

# Computer Graphics 2015

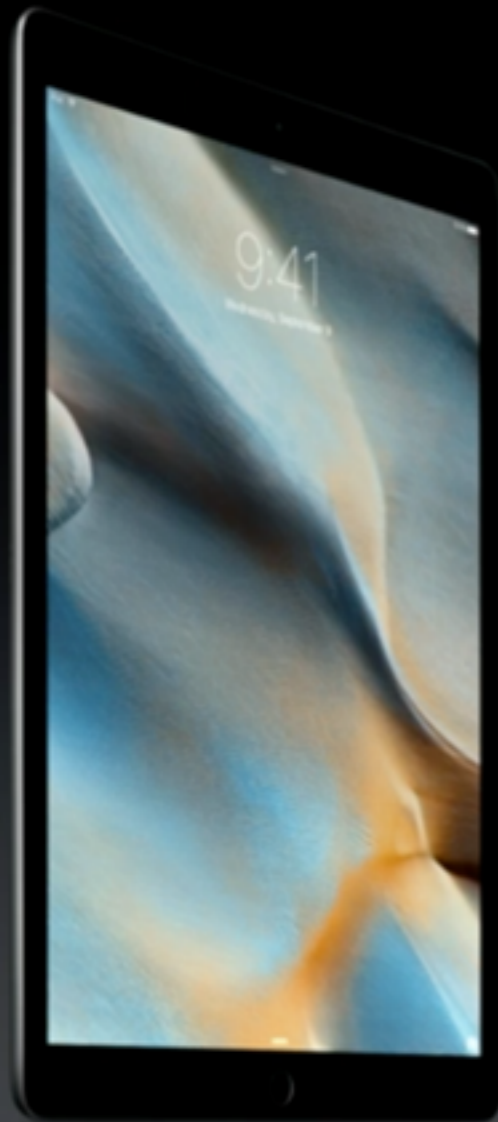
## 1. INTRODUCTION

Hongxin Zhang

State Key Lab of CAD&CG, Zhejiang University

2015-09-14

Why study  
computer graphics?



12.9-inch Retina display

3rd-generation 64-bit A9X chip

Four speaker audio

10-hour battery

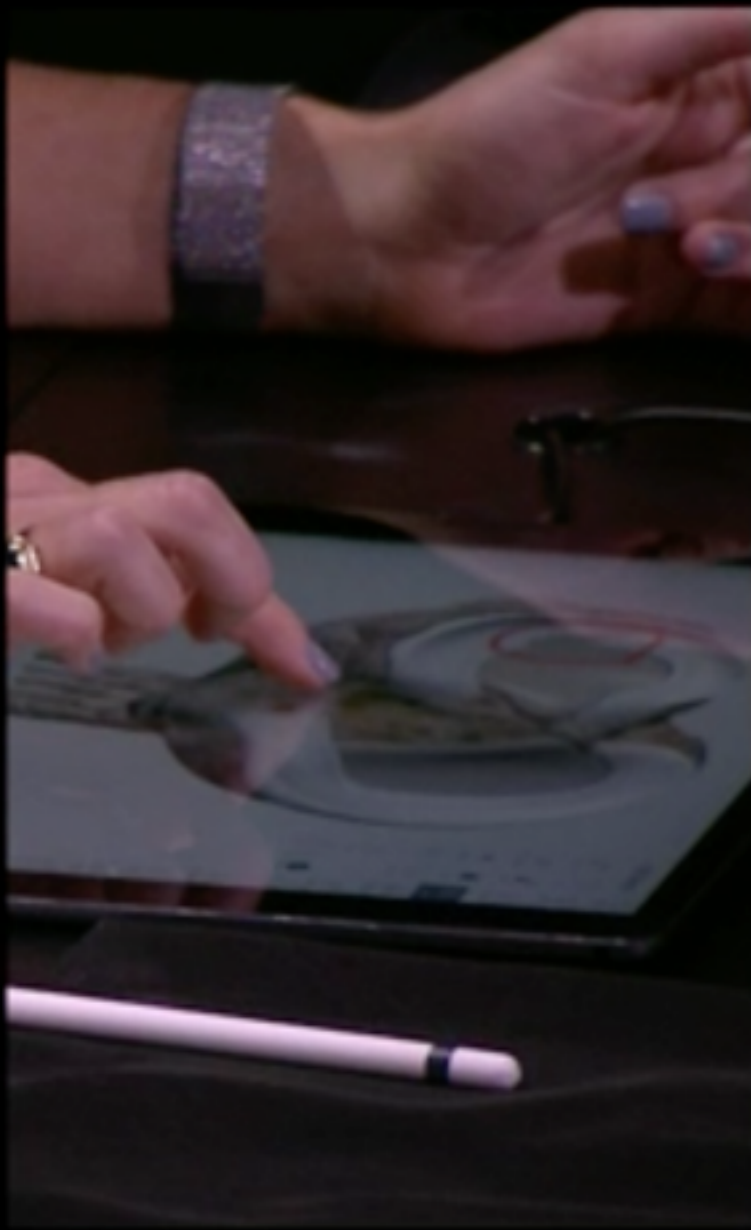
8MP iSight camera

802.11ac with MIMO

Up to 150 Mbps LTE

Touch ID





# Entertainment

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



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

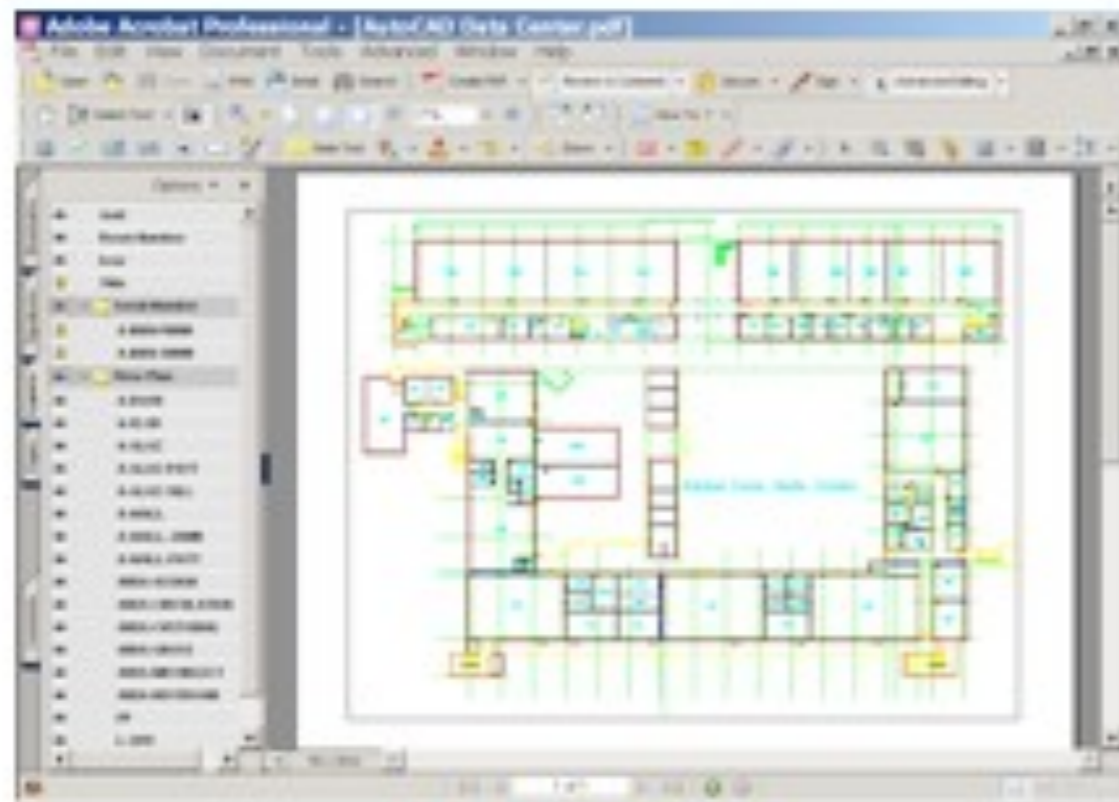
# Computer-Aided Design

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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)**

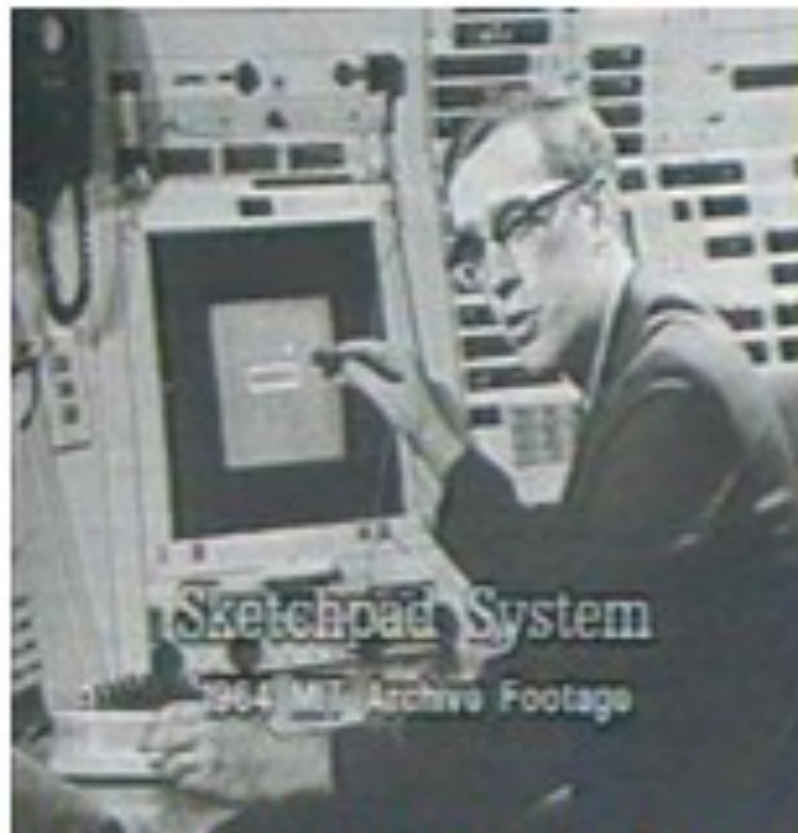
**With new possibilities for creating and mixing content from different sources**

# 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**

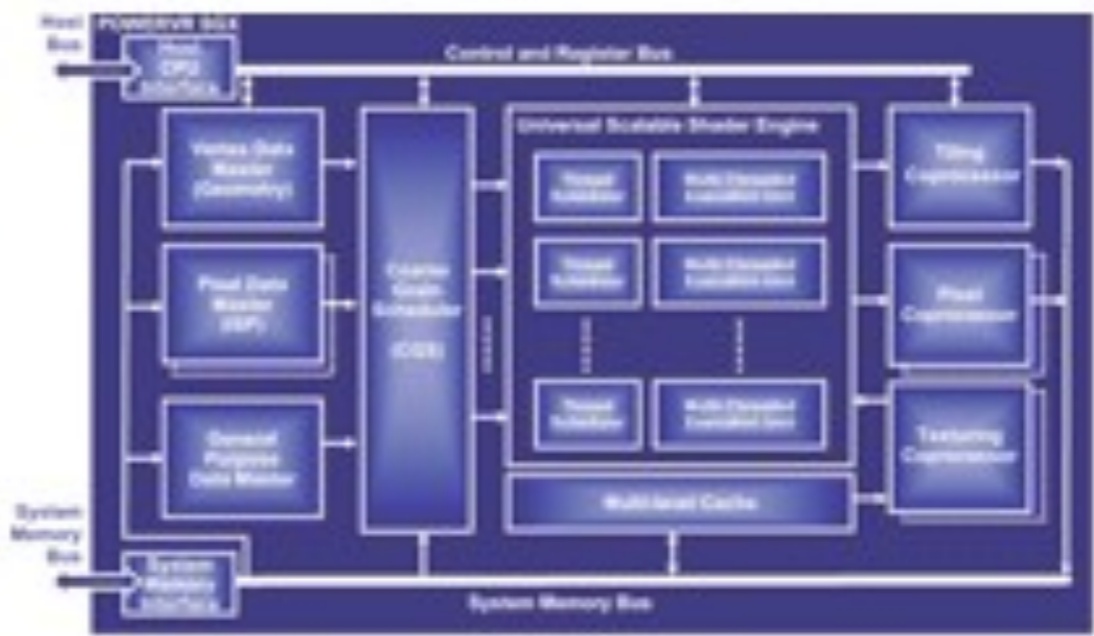
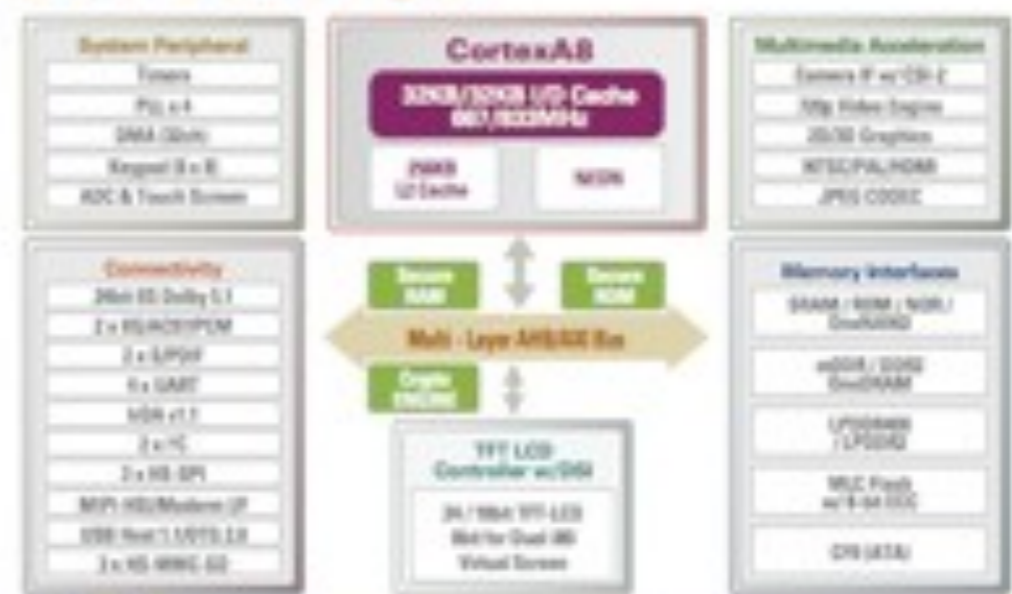
# Innovation in Hardware & Software

