



Computer Graphics 2024

1. Introduction

张宏鑫 (Hongxin Zhang)

zhx@cad.zju.edu.cn

浙江大学**CAD&CG**全国重点实验室，计算机学院
State Key Lab of CAD&CG, Zhejiang University

2024-09-13



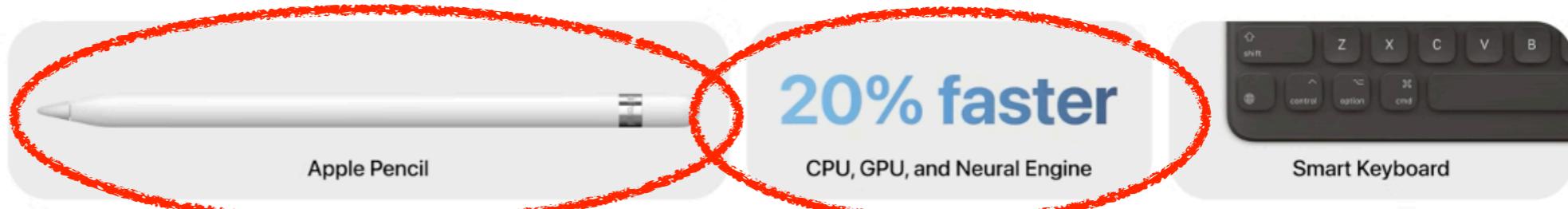
Why study
computer graphics?



100% recycled
aluminum enclosure



Touch ID



20% faster

CPU, GPU, and Neural Engine



Smart Keyboard

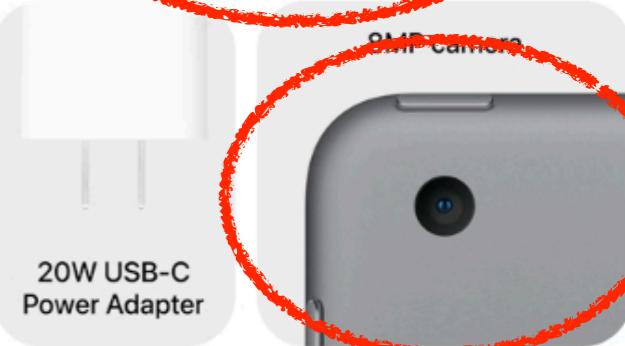
2x
more storage



10.2"
Retina display

12MP Ultra Wide camera with
Center Stage

True Tone display
原彩显示 翻倍的存储容量
All-day battery life
还有 iPadOS 15 带来的多用性
Pro bit-class LTE

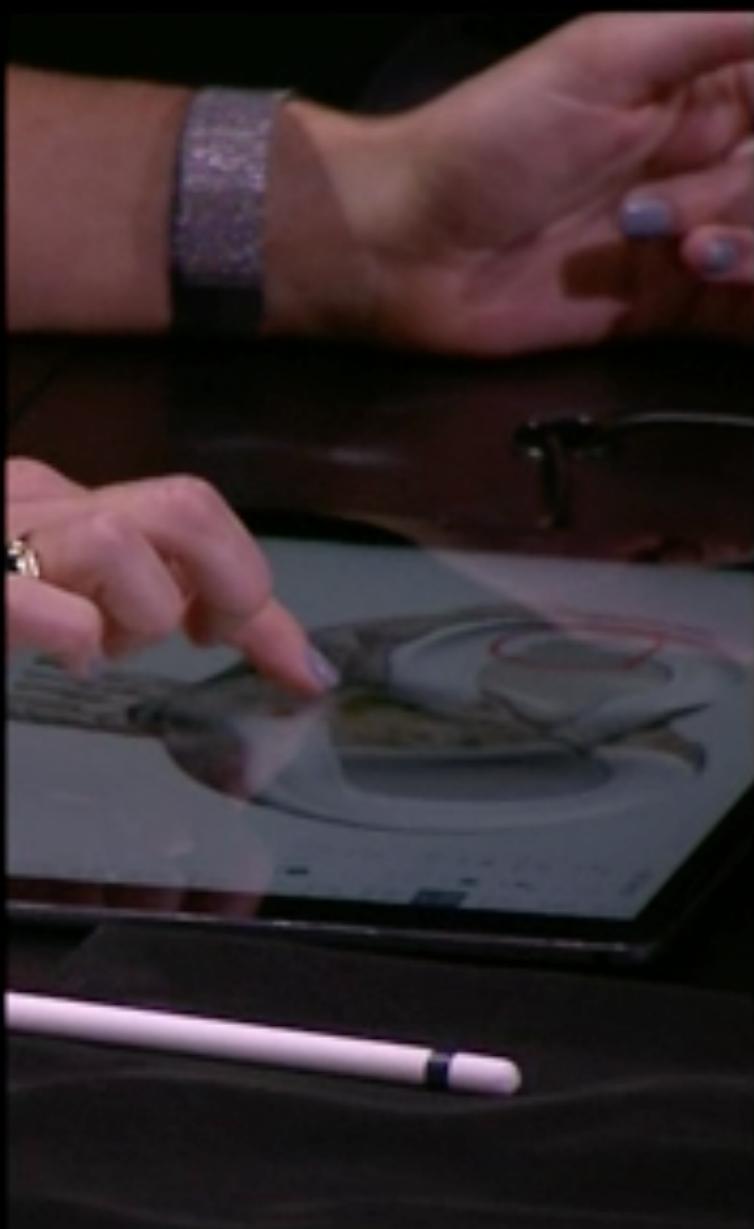


20W USB-C
Power Adapter

iPad (2021)



iPad mini (2021)



