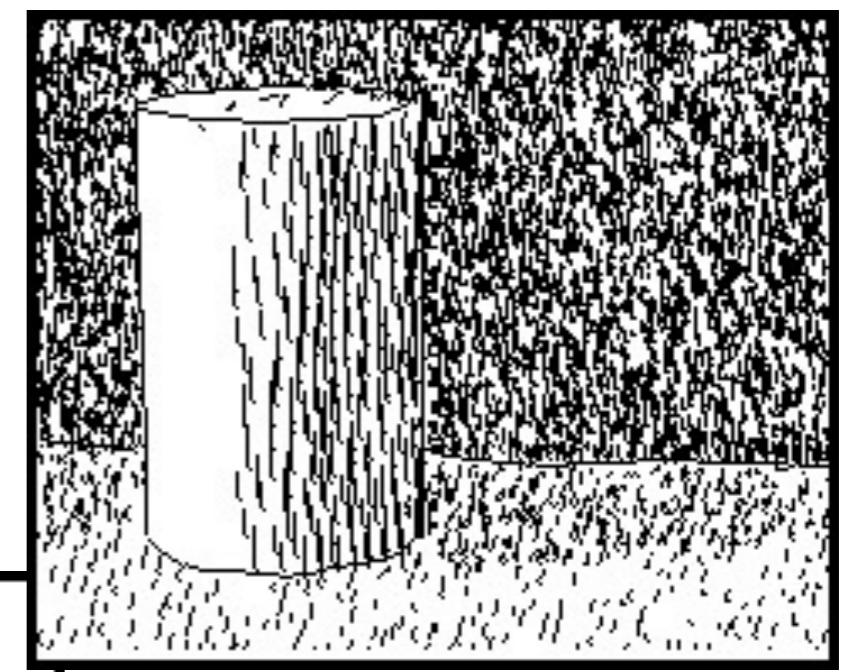
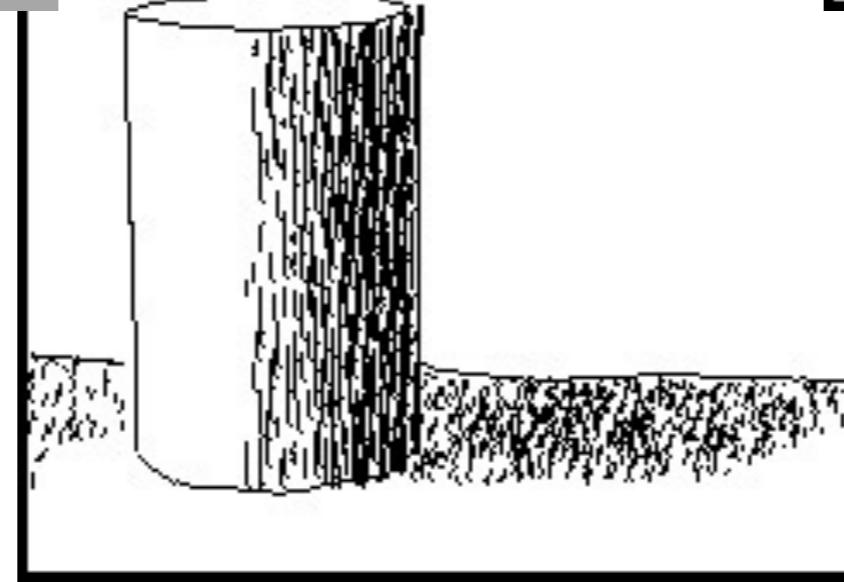
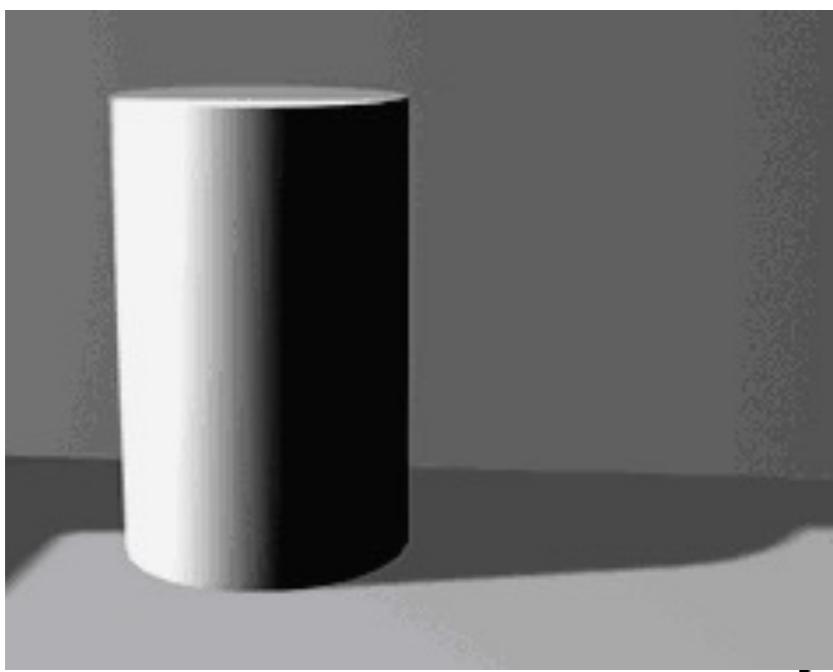


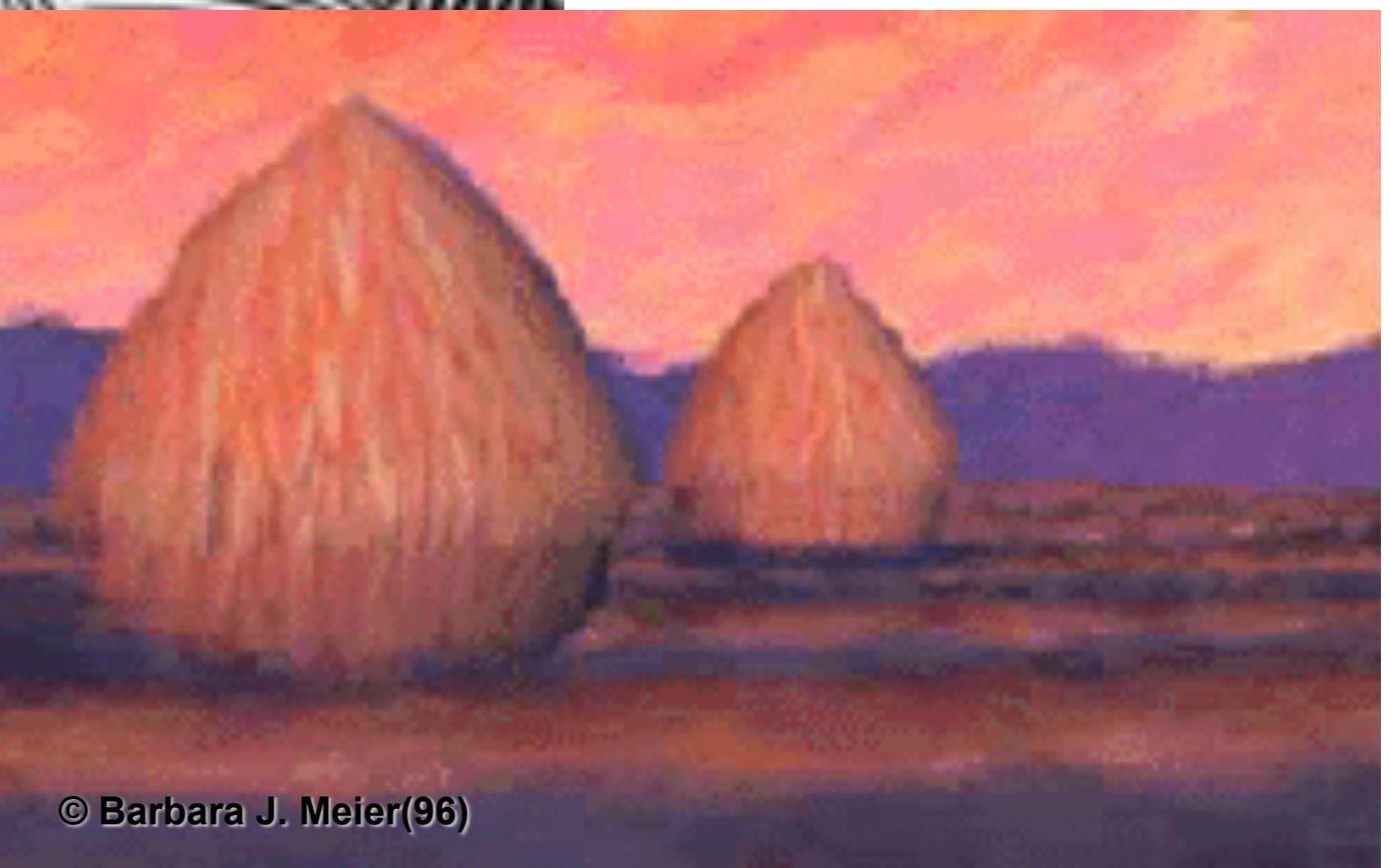