## iPhone and iPad



**Apple A4 = CPU+GPU**

### S5PC100 Block Diagram



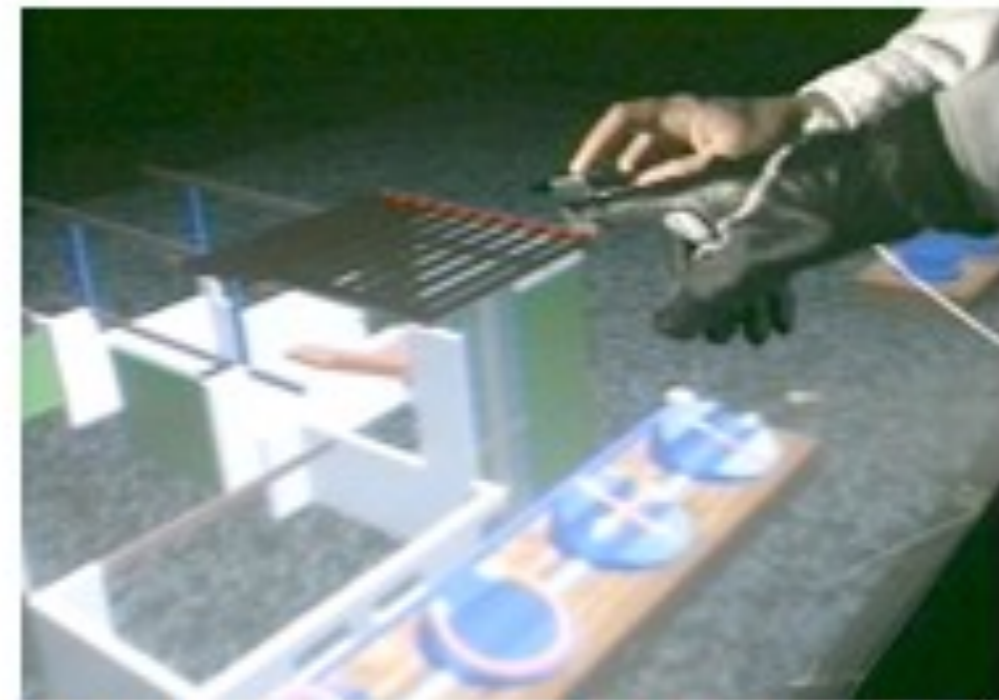
# Ultimate Display: Virtual Reality

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## Immersive interfaces

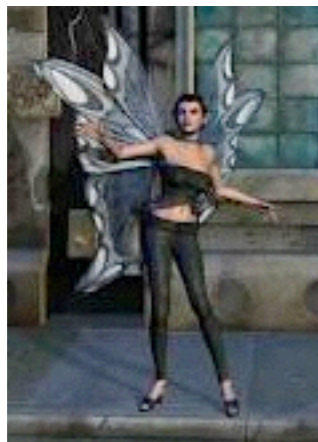
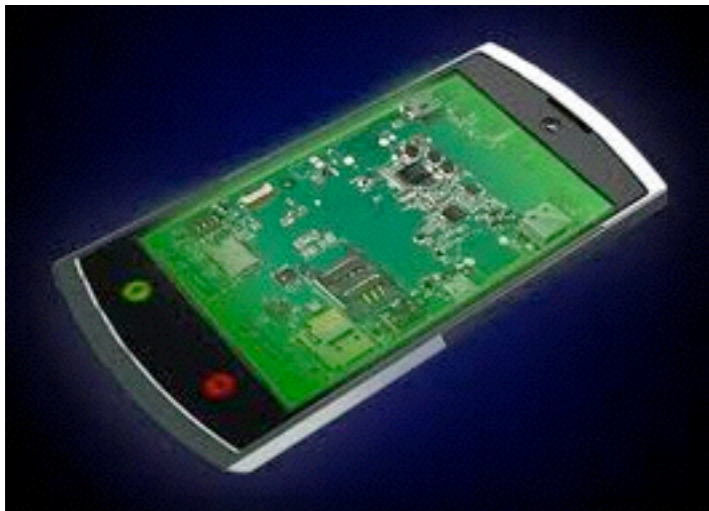
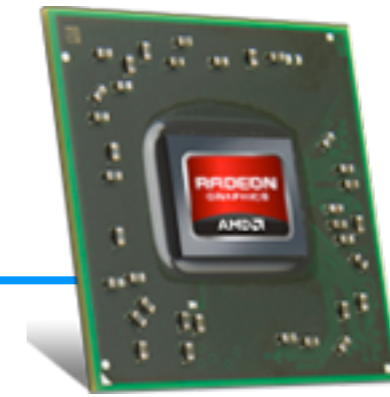
- **Input: 3D 6-DOF tracking, gloves**
- **Output: Head-mounted and projection displays**

**Ivan Sutherland**  
Head-mounted displays,  
mechanical tracker



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

# Mobile Graphics



# 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.

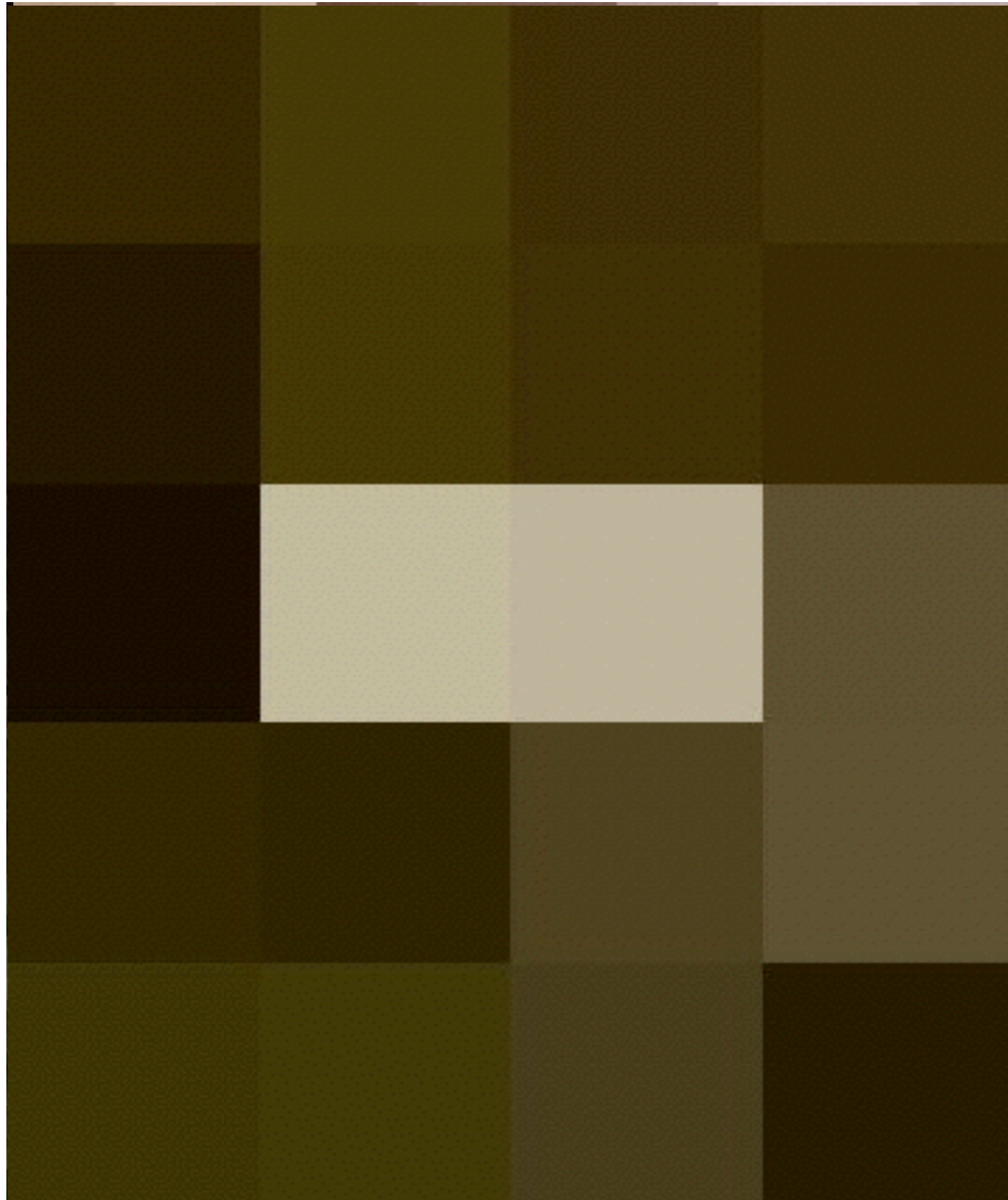
Can we give a definition  
for computer graphics?

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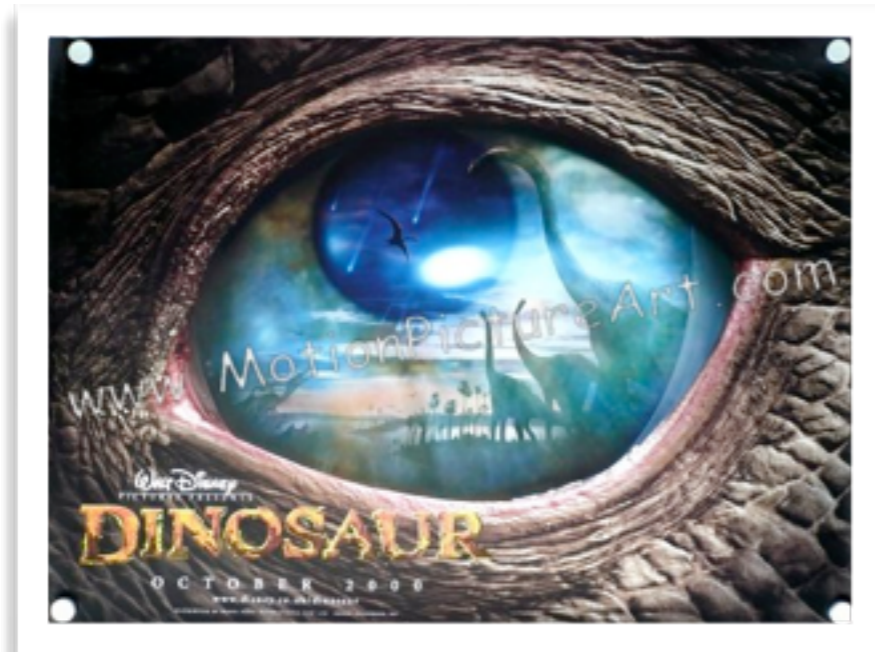
- The pixel has only two properties:
  - area of the pixel is fixed
  - color of the pixel is set under program control
  
- Image: array of pixels

# 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 ?

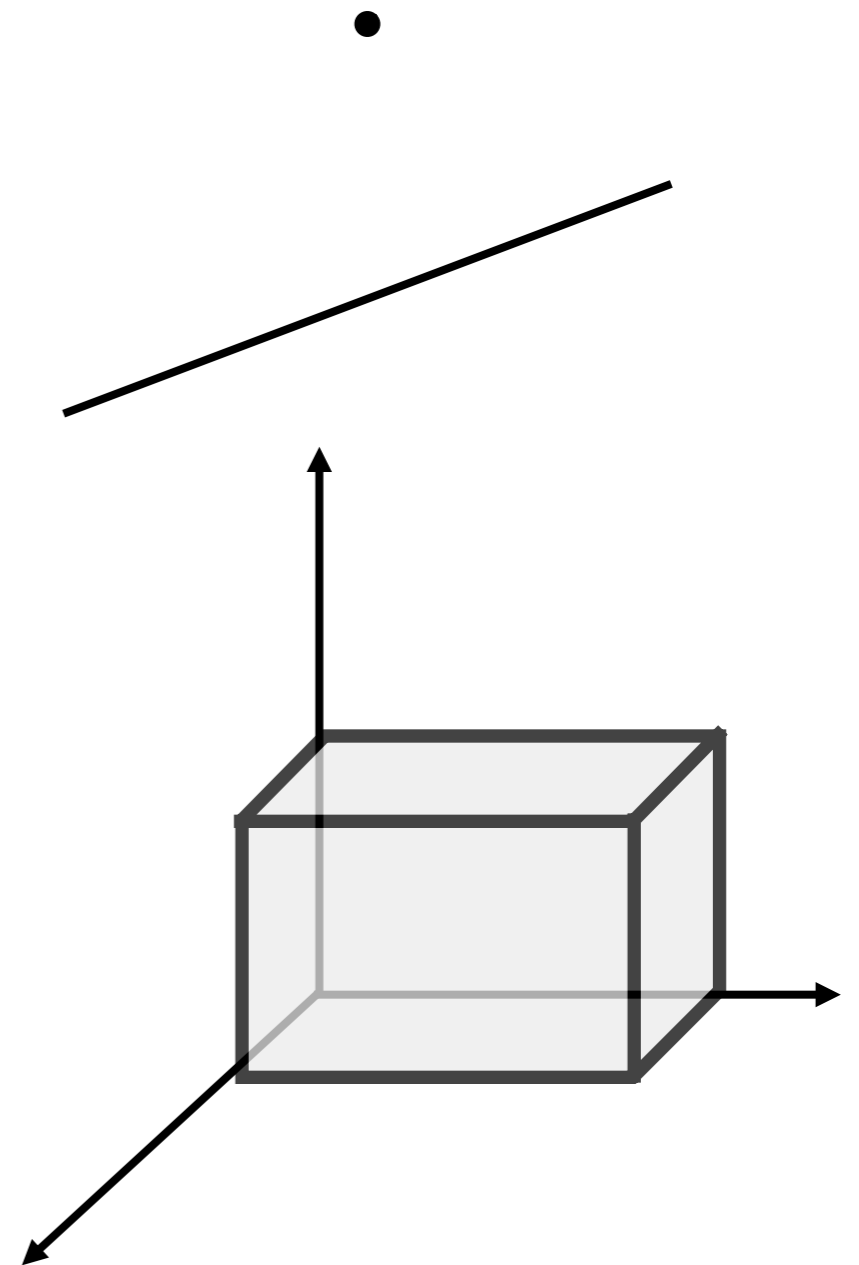
# Graphics Representation

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- 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
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# Three Fundamental Tasks

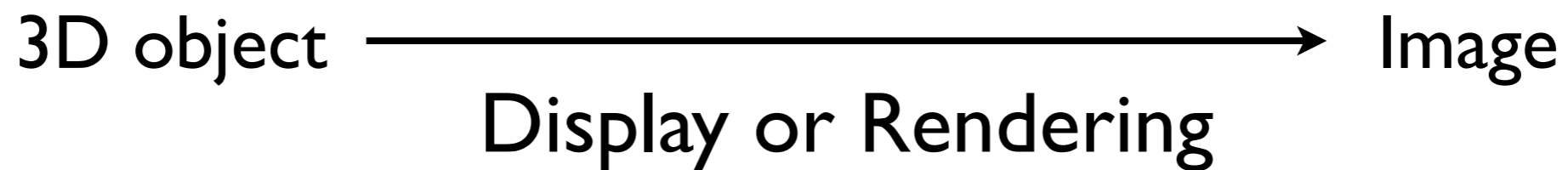
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- Modeling the World (World Representation)
  - Simulating the behavior of objects in the world
  - **Displaying the World**
- 
- Geometry and Physics are the traditional tools