Entertainment



Movies
Toy Story 3
Pixar



Spore-Monsters.com

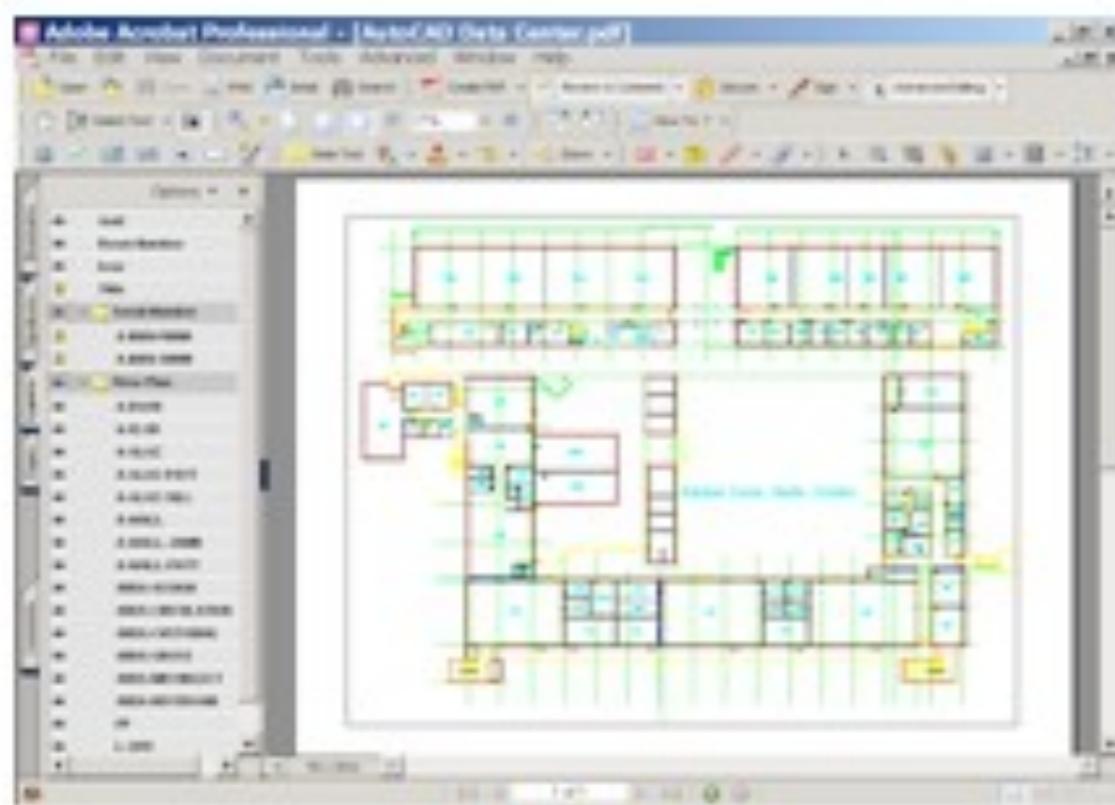
Games
Spore
W. Wright, Elec. Arts

Computer-Aided Design

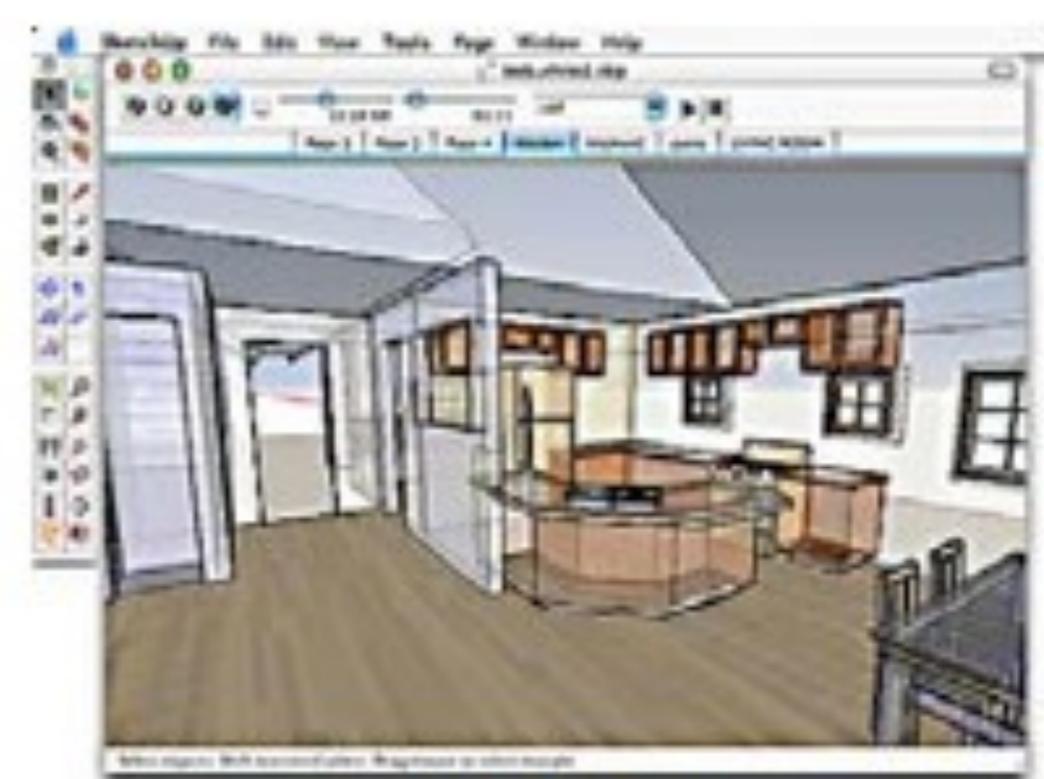
Mechanical CAD

Architectural CAD

Electronic CAD



AutoCAD



Sketchup

Visualization

Science, engineering and medicine



The Virtual Human
Karl-Heinz Hoehne



Outside-In
The Geometry Center

Visual Simulation and Training

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



**davinci surgical robot
Intuitive Surgical**



**Boeing 747 flight simulator
NASA**

Digital Media Technologies

Convert traditional analog media to digital media

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



Digital Media Technologies

Emergence of media

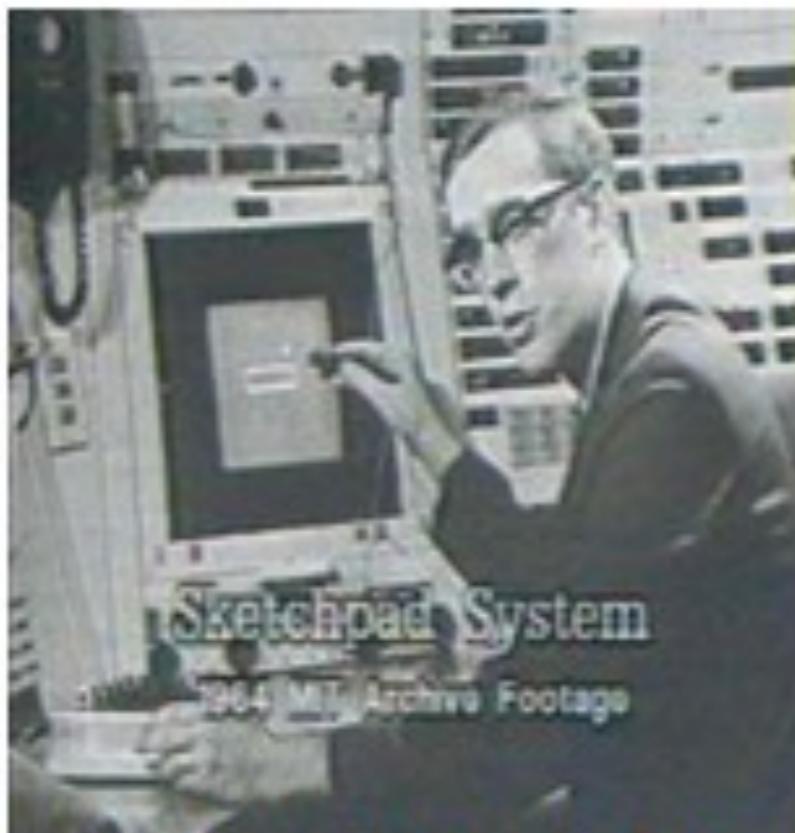
- Multimedia computer and media servers
- Networked graphics and the WWW
- Electronic books, magazines and newspapers
- Sharing photos (flickr) and videos (youtube)
- Virtual worlds (Google Earth, Second Life)

With new possibilities for creating and mixing
content from different sources

Graphical User Interfaces

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

Different scales: Small and large

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



Apple iPad



Microsoft Surface

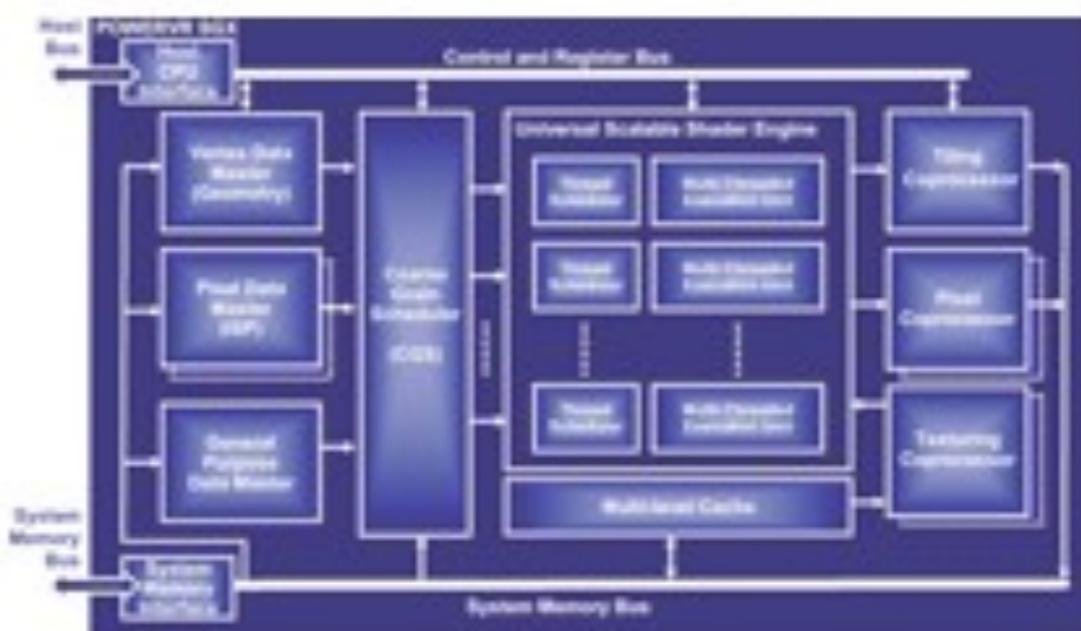
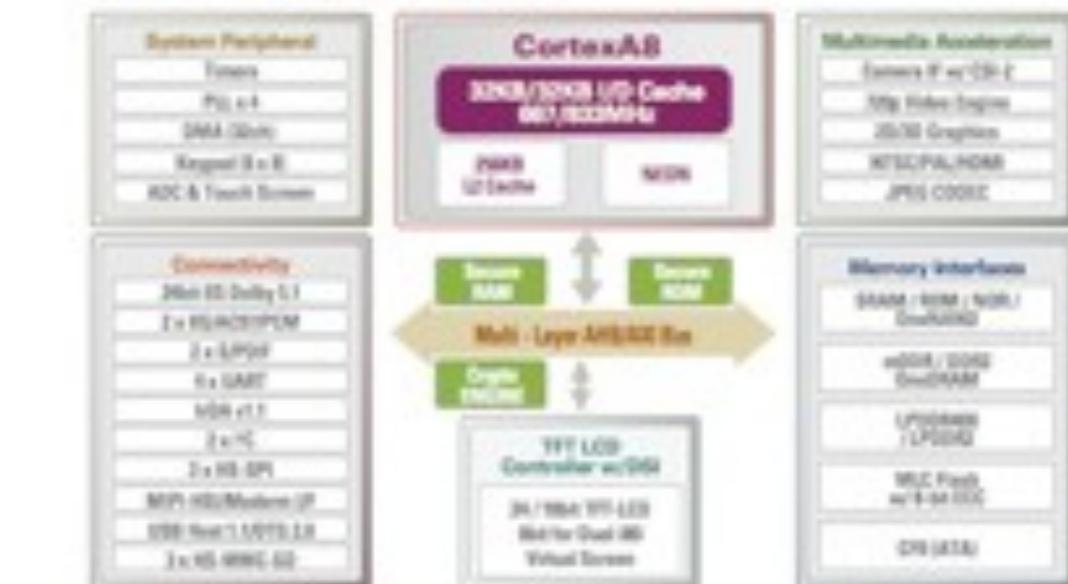
Innovation in Hardware & Software