# Topics Not Addressed

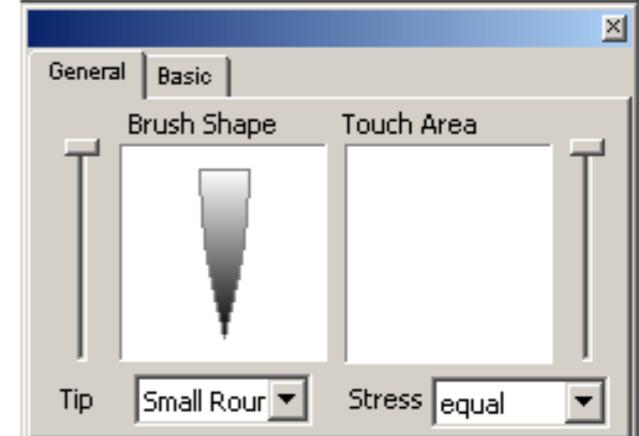
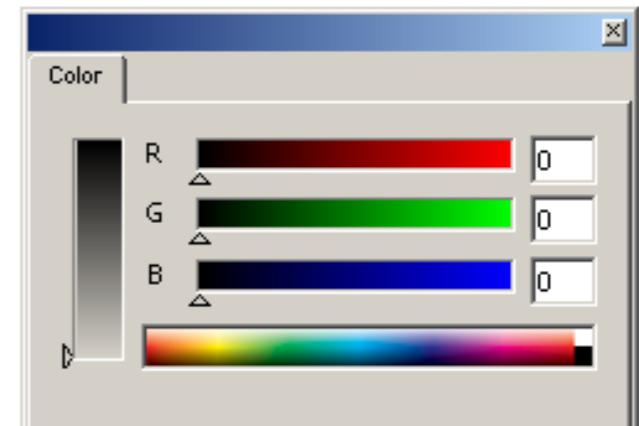
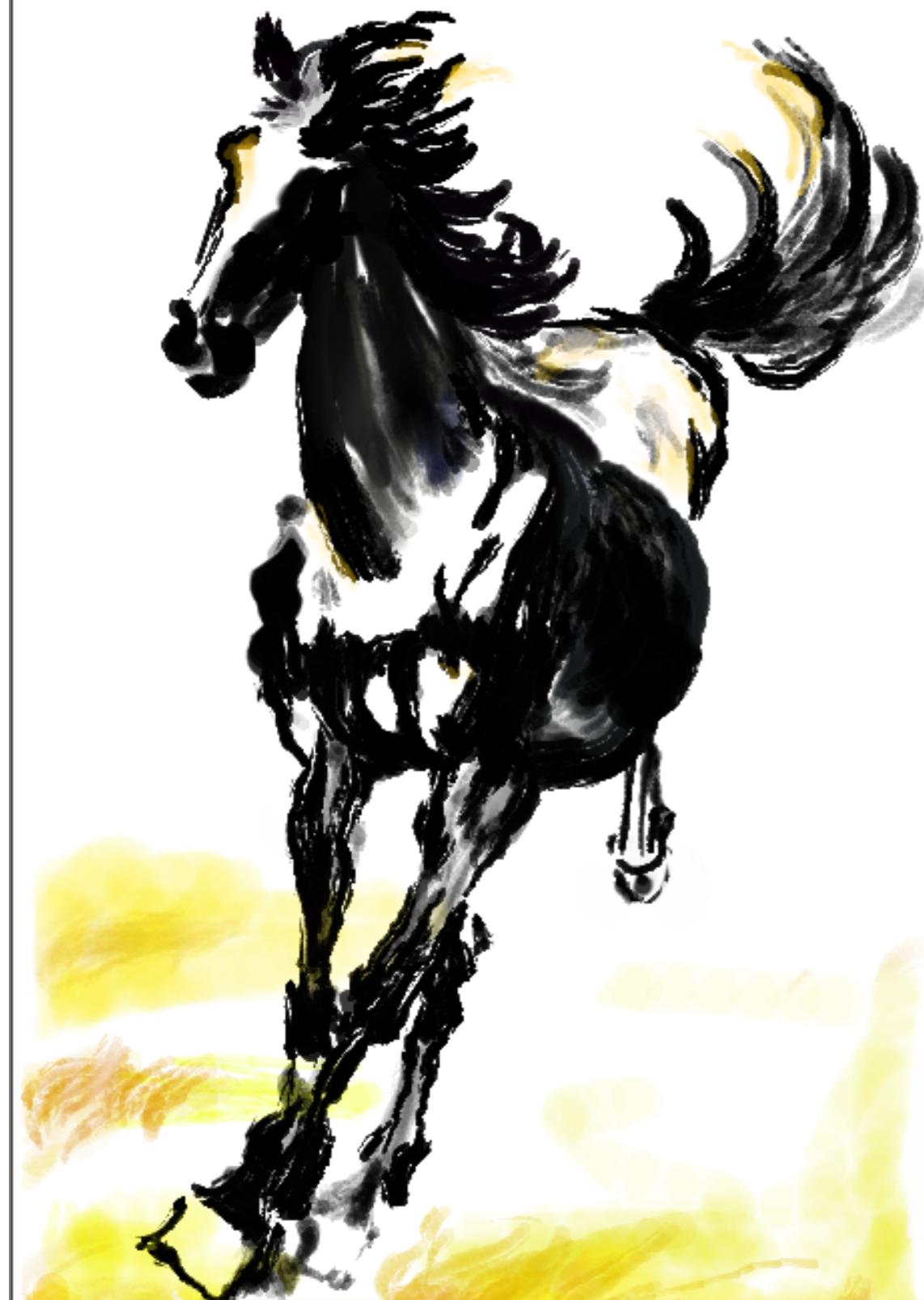
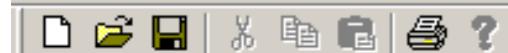
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- Non-photo realistic rendering









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