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

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CAE

2D Drawing  
(AutoCAD)

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

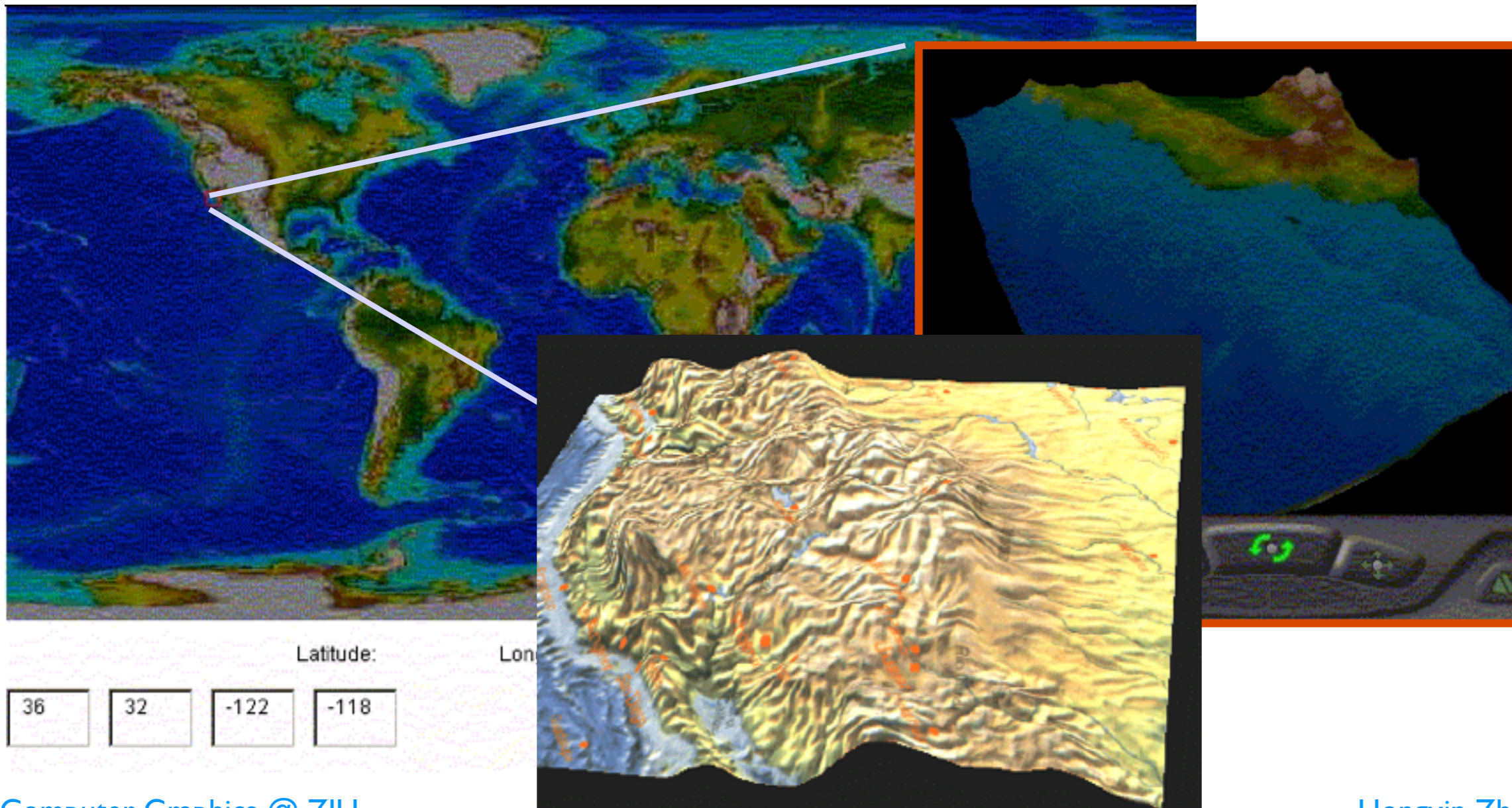
Computer Aided

Design

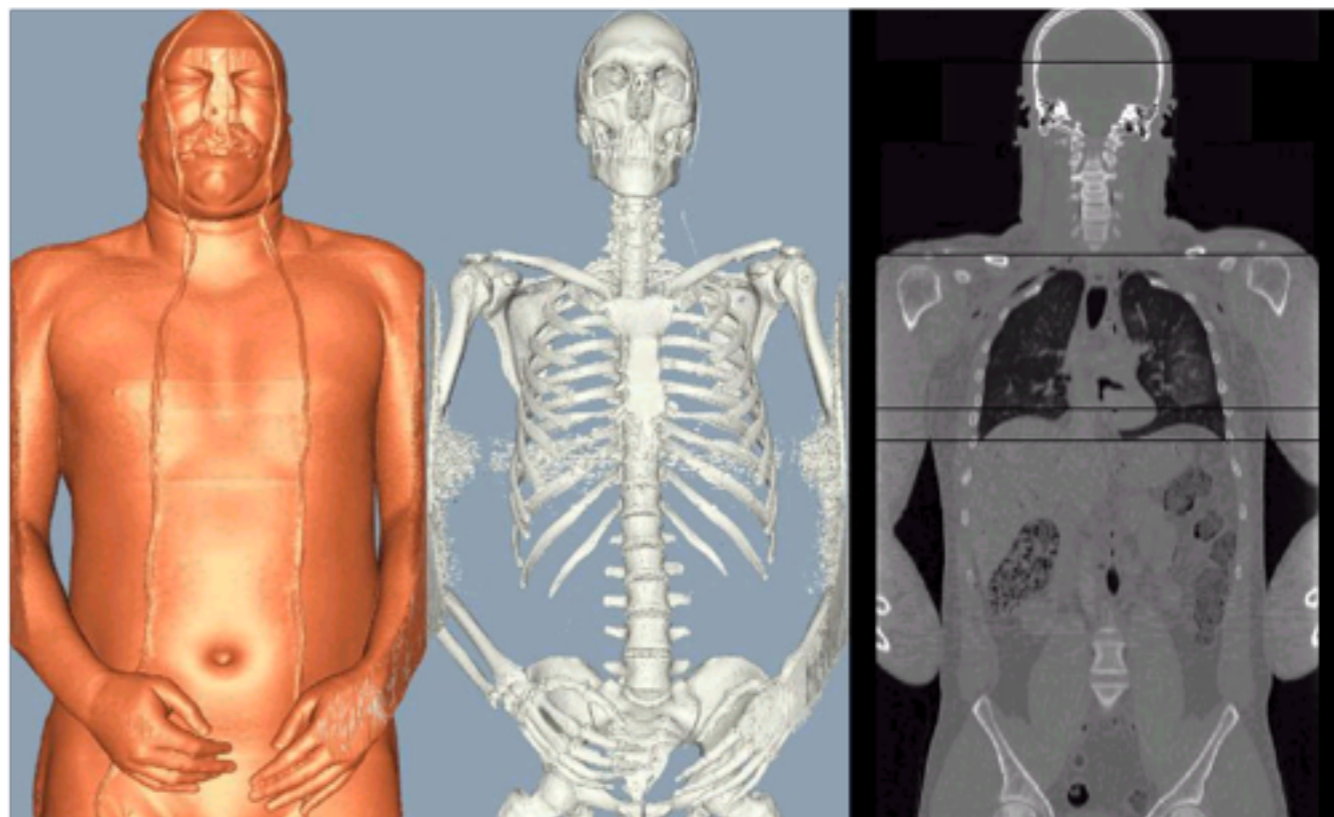
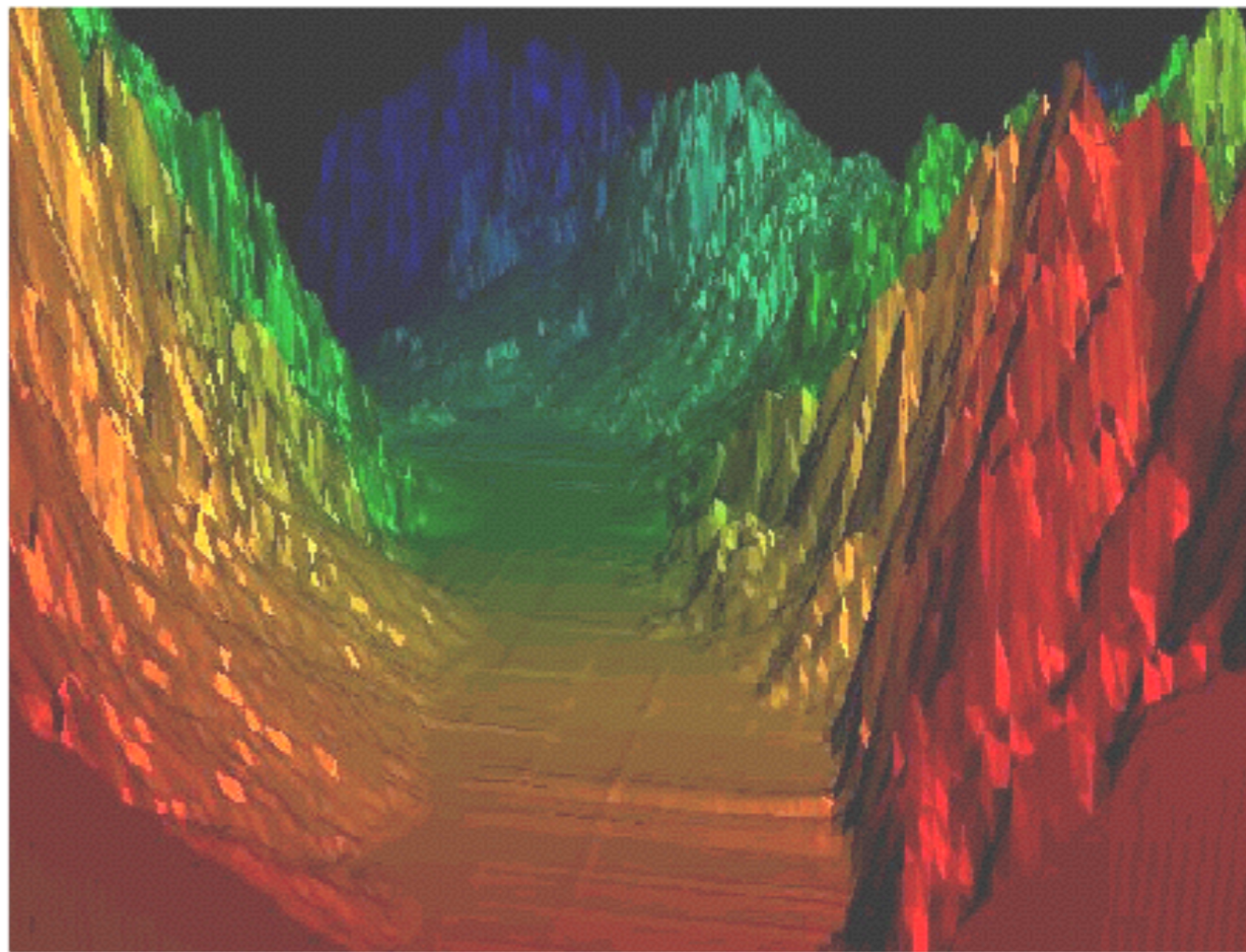
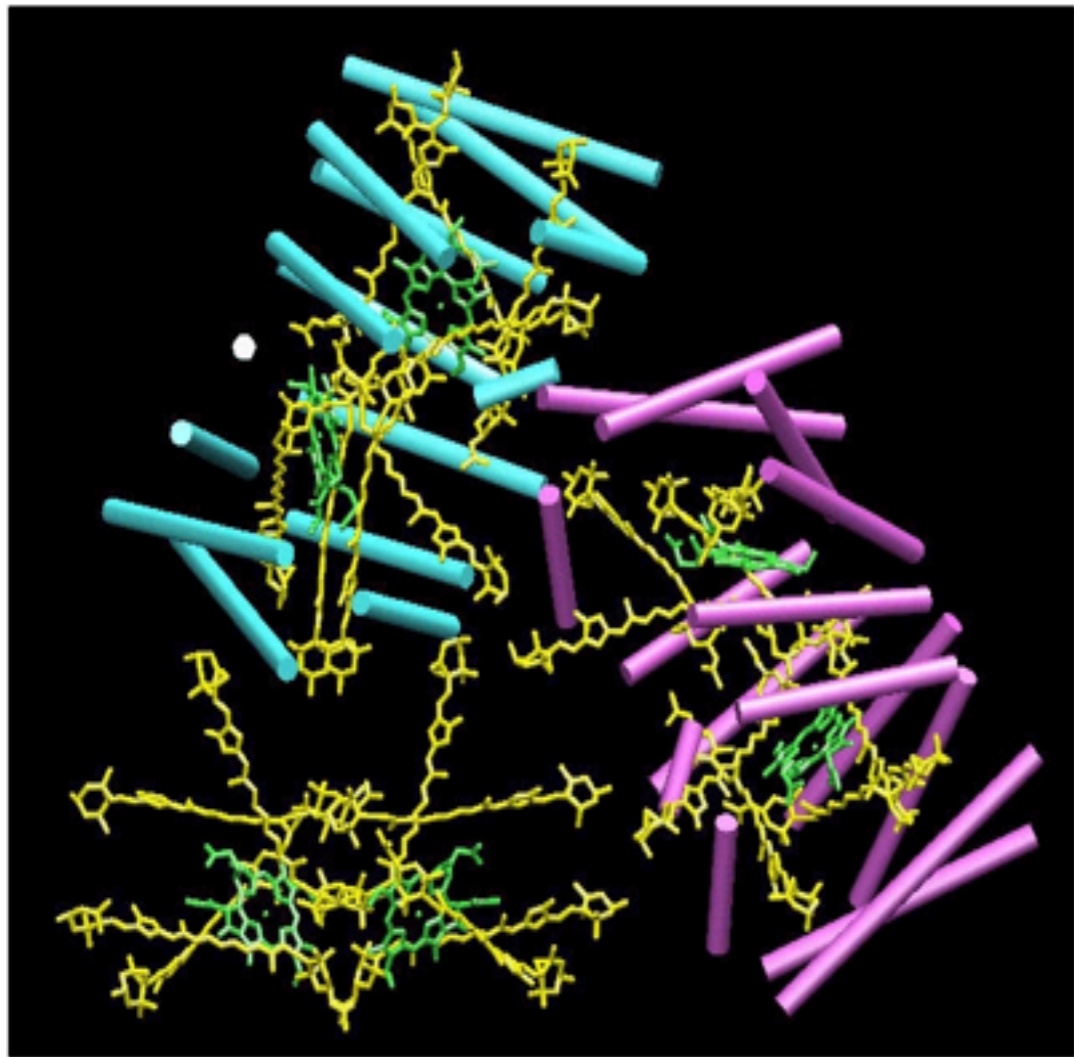
CAM