iPhone and iPad



Apple A4 = CPU+GPU

S5PC100 Block Diagram



New Era

Big Screens



Mobile Graphics



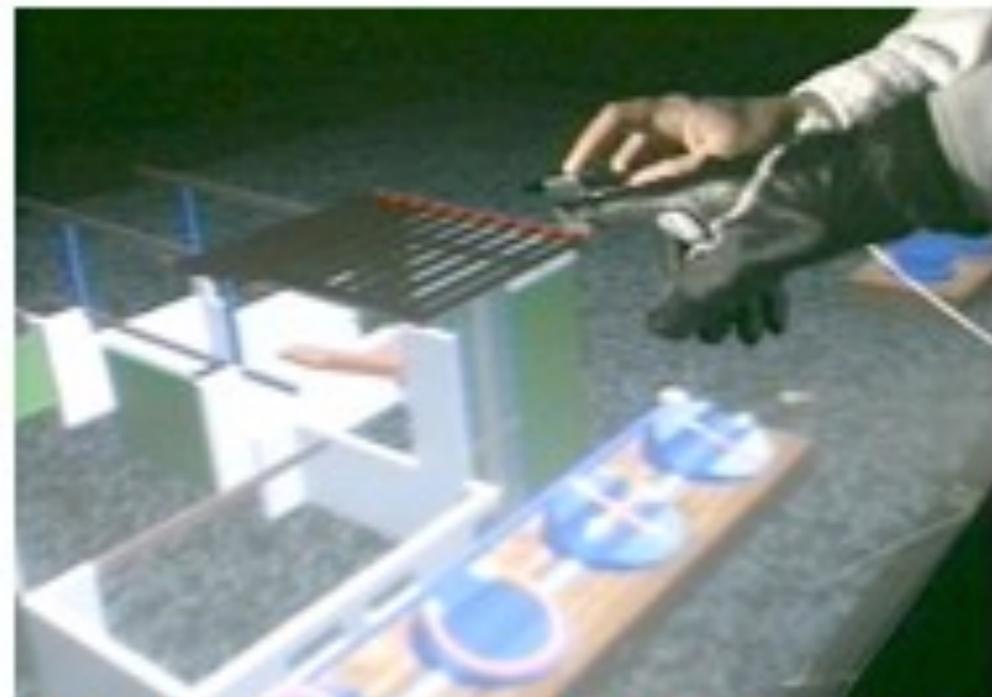
Ultimate Display: Virtual Reality

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

Ultimate Display: Virtual Reality

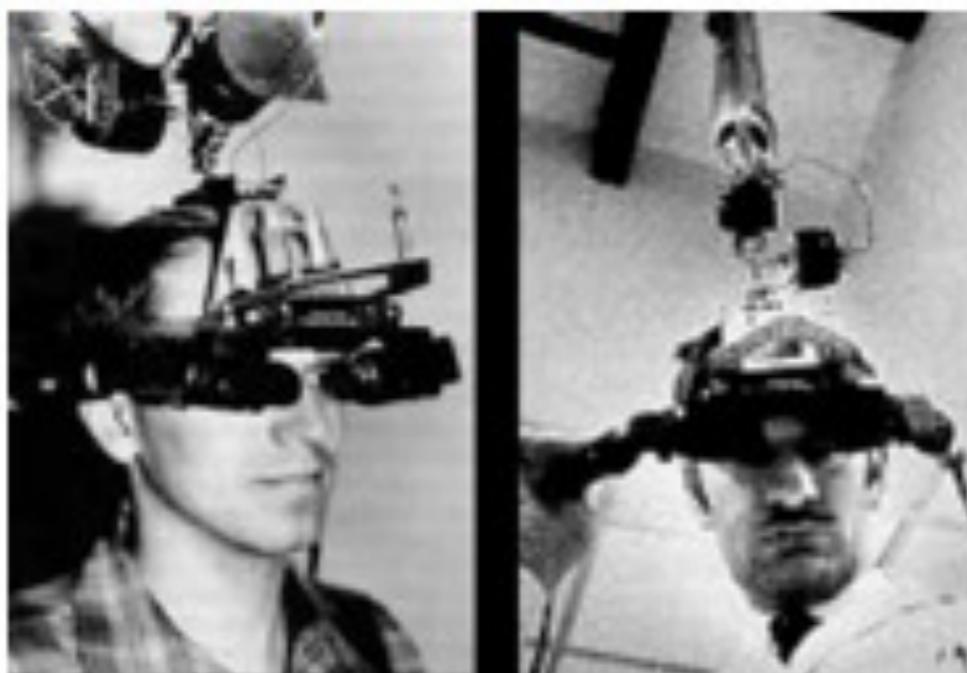
Immersive interfaces

■ Input: 3D 6-DOF track

■ Output: Head-moun

Ivan Sutherland

Head-mounted displays,
mechanical tracker



CS148 Lecture 1

未来手术: SurgicalAR

医疗AR革命已来



FDA认证的surgical AR设备

New Devices in Home



早晨，若琪的一天

New Personal Devices

ROKID GLASS

[See More](#)

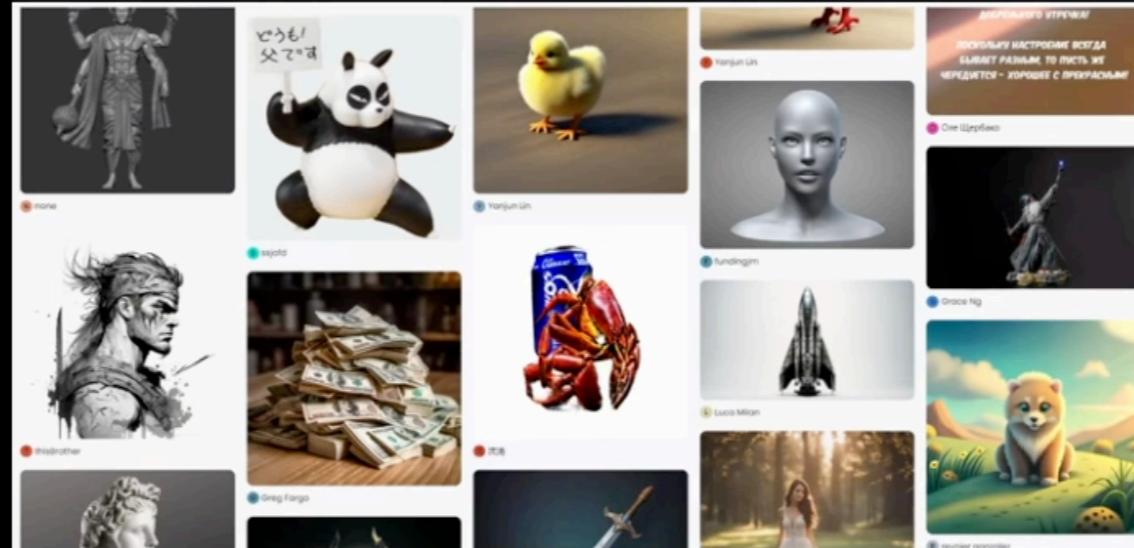


AR Glass Application



打造世界级精益工厂
Build out world-class lean factory

图片秒变3D模型 有手就会的AI建模神器



简直把我惊呆了

Theory and Practice

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

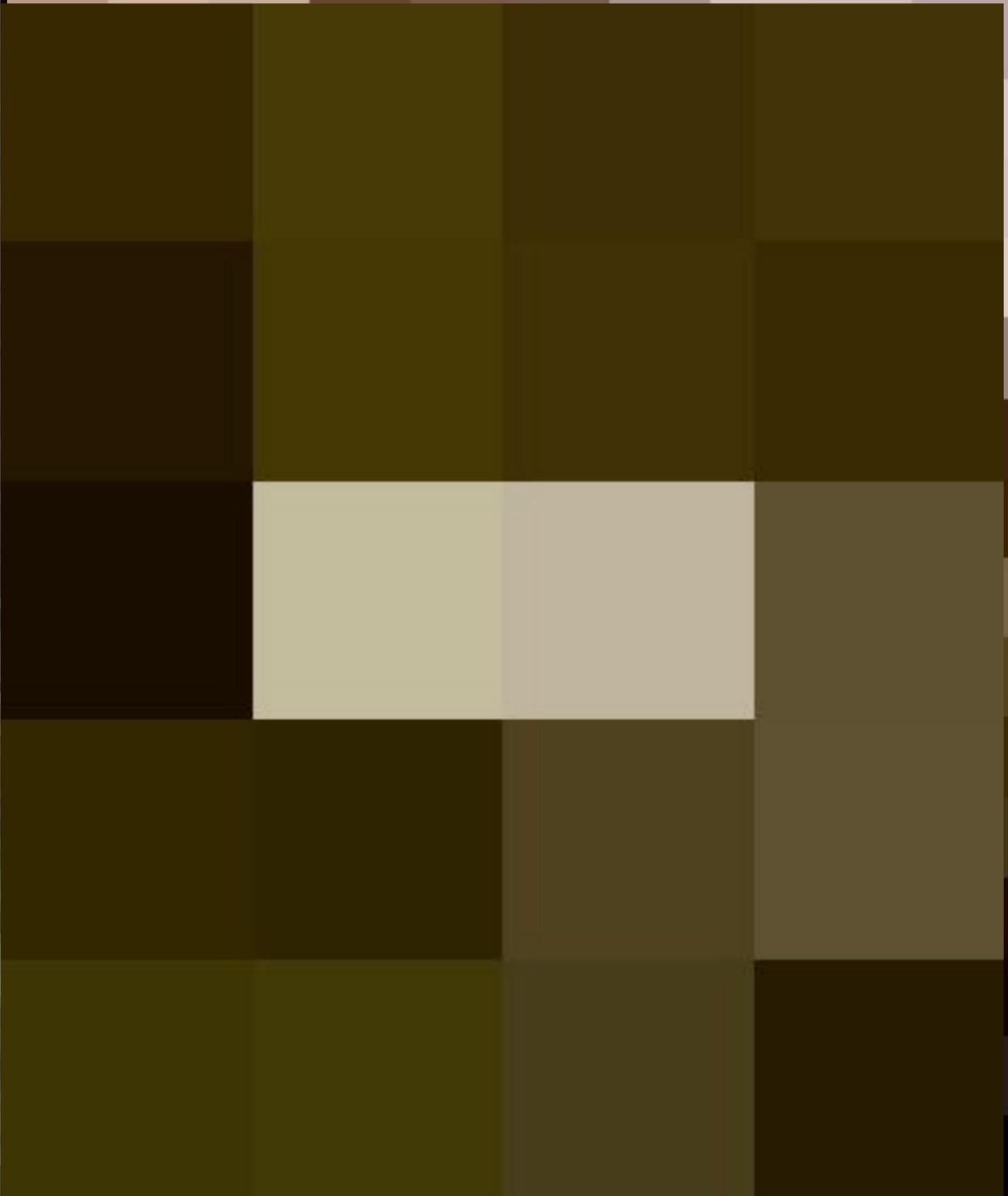
- Computers (with suitable output devices) can draw geometric stuff, not just manipulate numbers
- Computers can draw images of 3D worlds with realistic shapes and light and animate them as well
- People can create 2D and 3D models
- People can interact with them in 2D and 3D through innate visual and 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

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 ...