# Computer Graphics Applications

## GIS: Geography information system



# Visualization



# Virtual Reality



# Technology Developments

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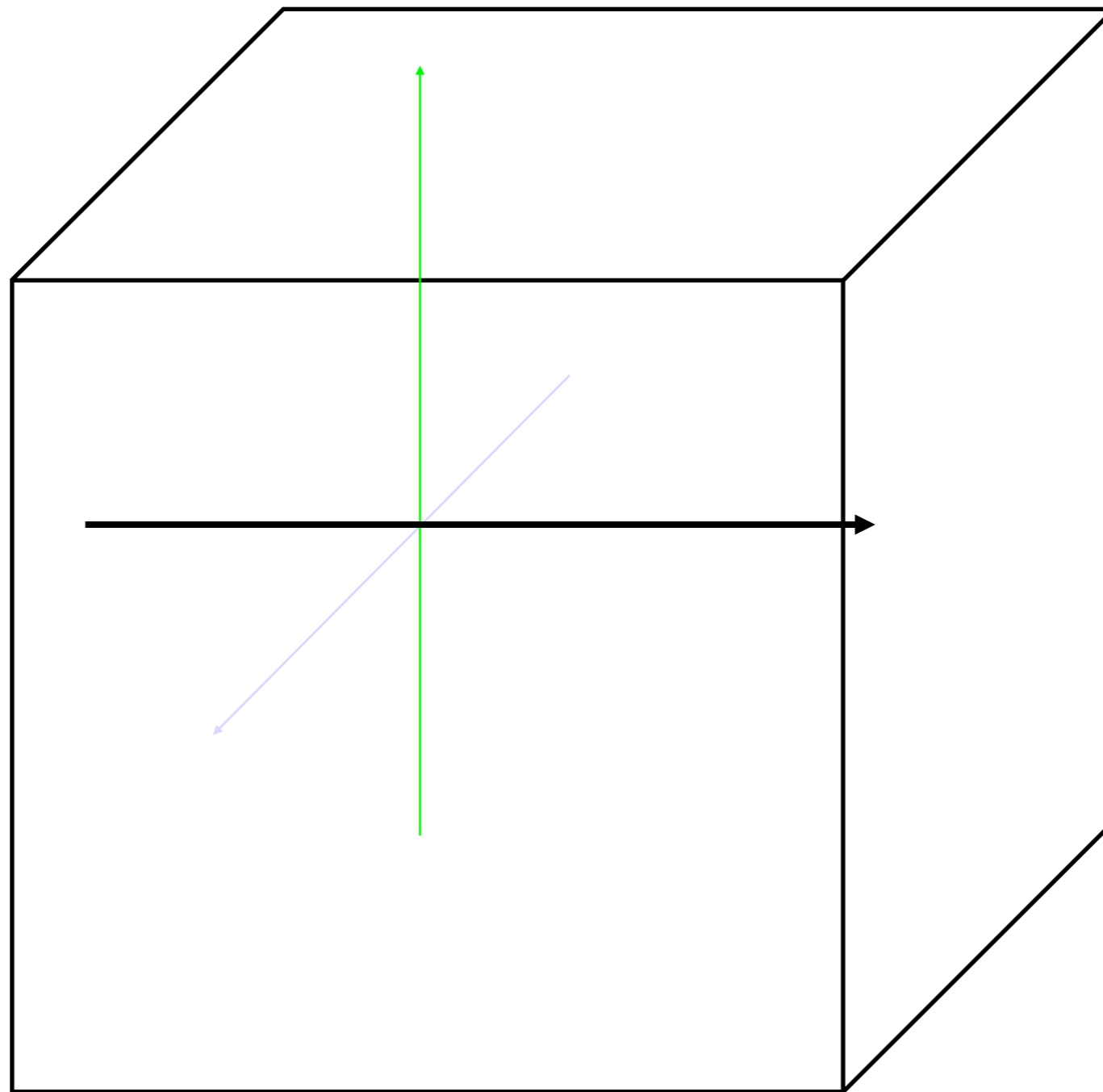
- 1962 : Sutherland's Sketchpad
- 1970s: Special Hardware
- 1980s: Raster Graphics
- 1990s: Reality Engines
- 2000s: 3D acceleration
- 2010s: Mobile graphics
  
- 2020s: ??? Intelligence ???



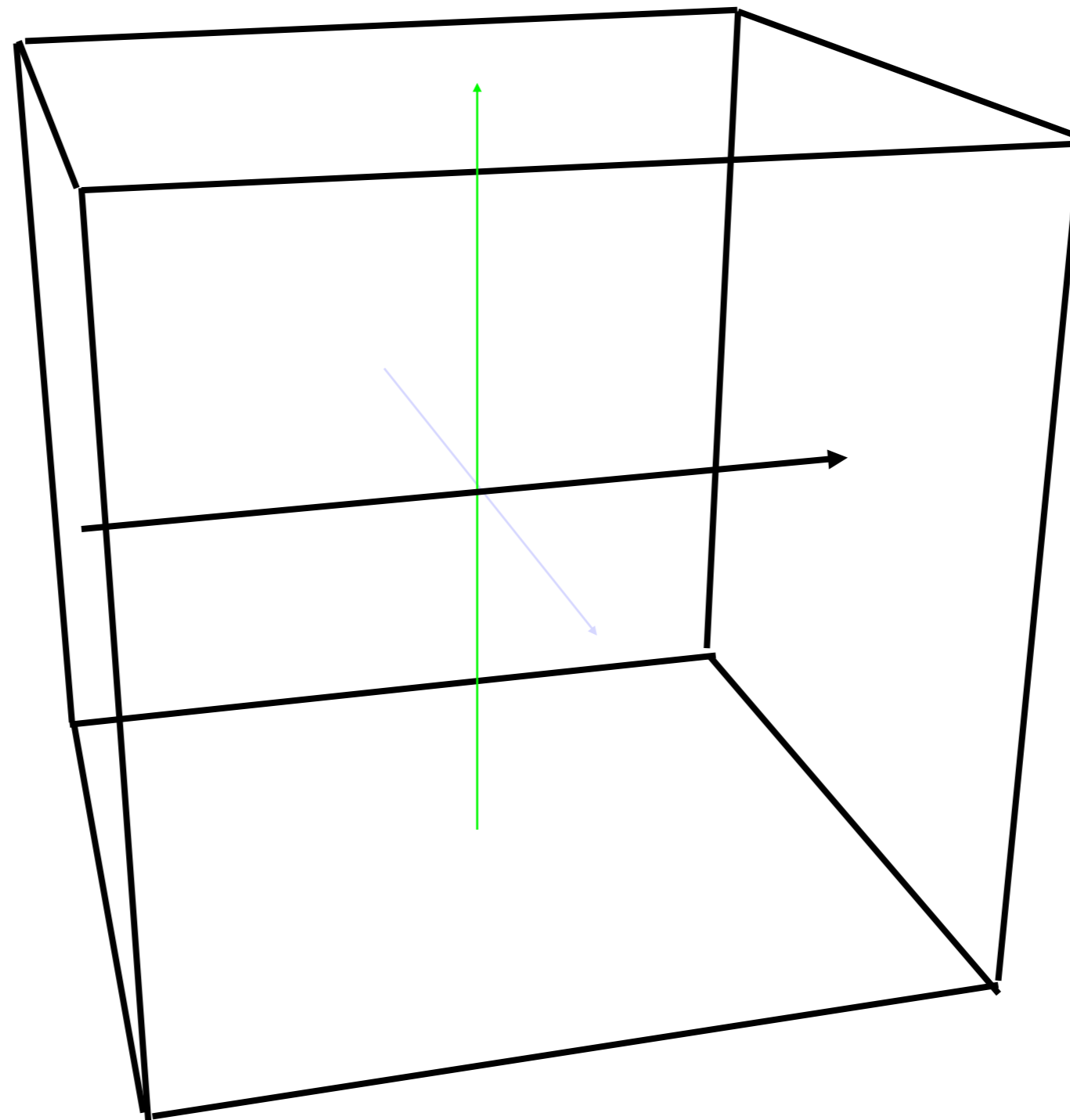
# Topics Addressed in this Class

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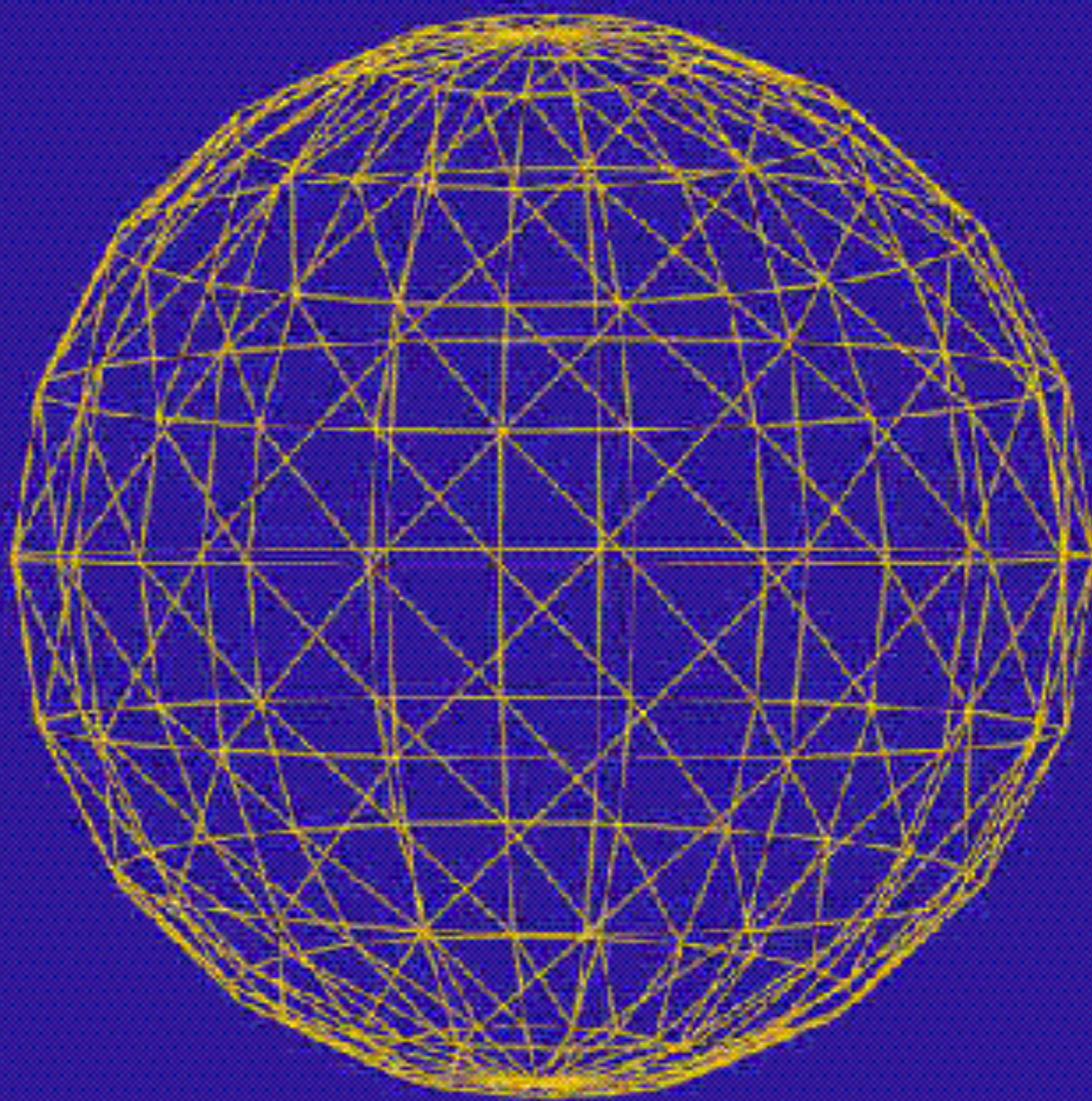
- Basics - Transformations and Synthetic Camera for Viewing the World
- Modeling techniques and tools - Meshes, Surfaces and Solid Objects



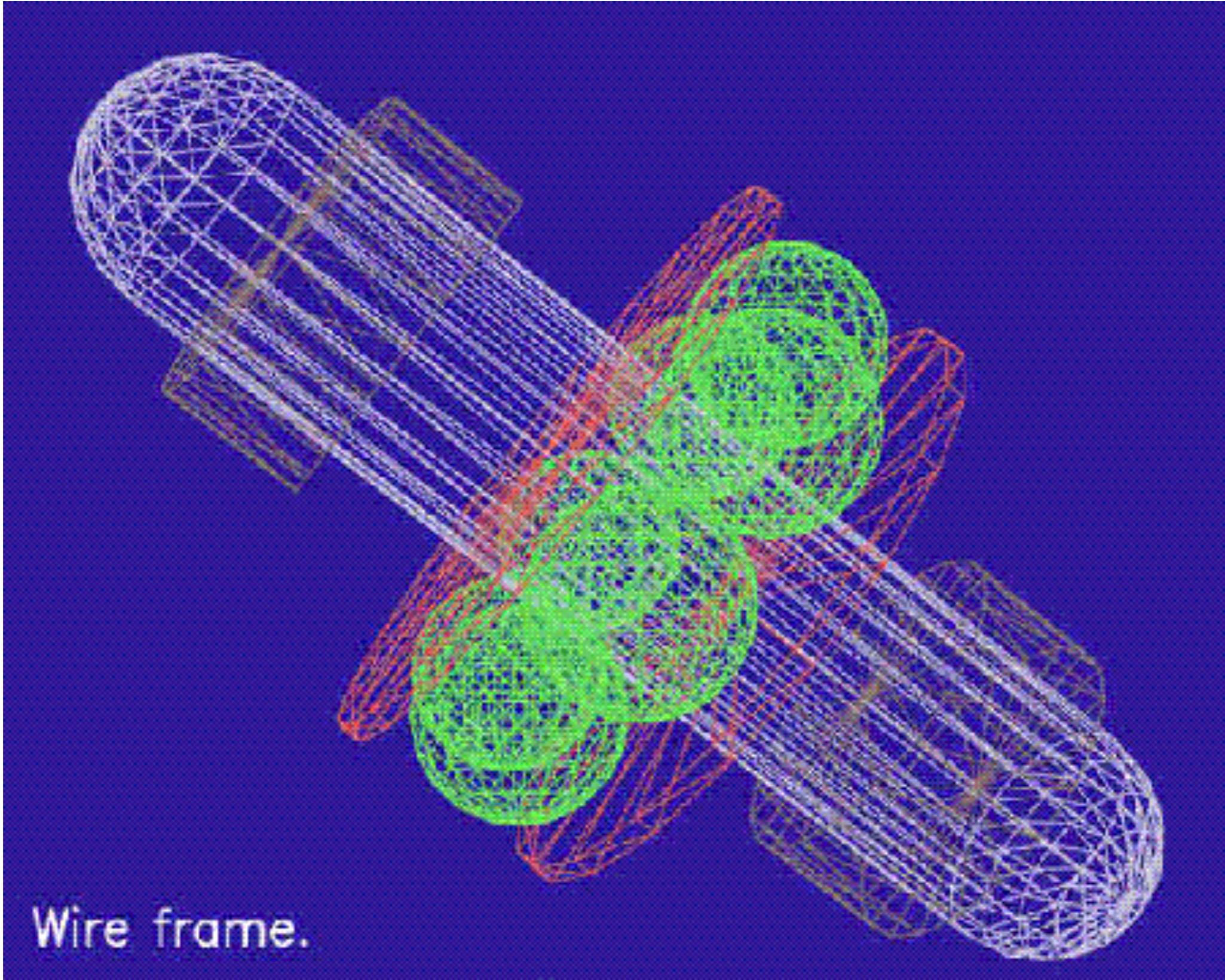
**Parallel Projection**



Perspective Projection



Wire frame.

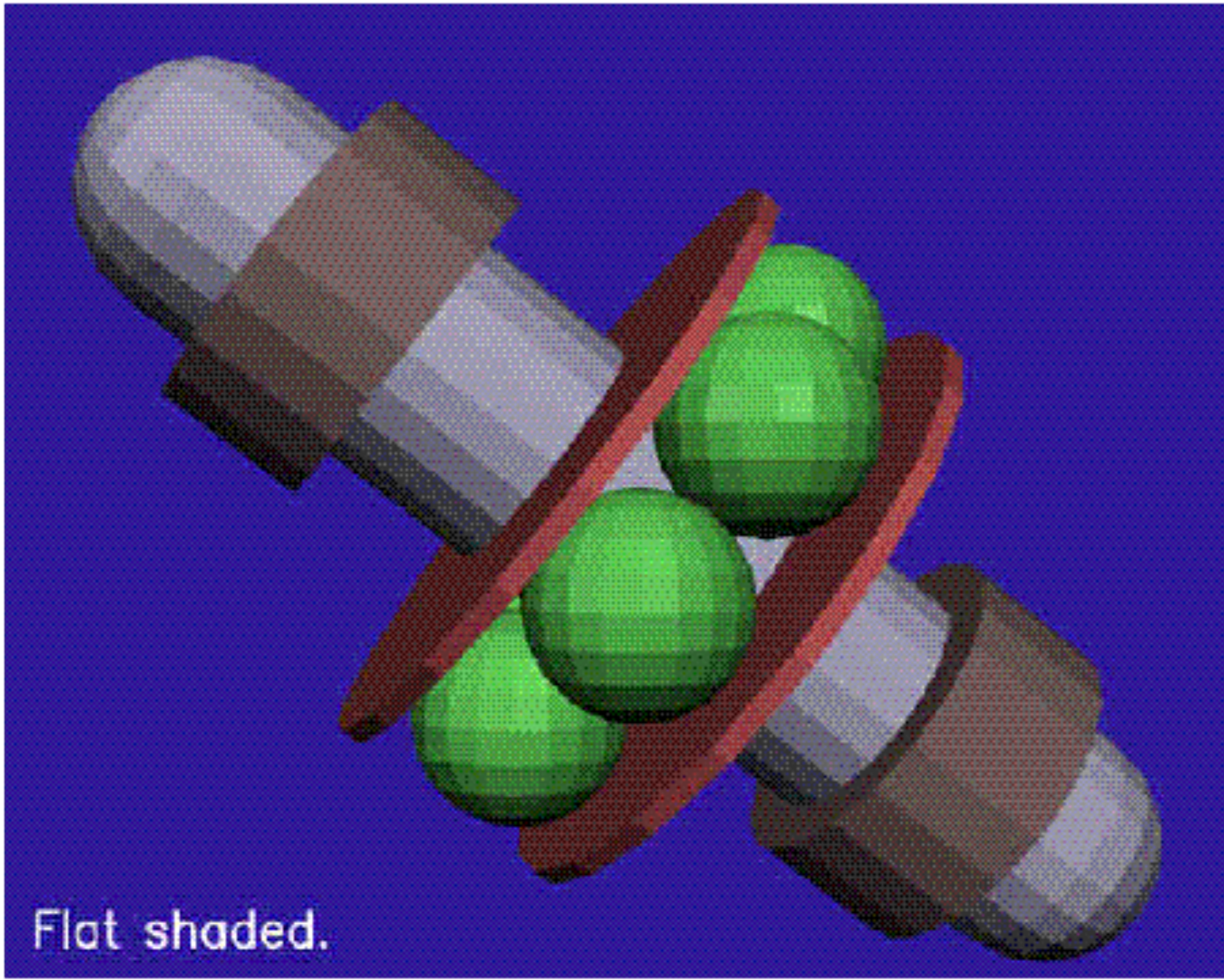


Wire frame.

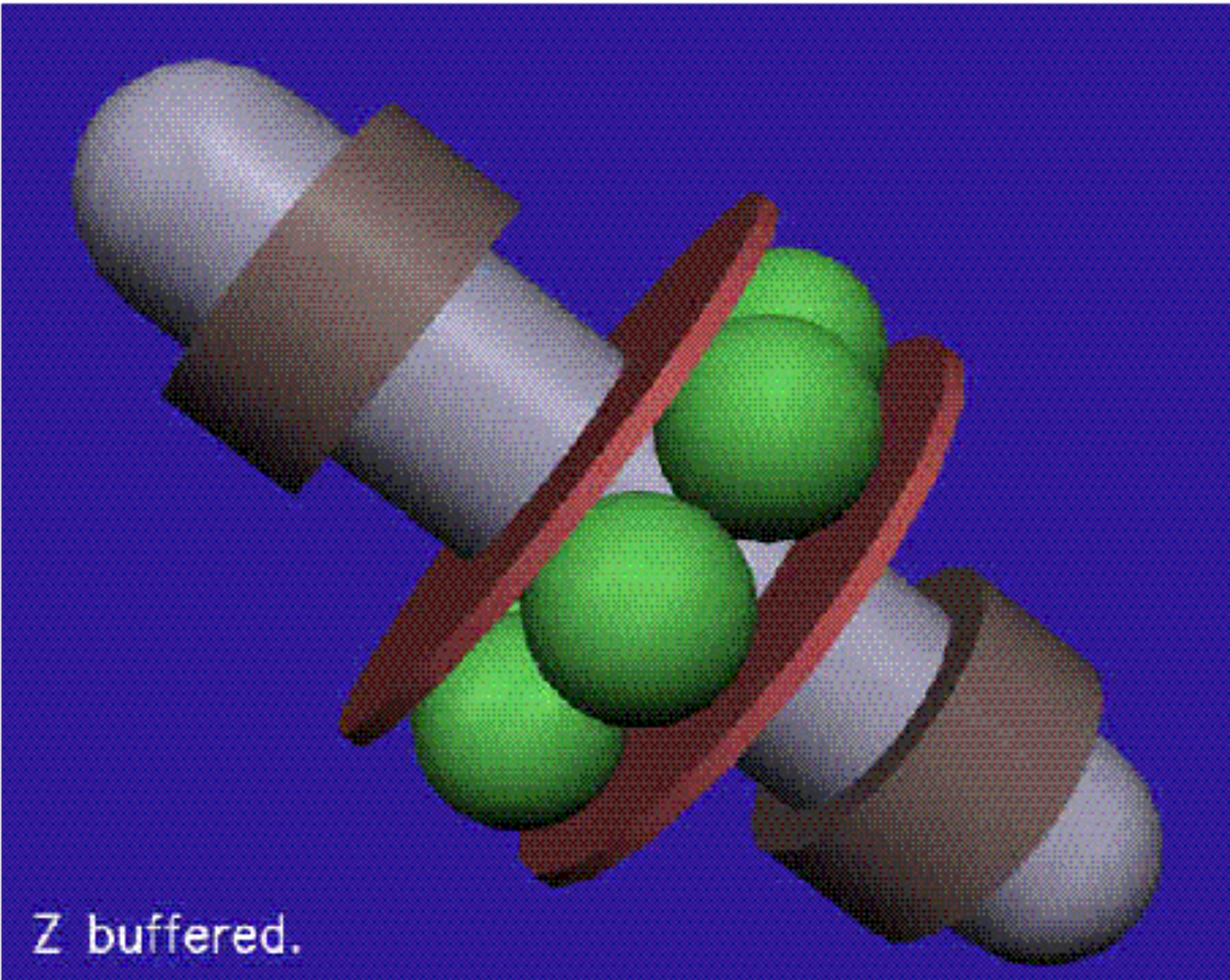
# Topics Addressed (contd)

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

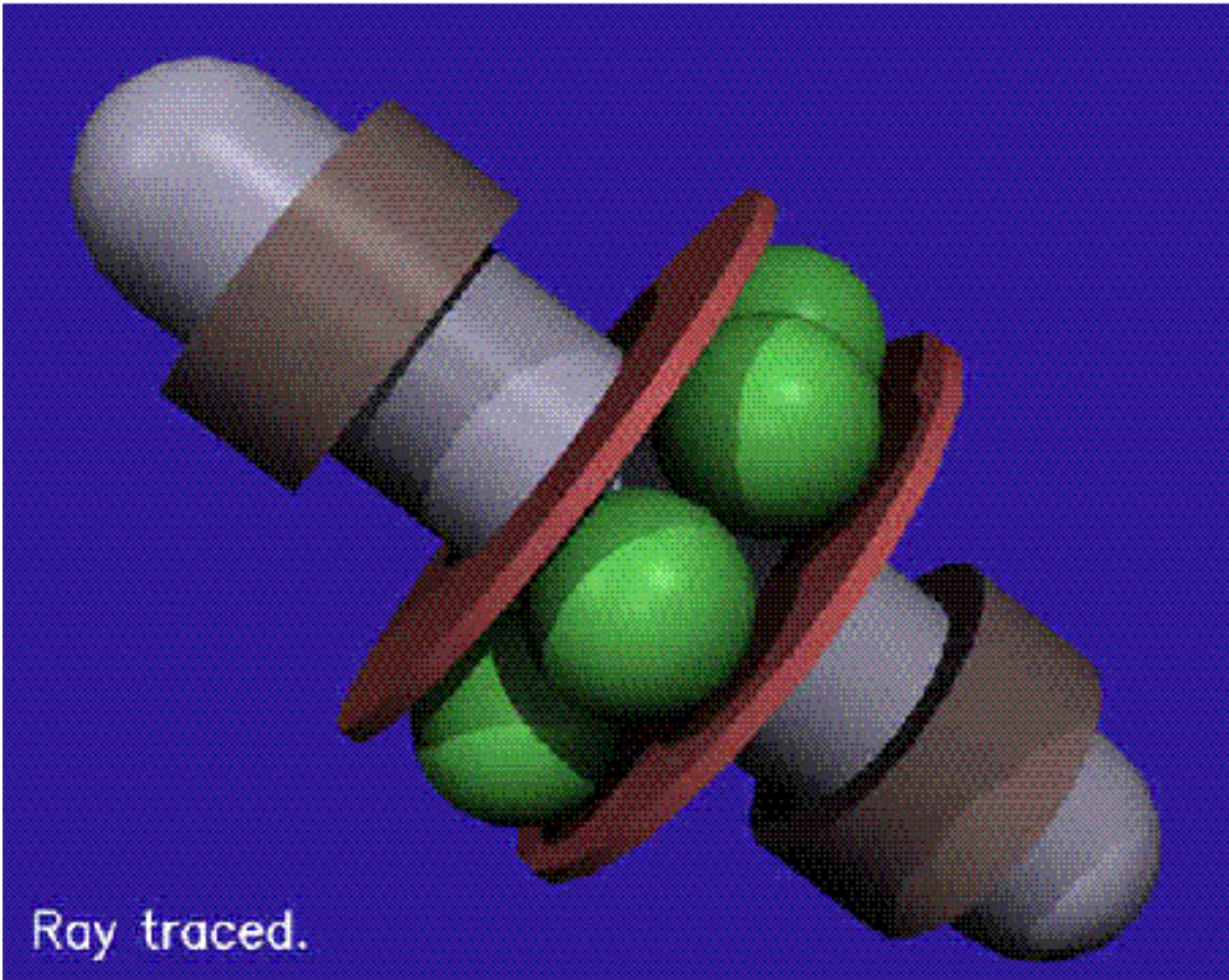


Flat shaded.