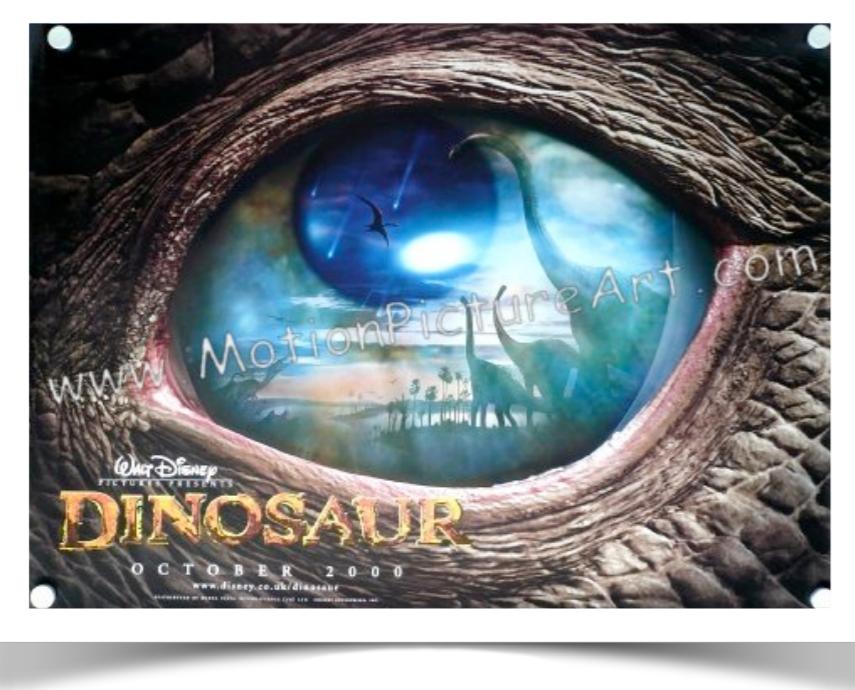
Pixel Representation Problem

- 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

recommended description

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



Three Fundamental Tasks

Computer Graphics

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



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

Different Digital Representations of the World

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

Different Digital Representations of the World

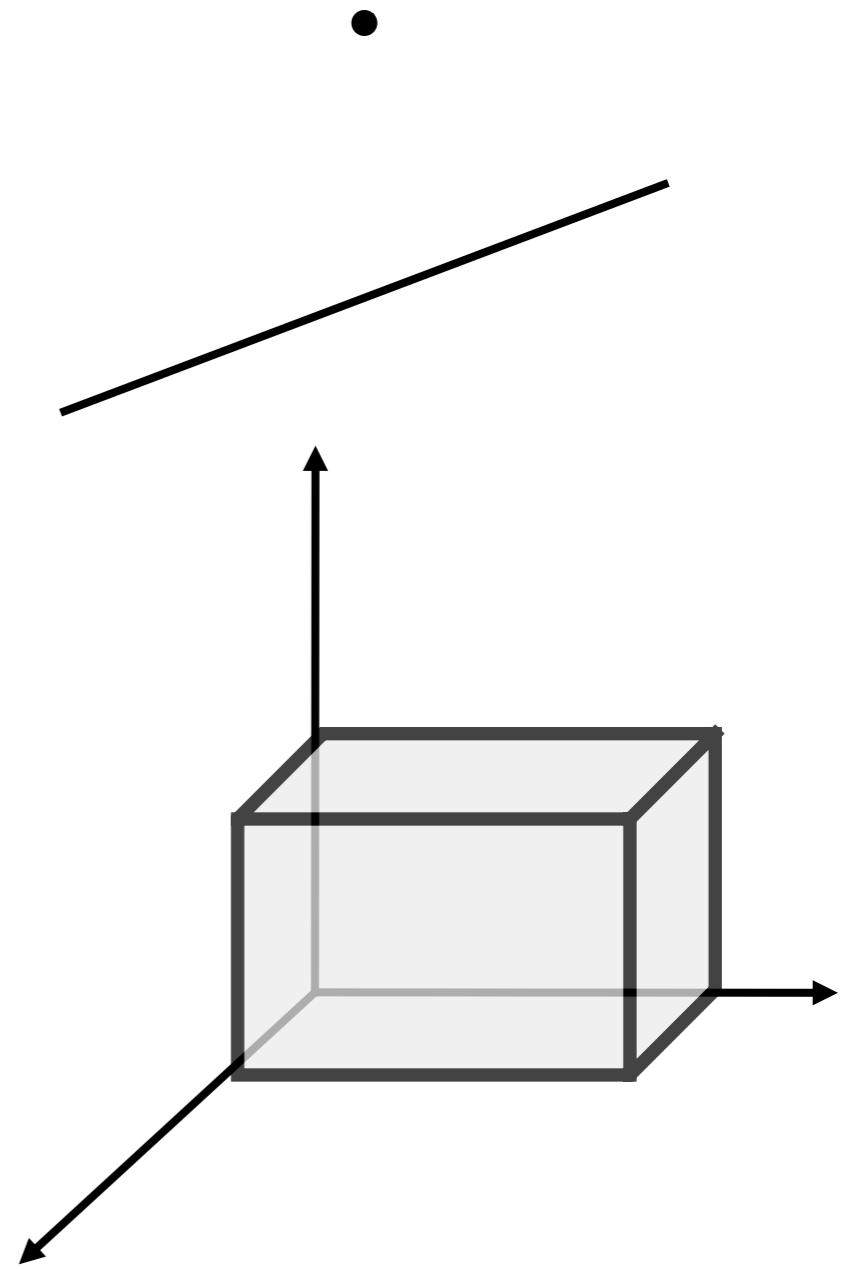
- Digital Images
- 3D Geometric Objects (Graphics)
- Symbolic Descriptions
- Question:
 - Difference?
 - Advantages and disadvantages ?

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

- 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

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



Avatar (2009)

<https://www.imdb.com/title/tt0499549/>

3 Fundamental Tasks of CG

- 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

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



Different Digital Representations of the World

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

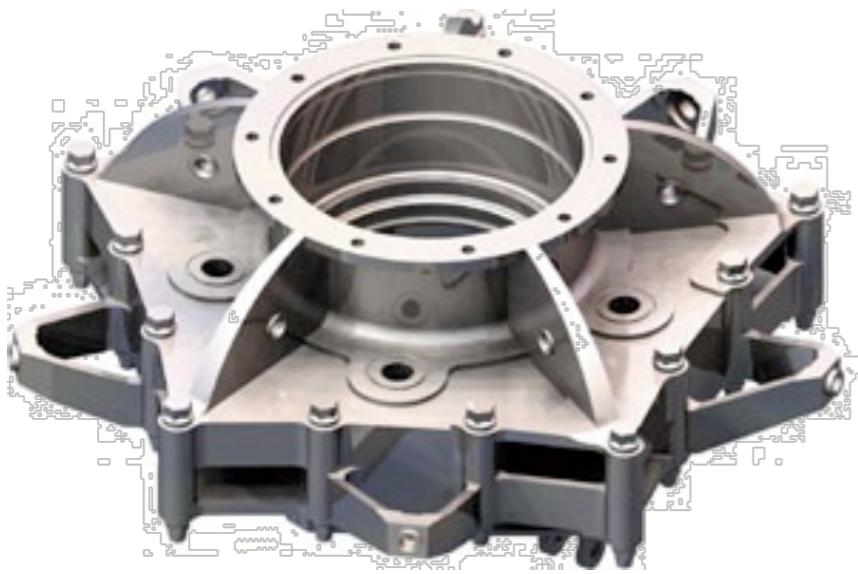
Research Fields of Visual Computing

- **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

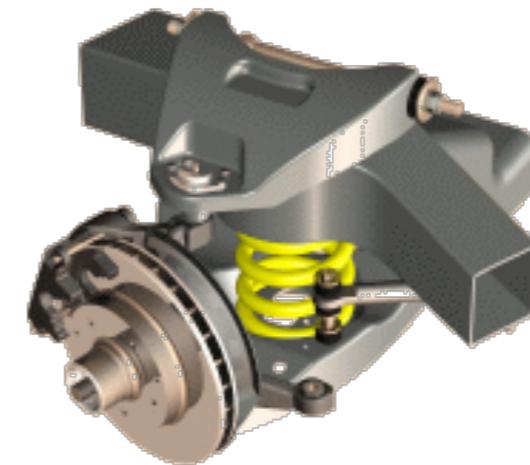
Computer Graphics Applications

- 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)