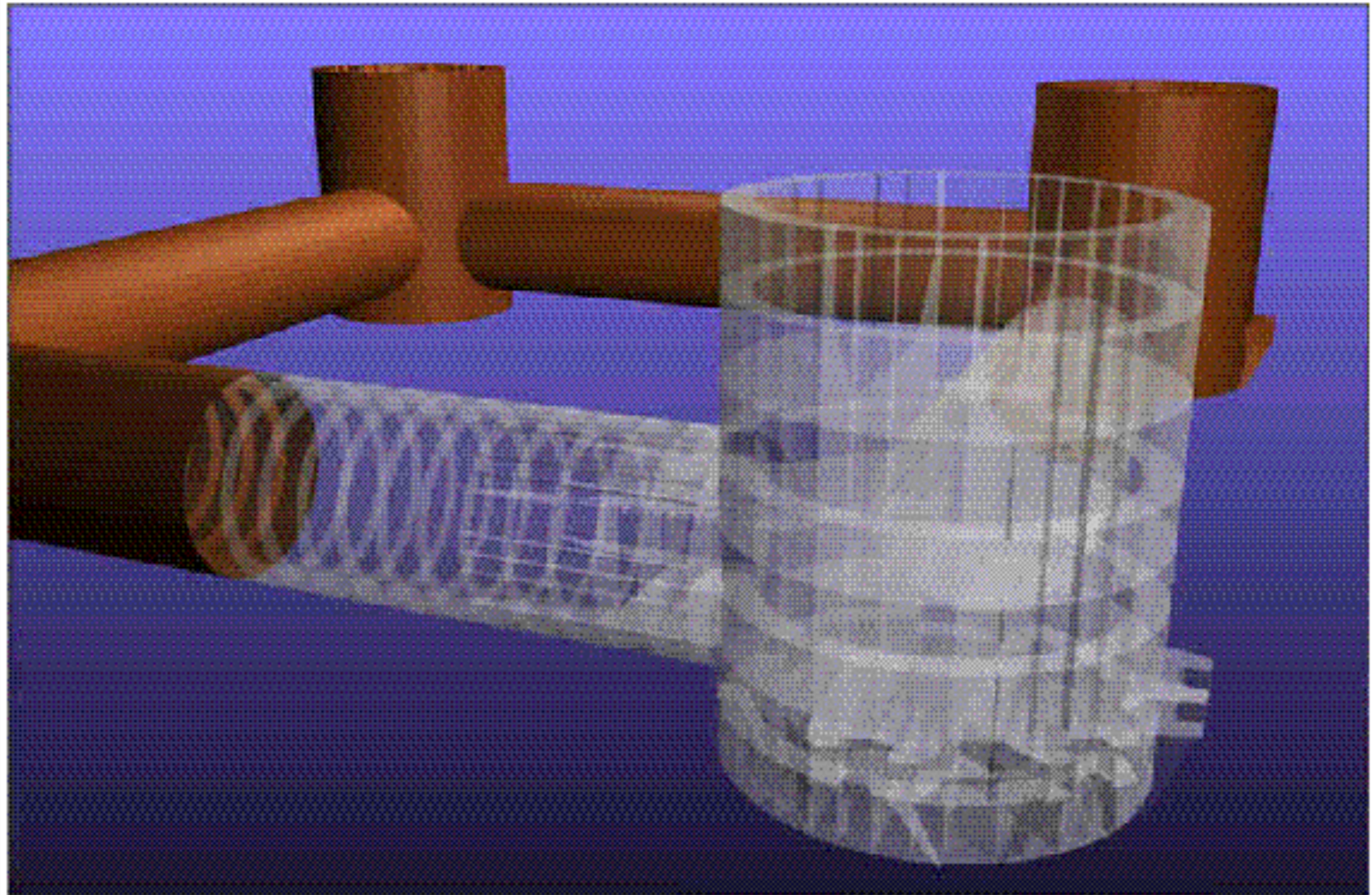


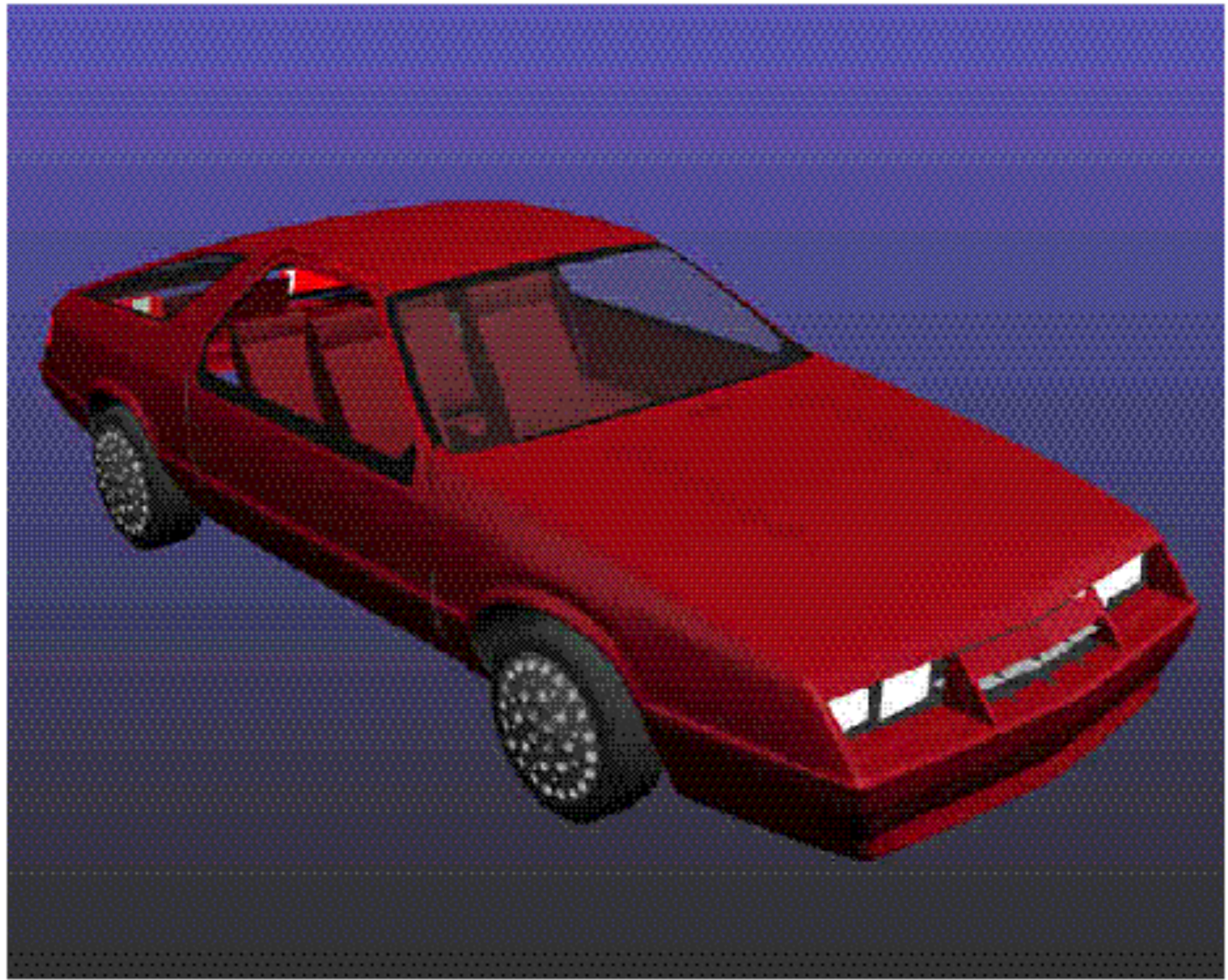
Z buffered.





Ray traced.

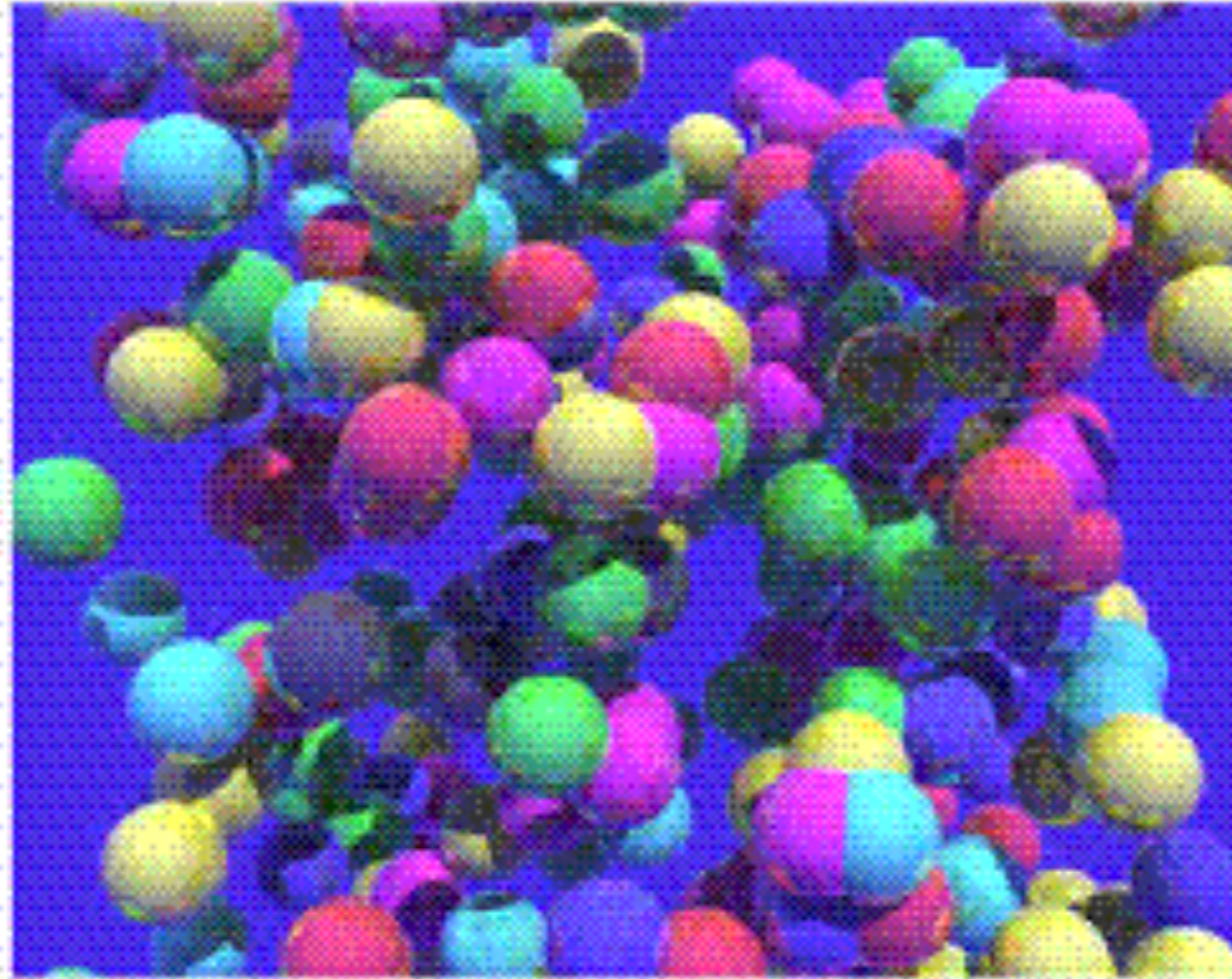




# Texture Mapping

## (Only Brief Overview)

# SPHEREO's

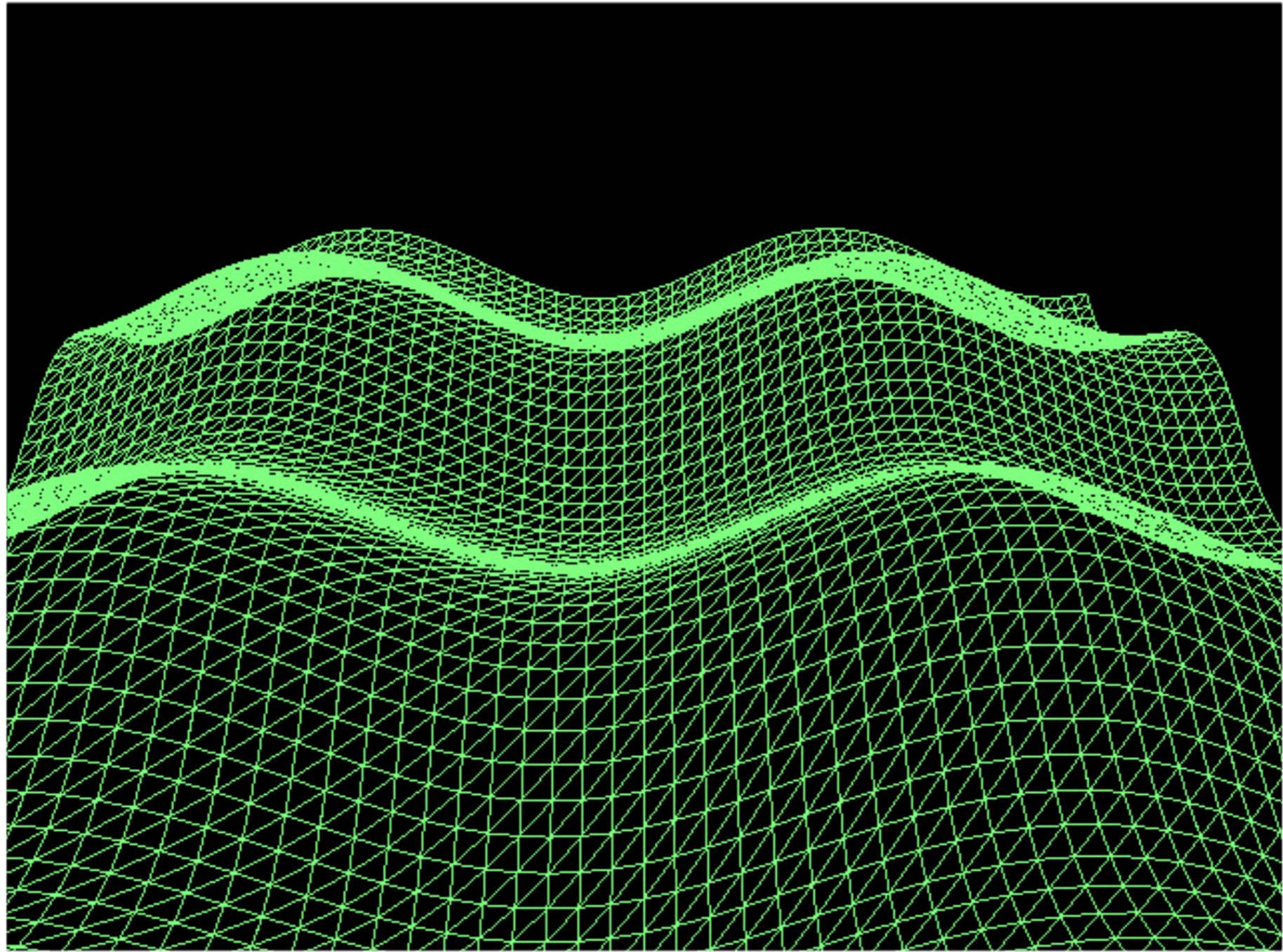


*A different color  
in every byte*

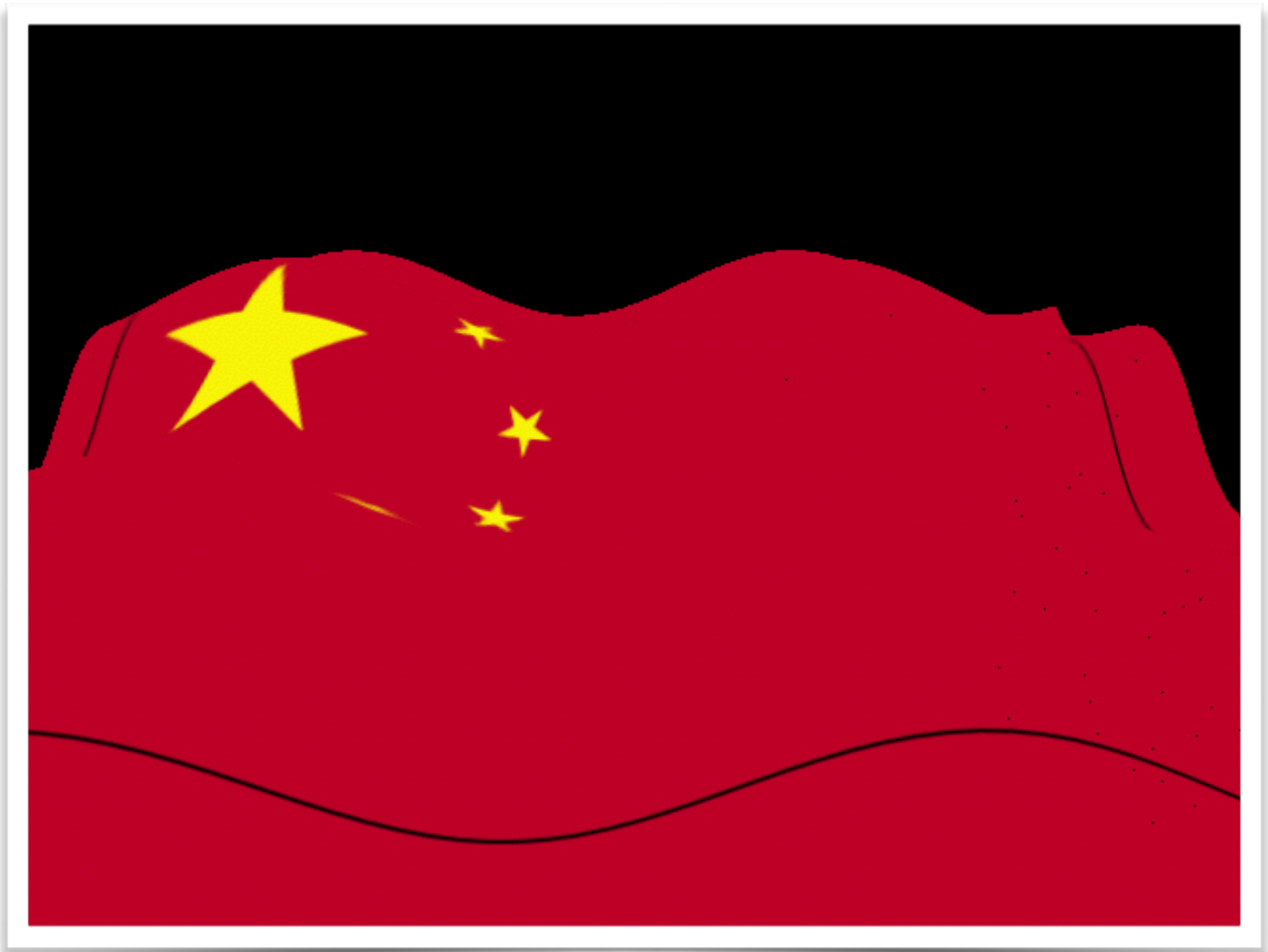
INGREDIENTS: Ray-traced spheres, FO&C blue background No. 7, directional light sources, contains no more than 1/2 of 1 percent ocree remnants. Specular highlights added to preserve technicalness.