CAE

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

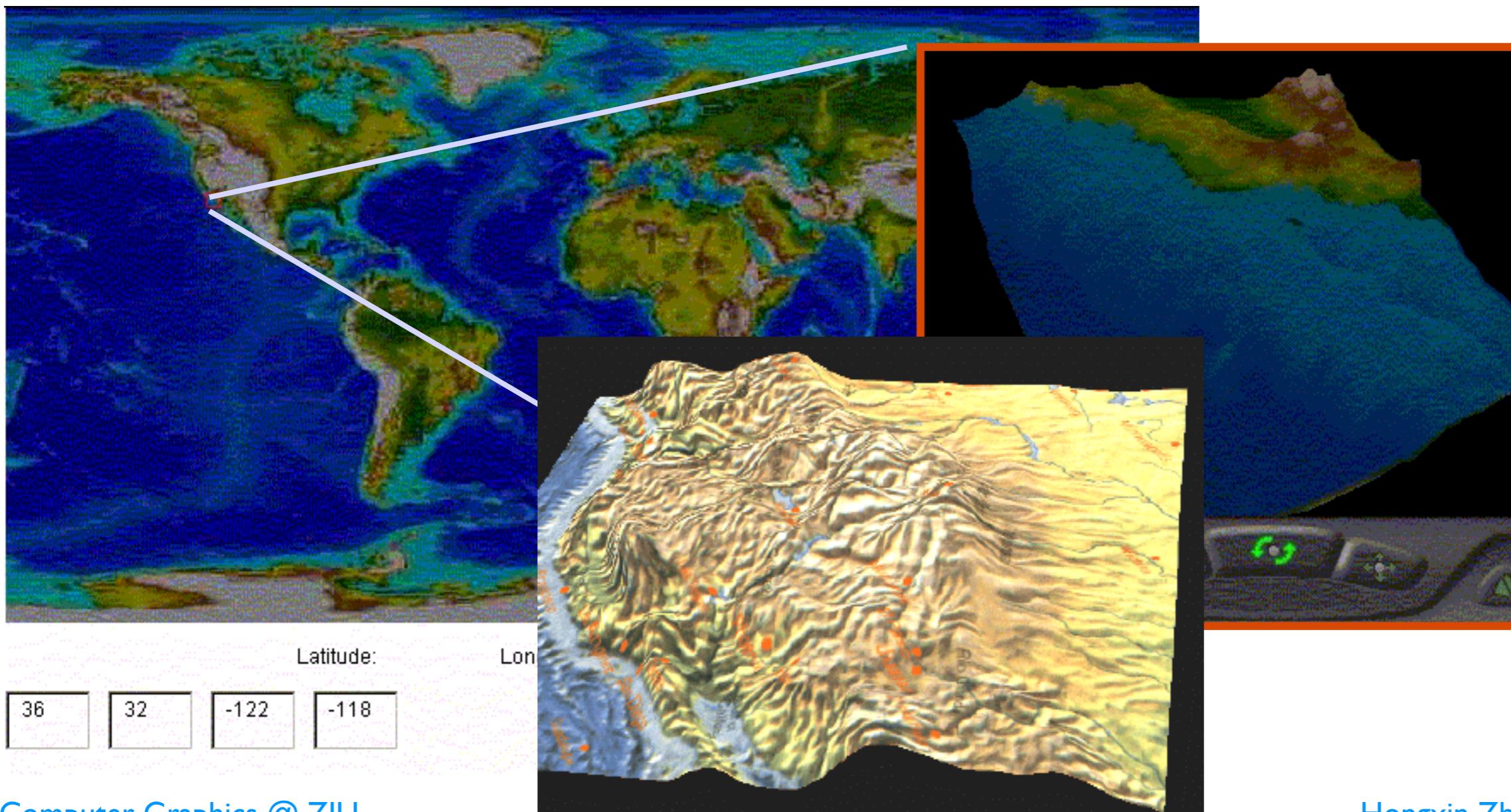
Computer Aided

Design

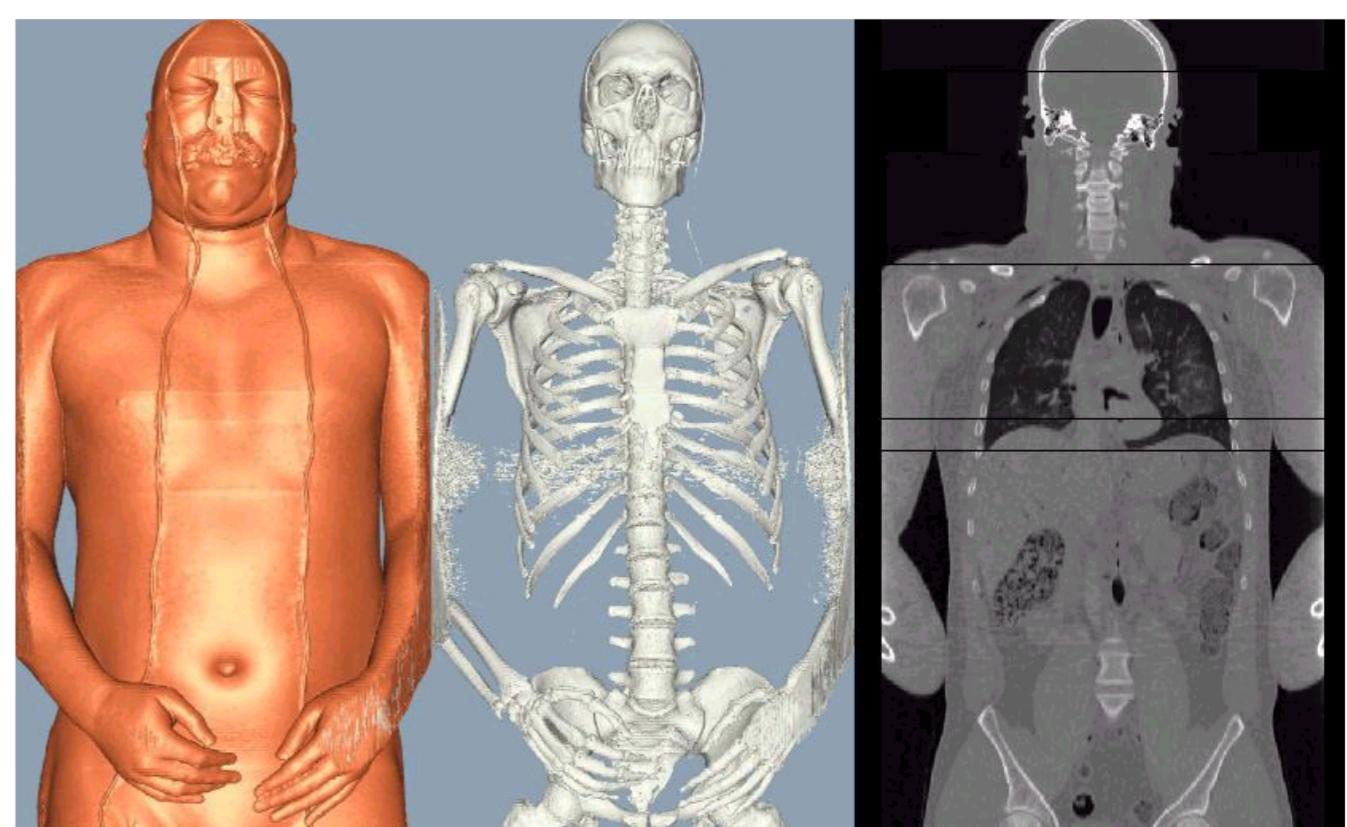
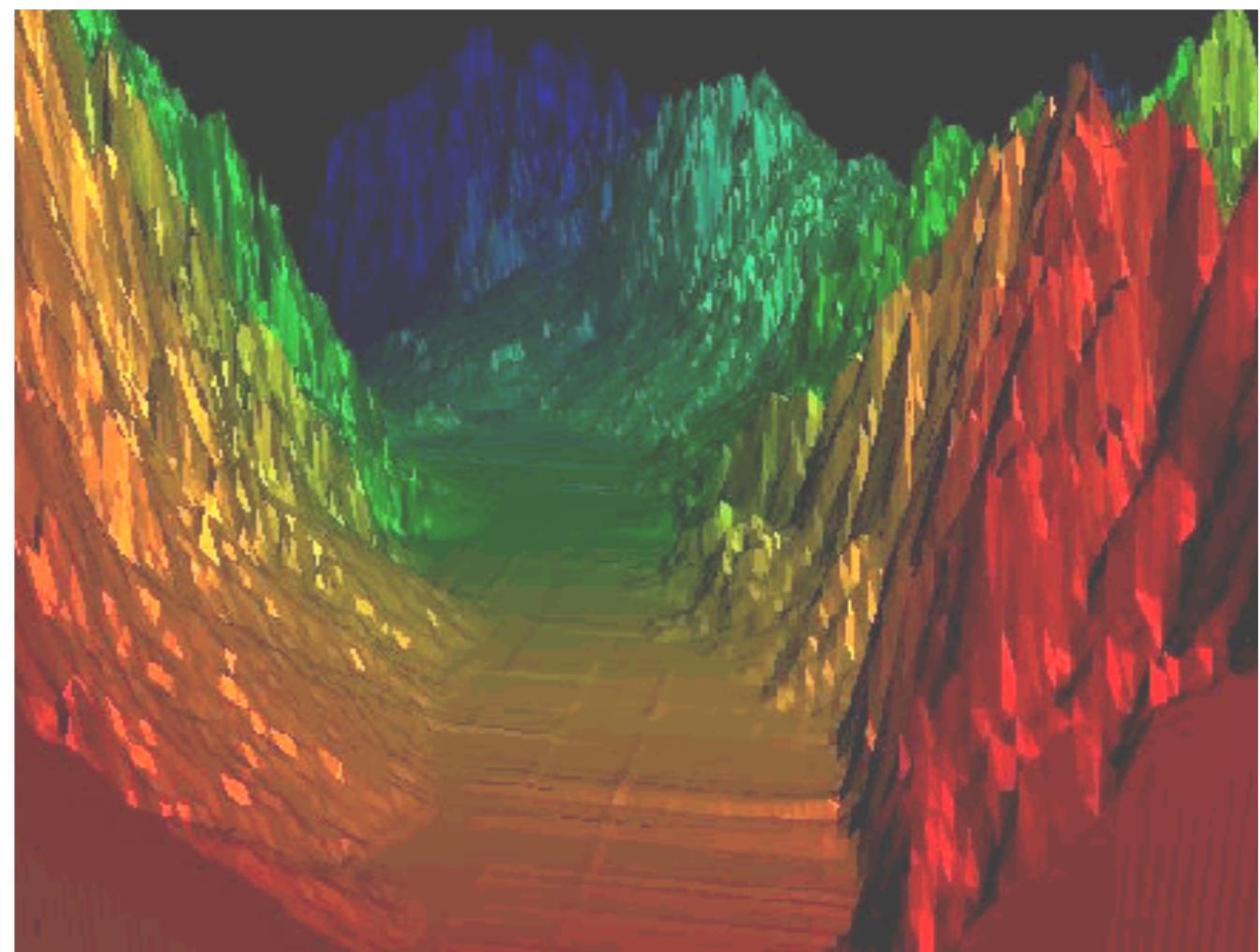
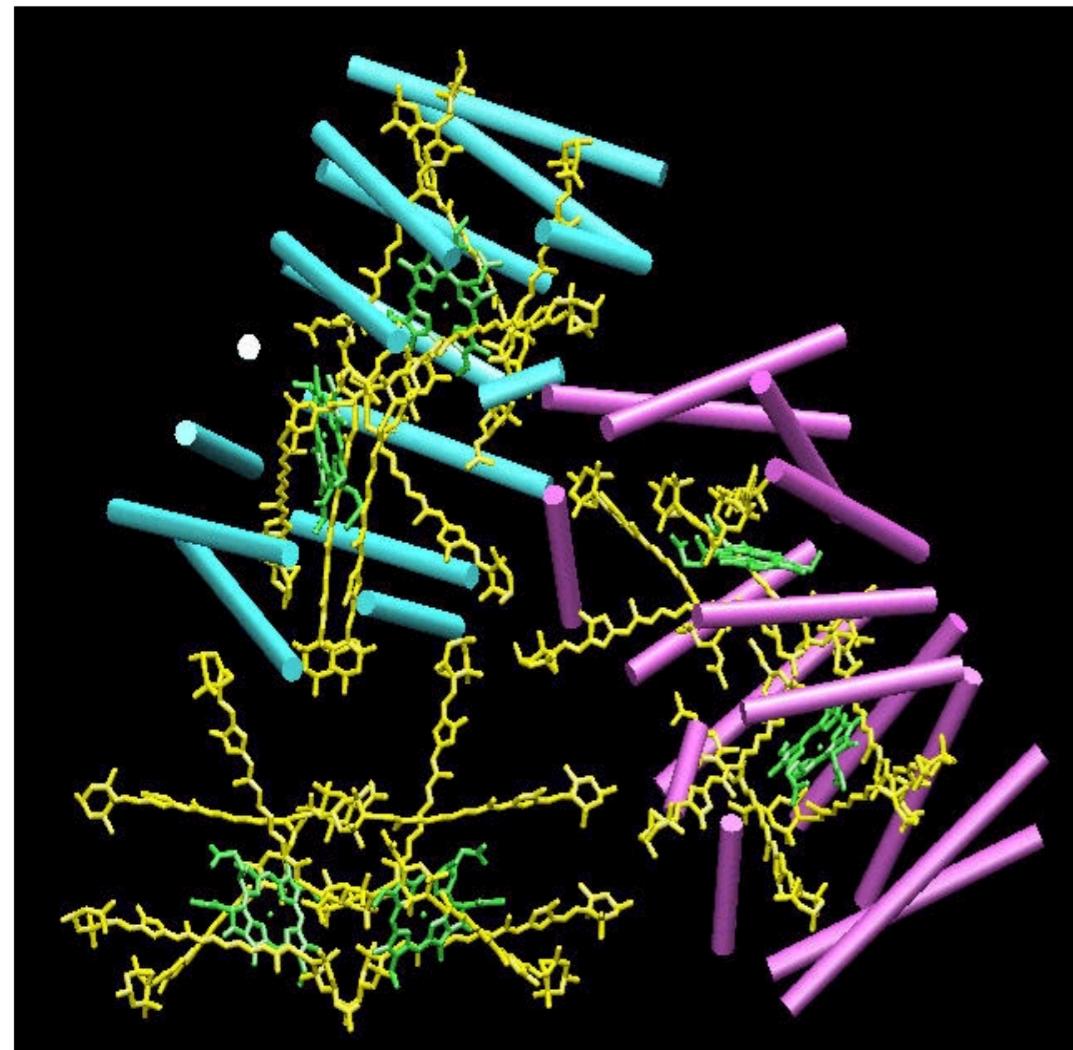
CAM