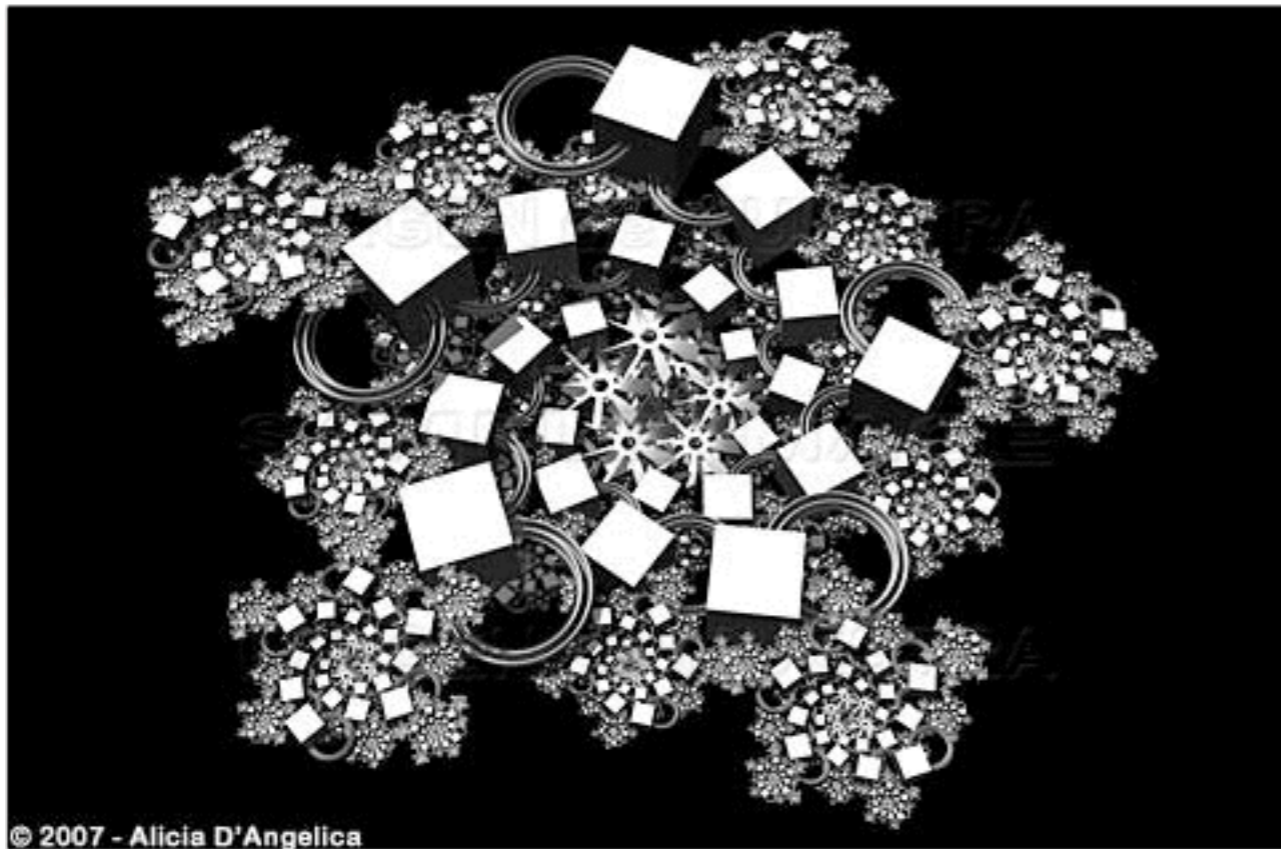
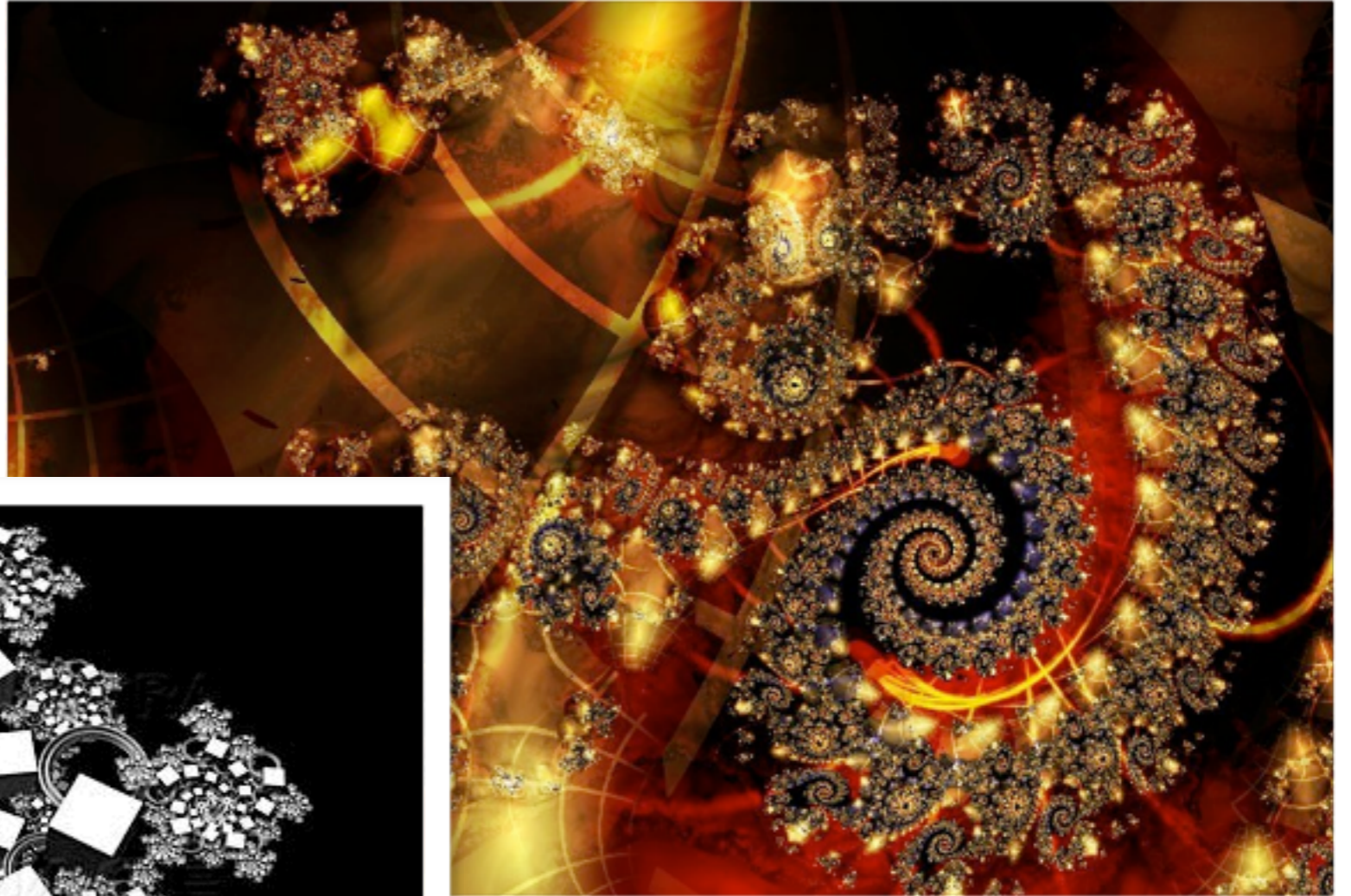
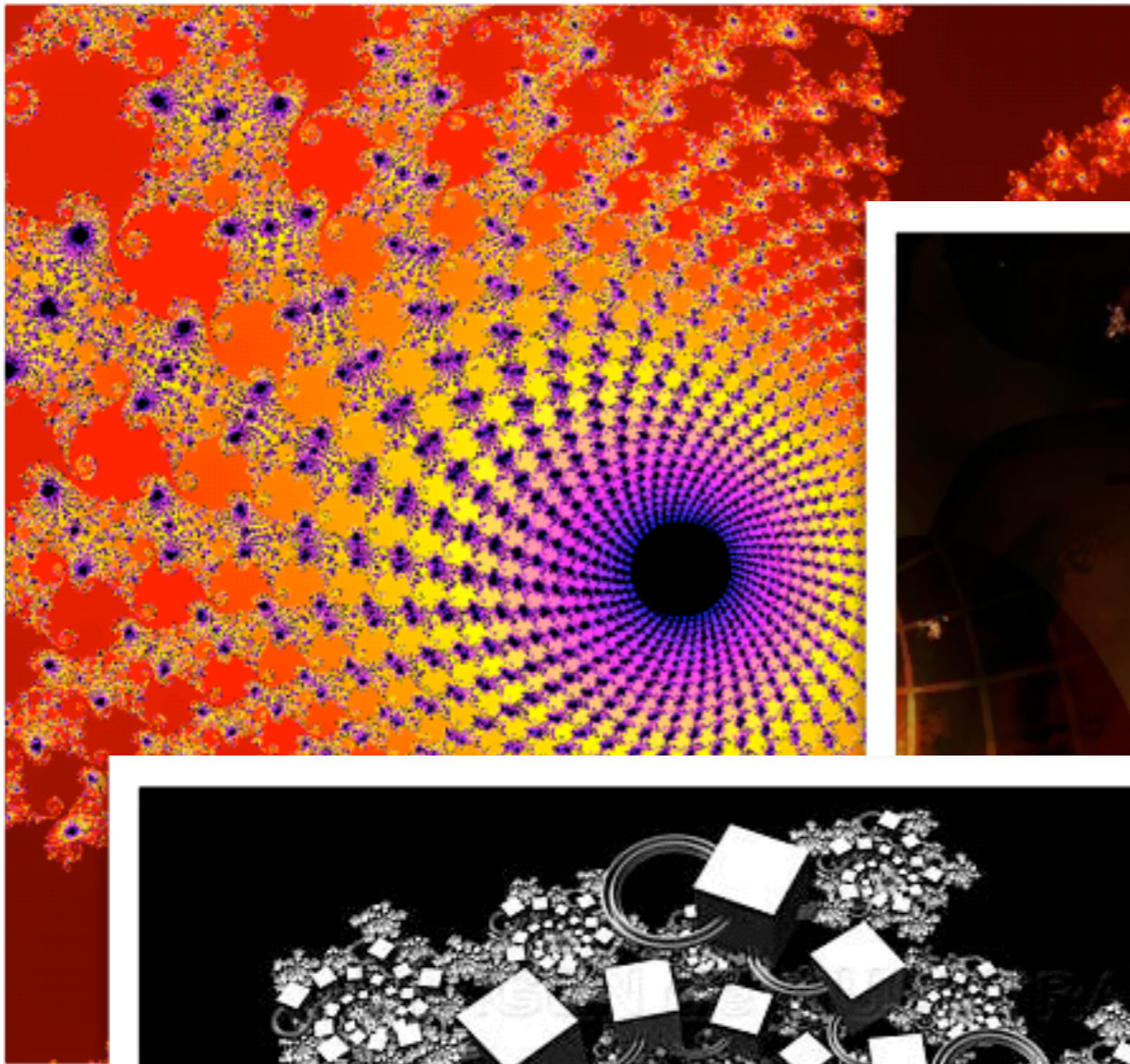
# Topics Not Addressed

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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**