Computer Graphics Applications

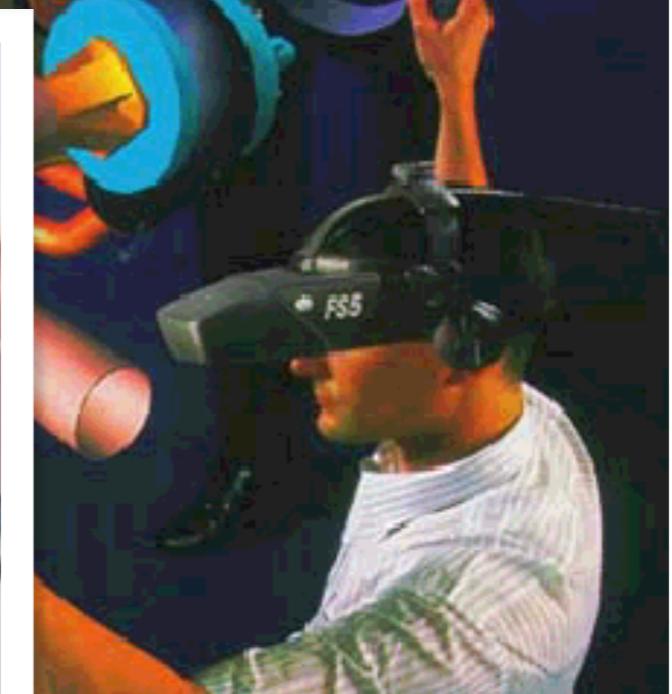
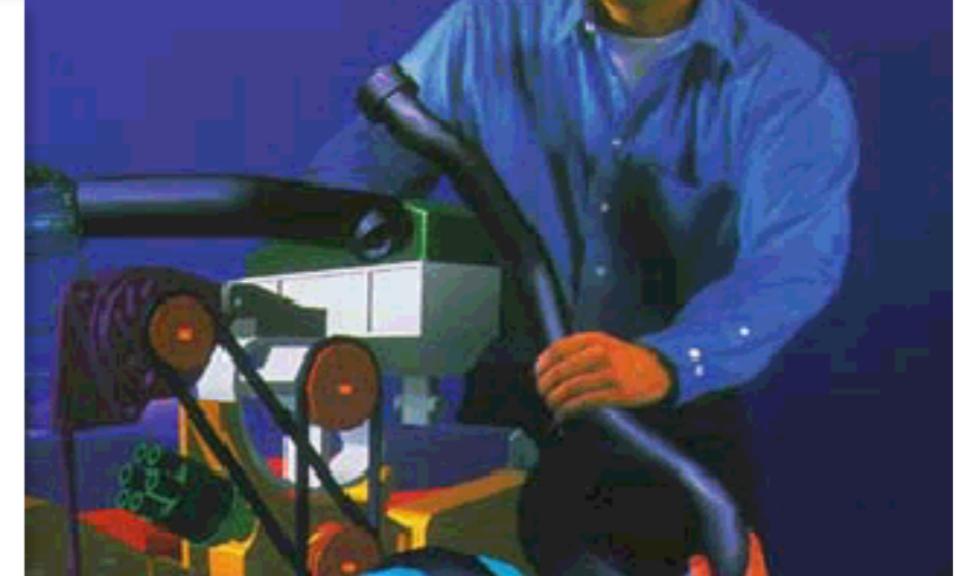
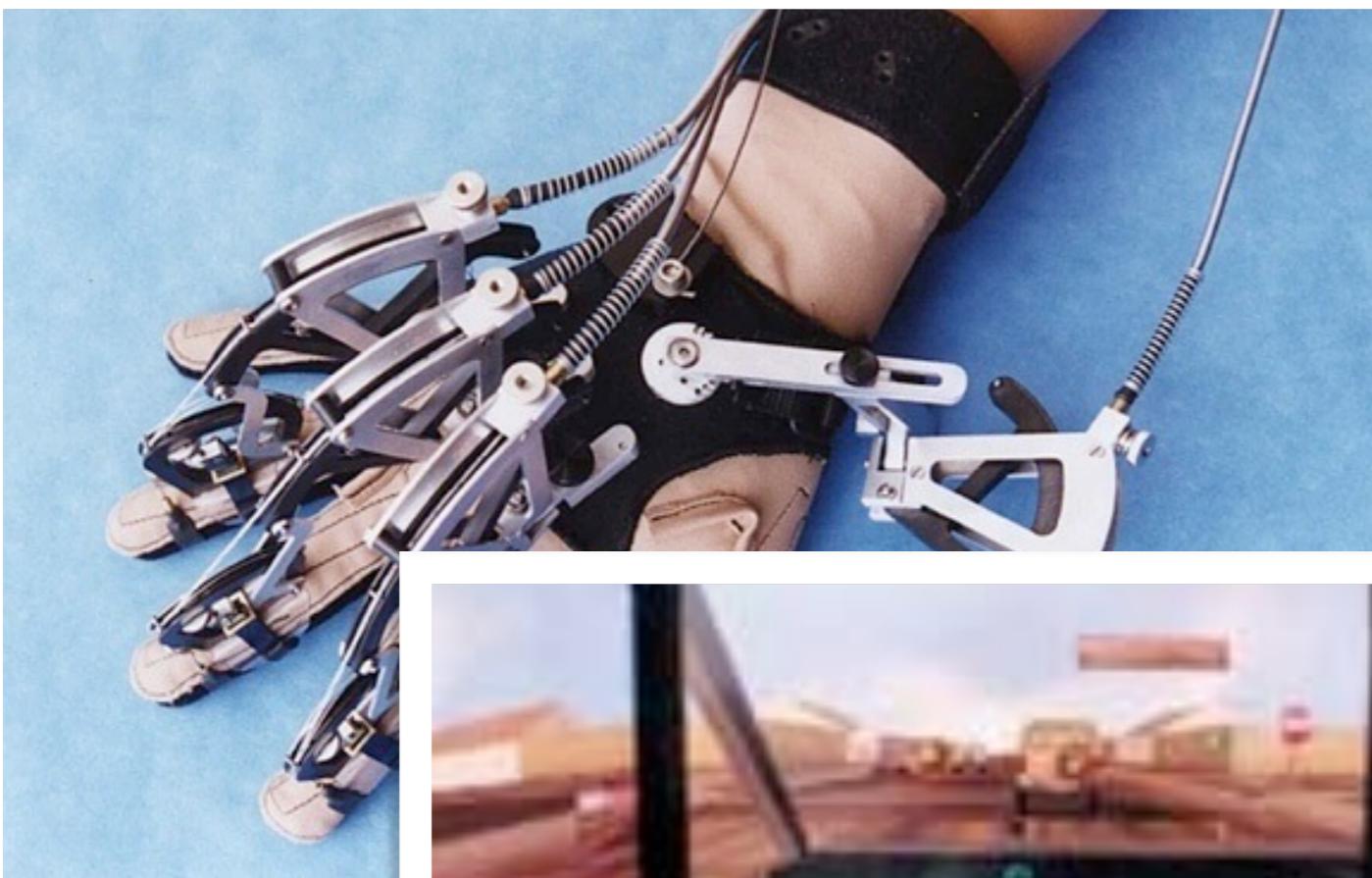
GIS: Geography information system



Visualization



Virtual Reality

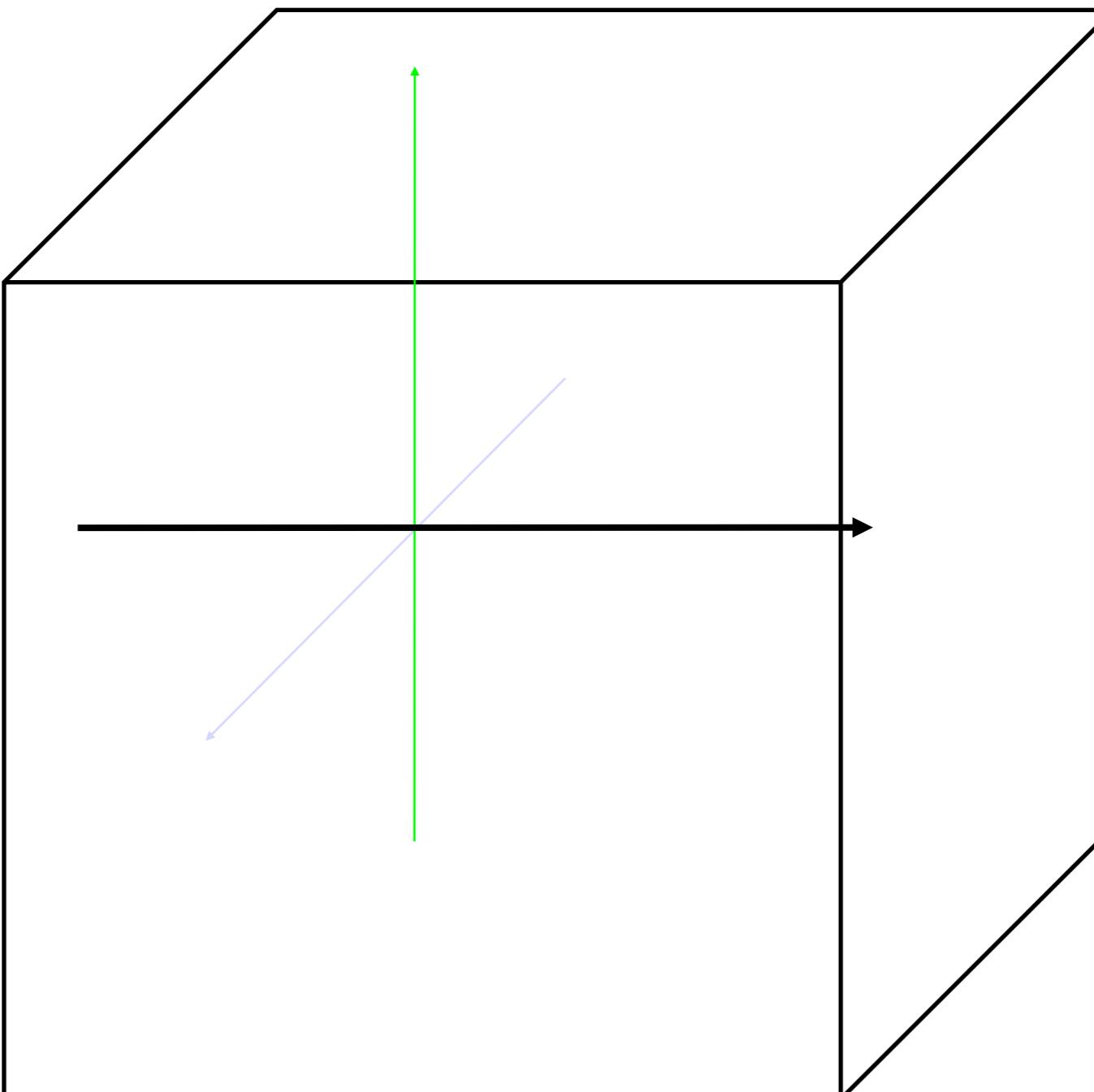


Technology Developments

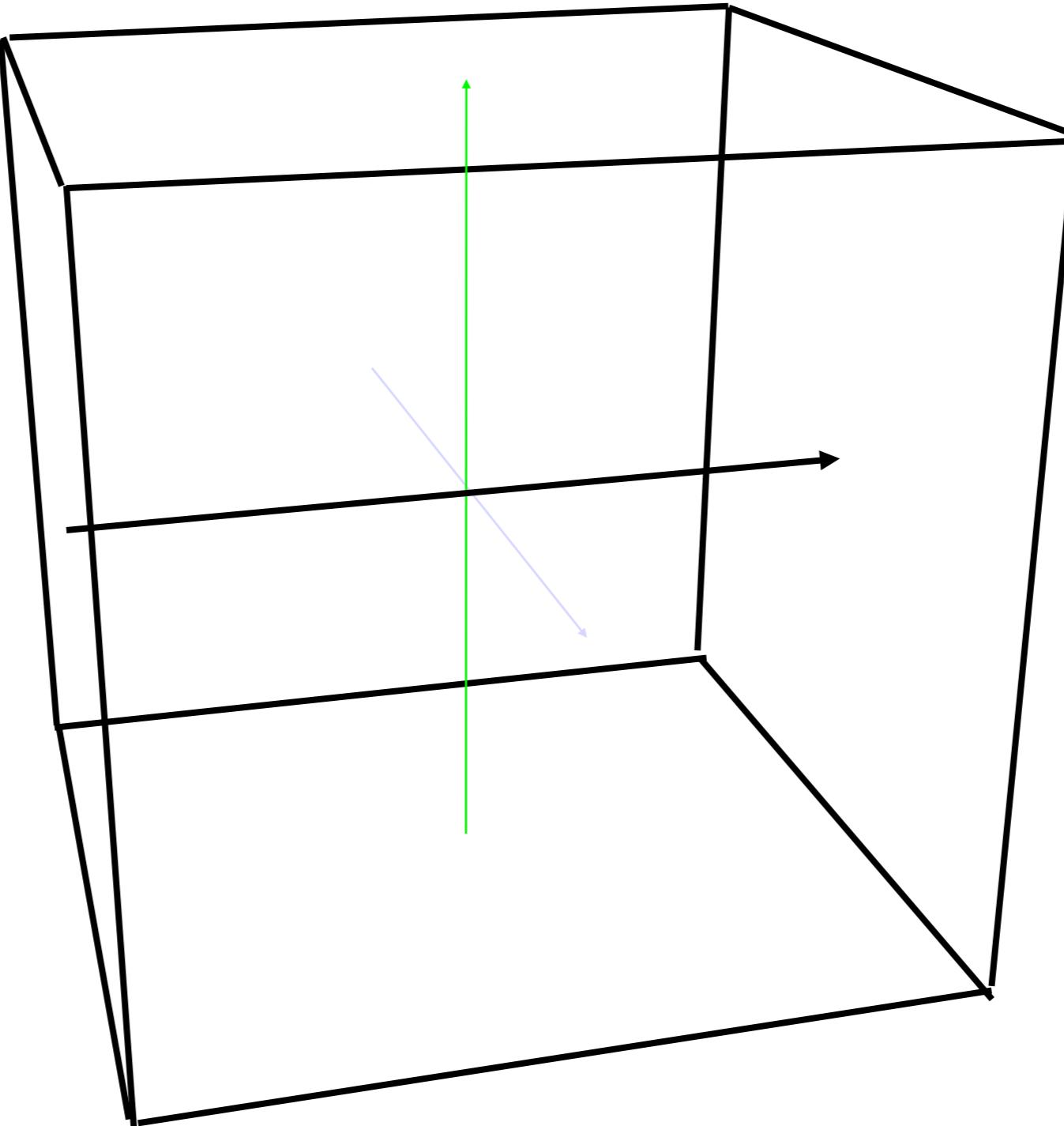
- 1962 : Sutherland's Sketchpad
- 1970s: Special Hardware
- 1980s: Raster Graphics
- 1990s: Reality Engines
- 2000s: 3D acceleration
- 2010s: Mobile graphics
- 2020s: ??? Intelligence ???

Topics Addressed in this Class

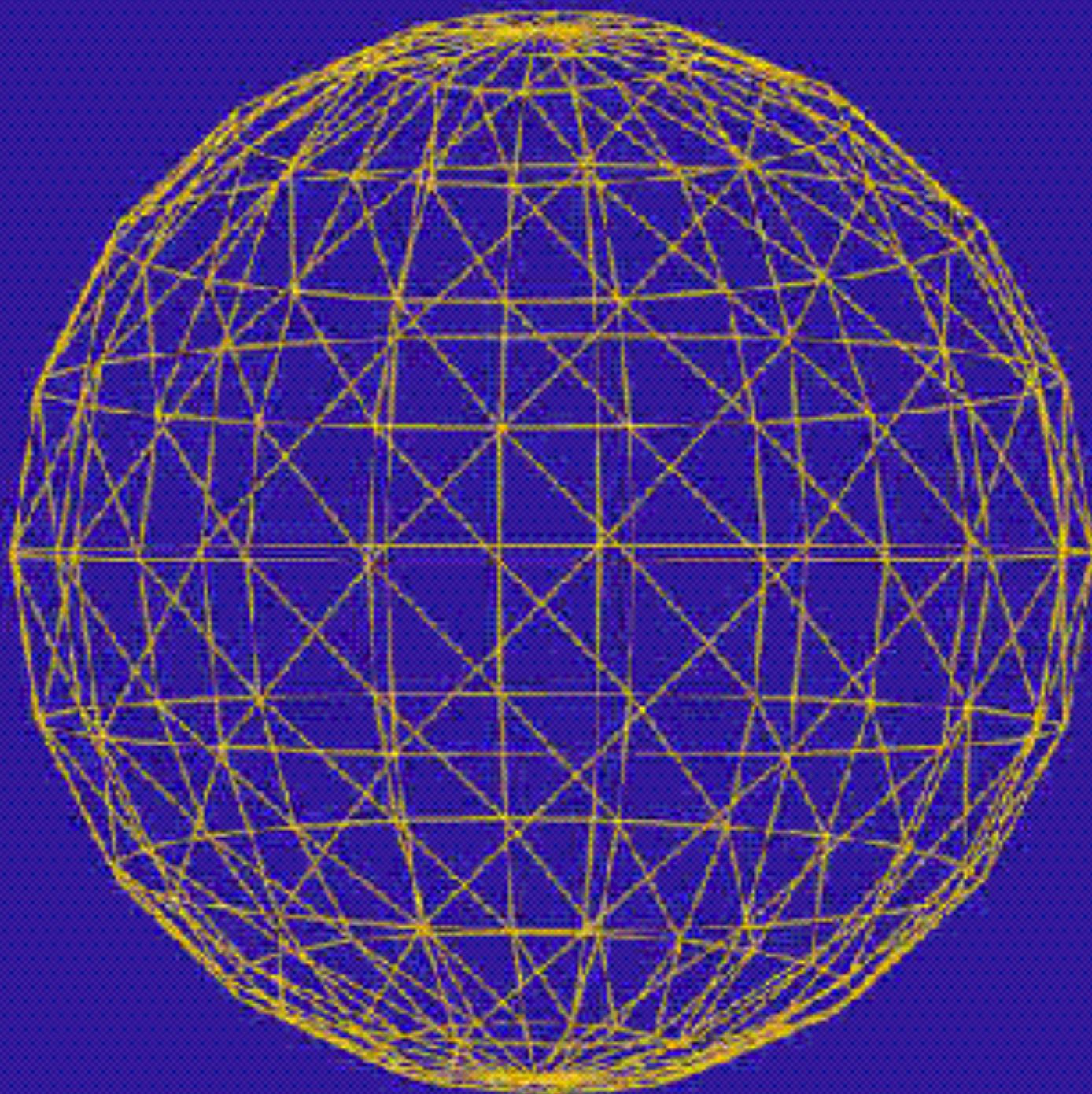
- Basics - Transformations and Synthetic Camera for Viewing the World
- Modeling techniques and tools - Meshes, Surfaces and Solid Objects