© 2007 - Alicia D'Angelica

fractal images



© Ken  
Musgrave



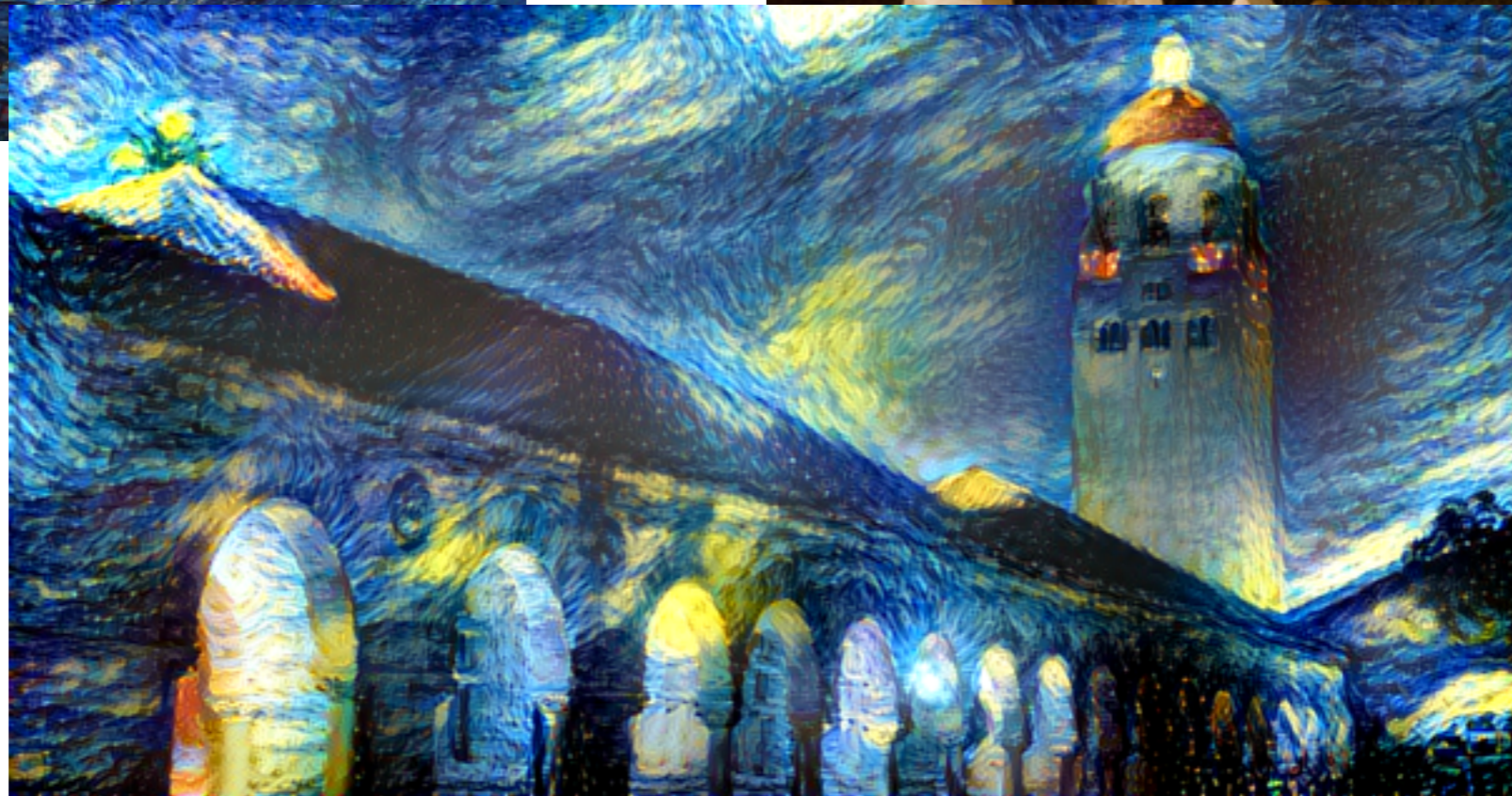
# 3D Graphics and Visualization

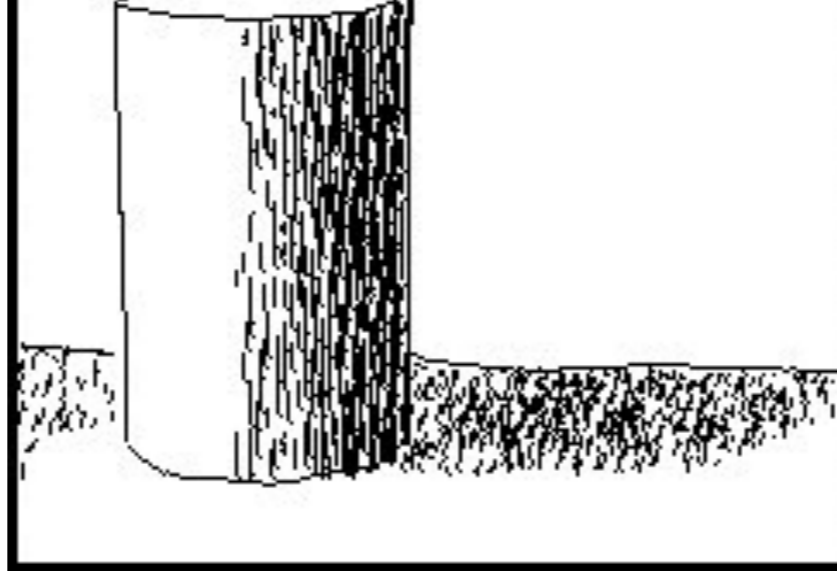
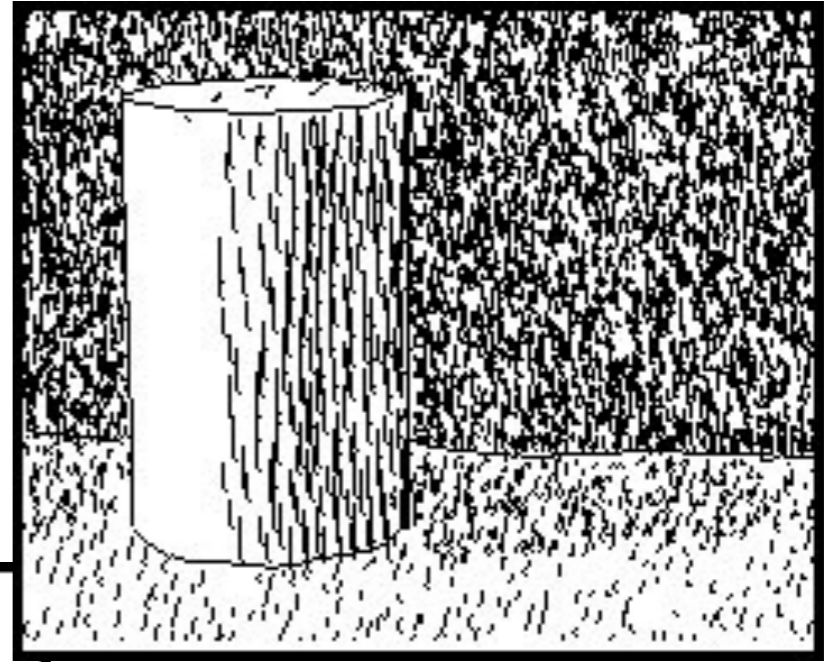
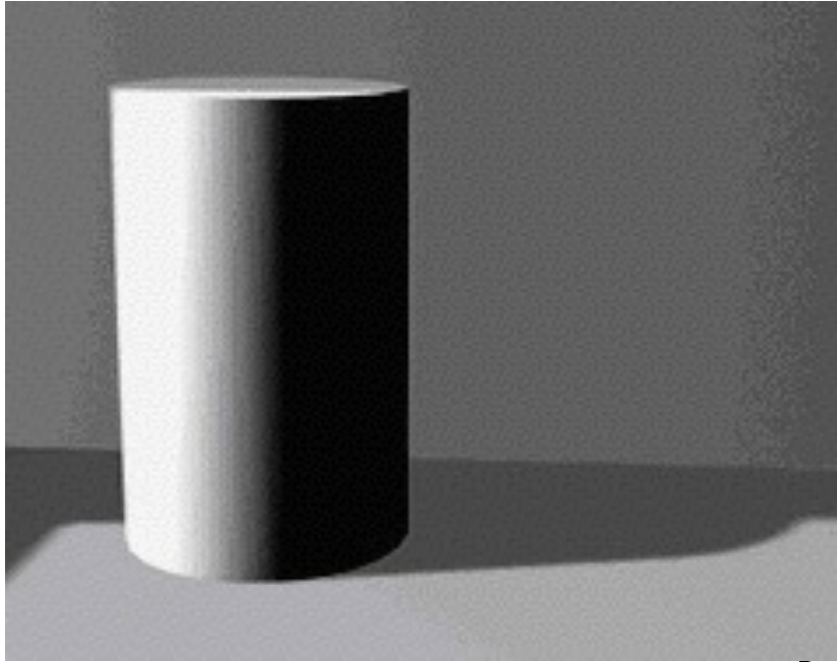


# Topics Not Addressed

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- Non-photo realistic rendering





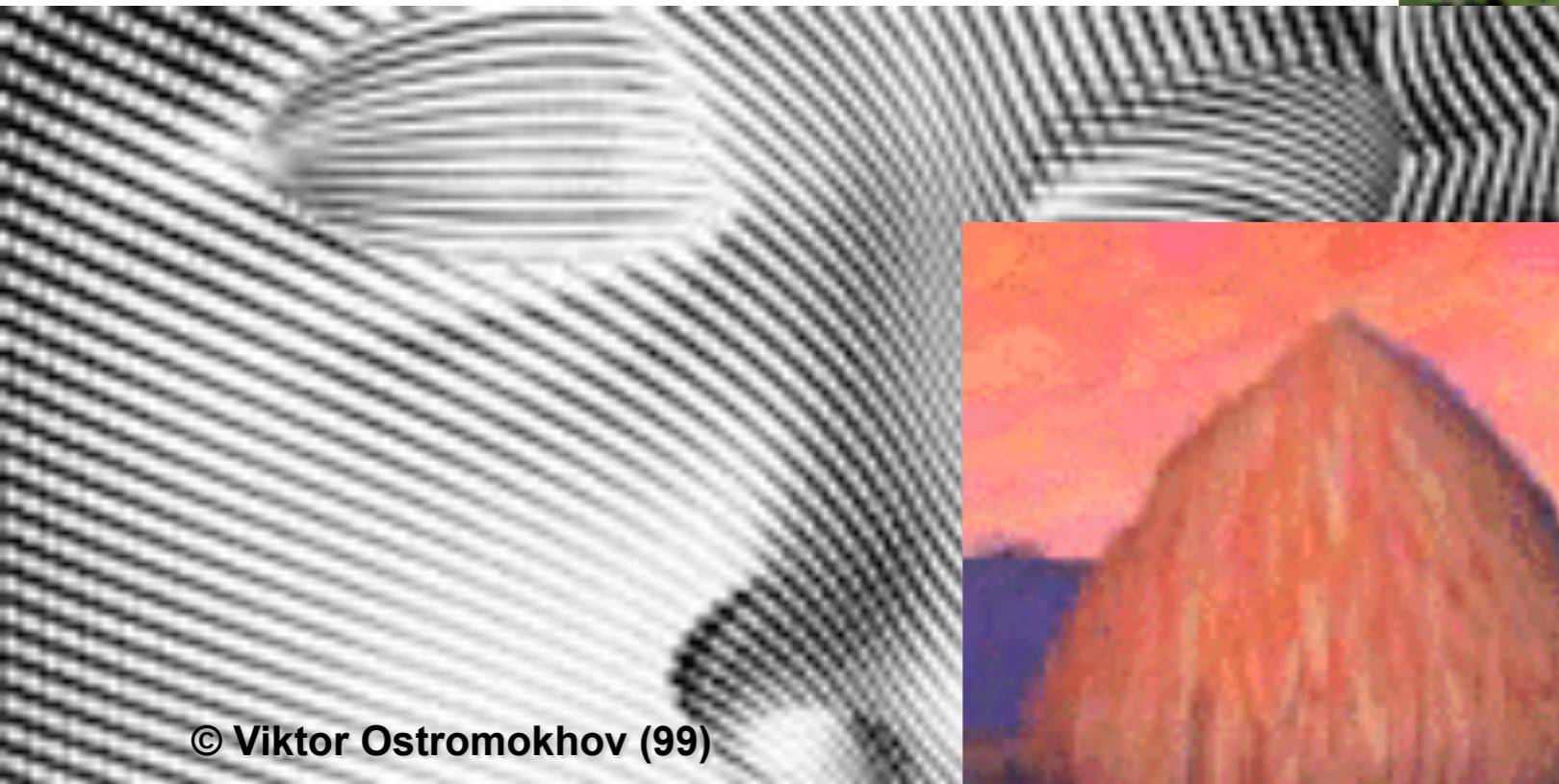




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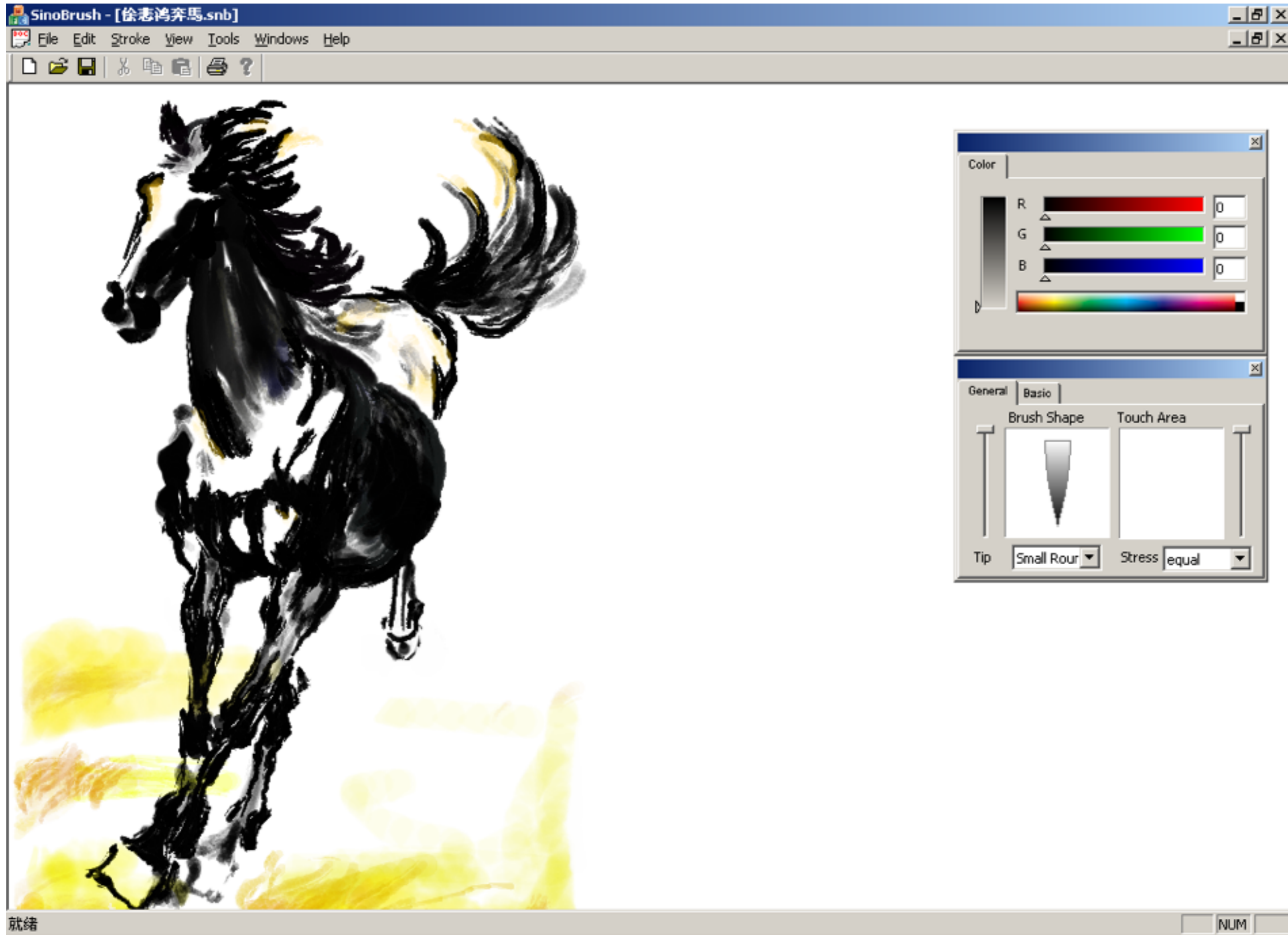
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就绪

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新浪微博

@浙大张宏鑫