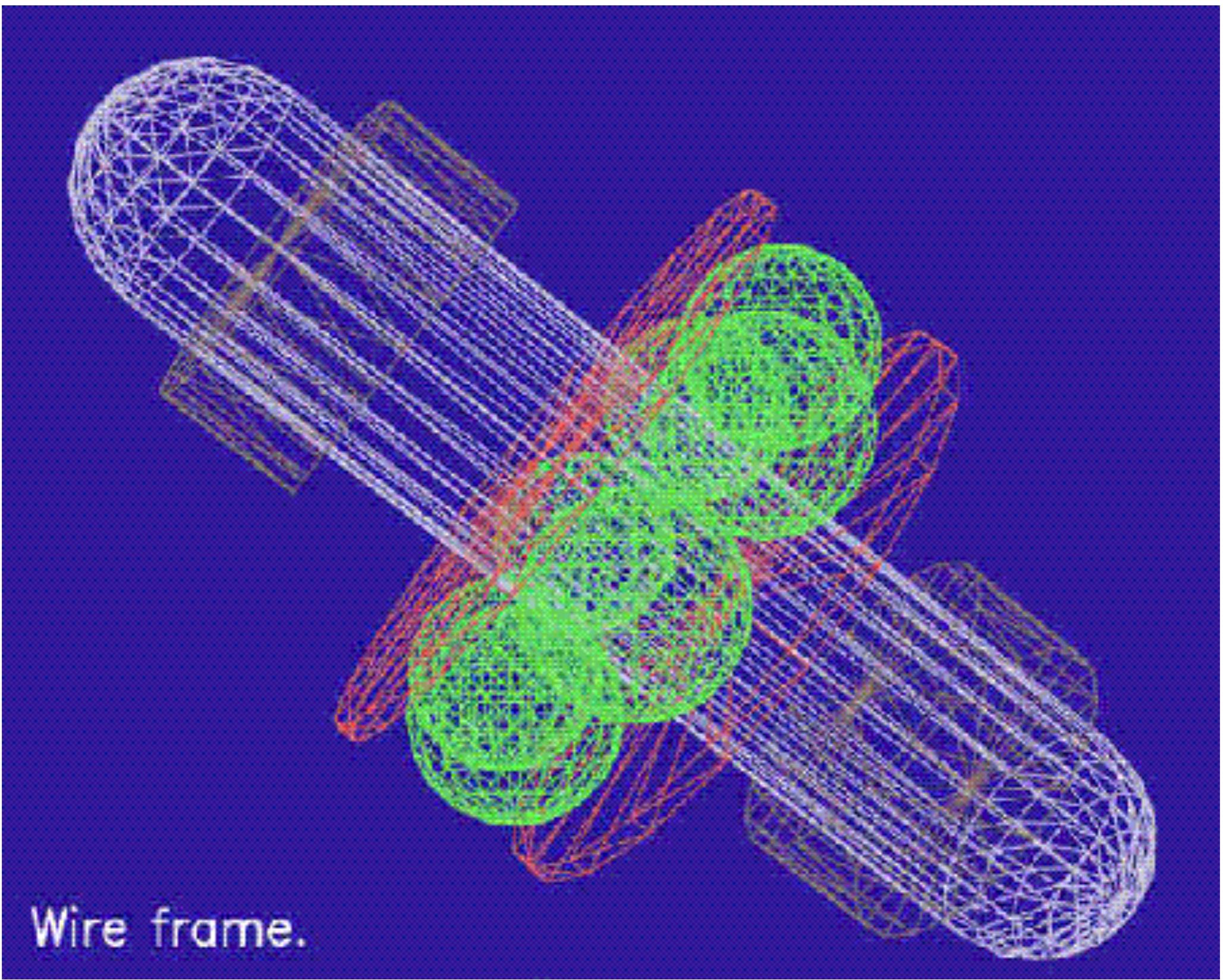
Parallel Projection



Perspective Projection



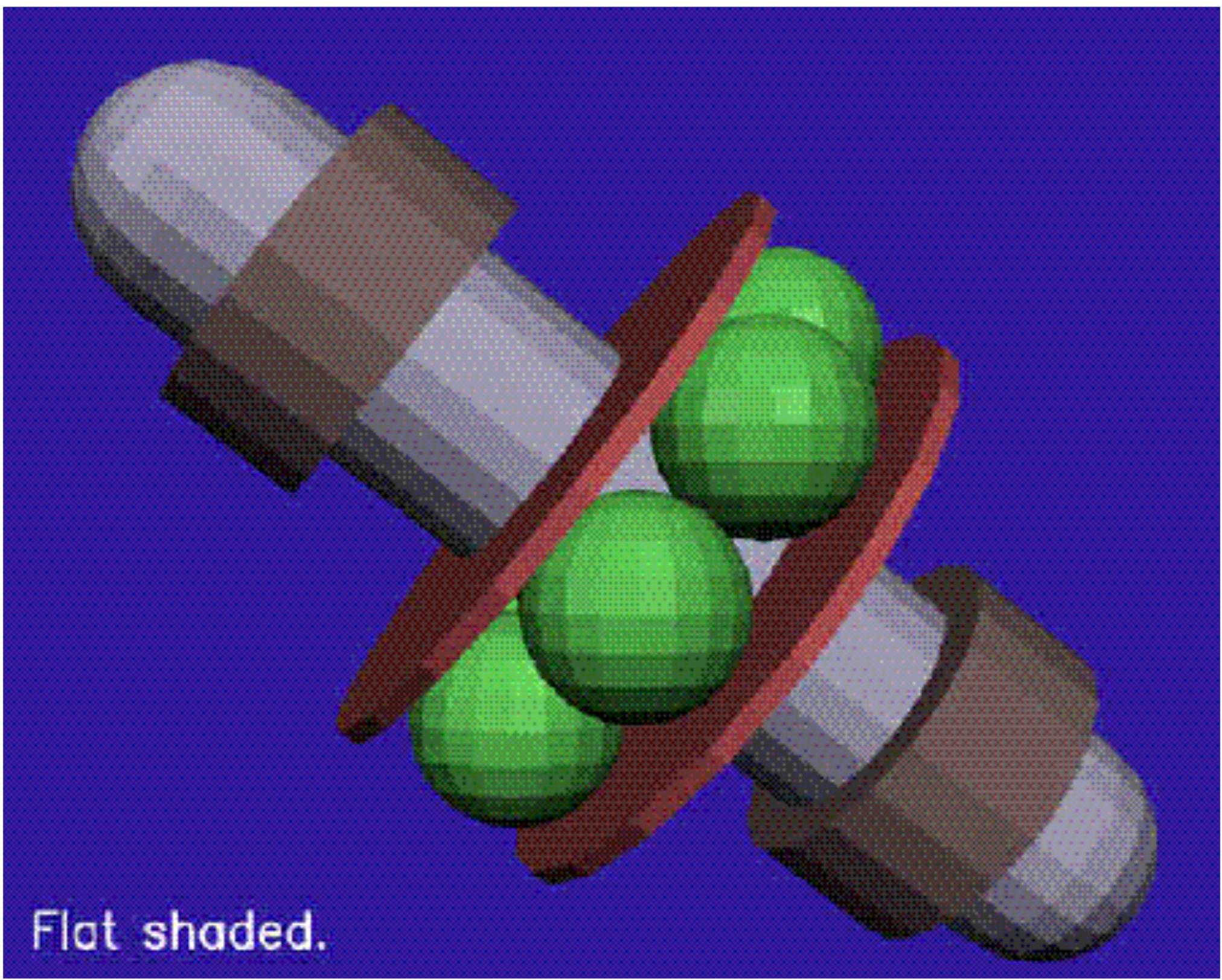
Wire frame.



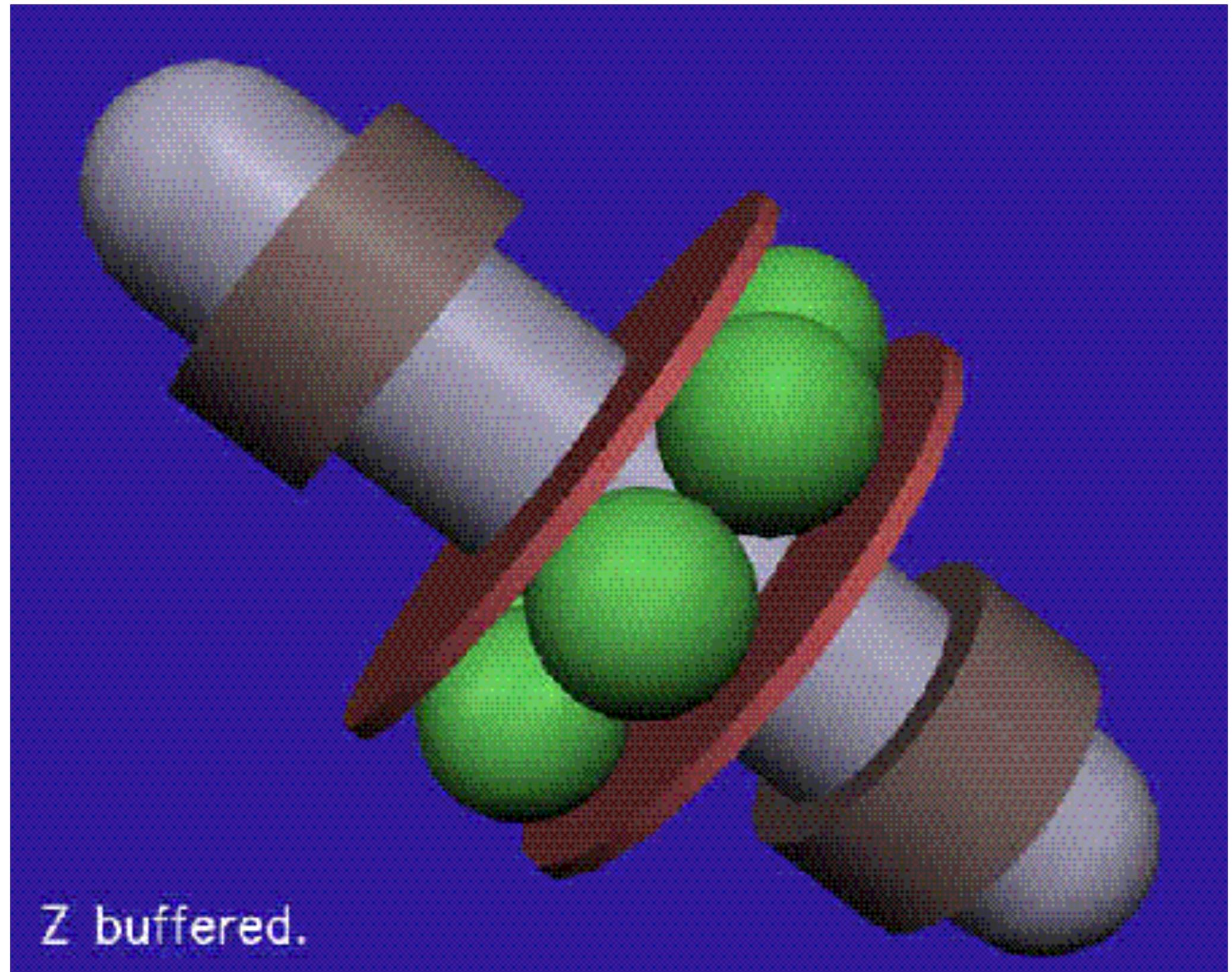
Wire frame.

Topics Addressed (contd)

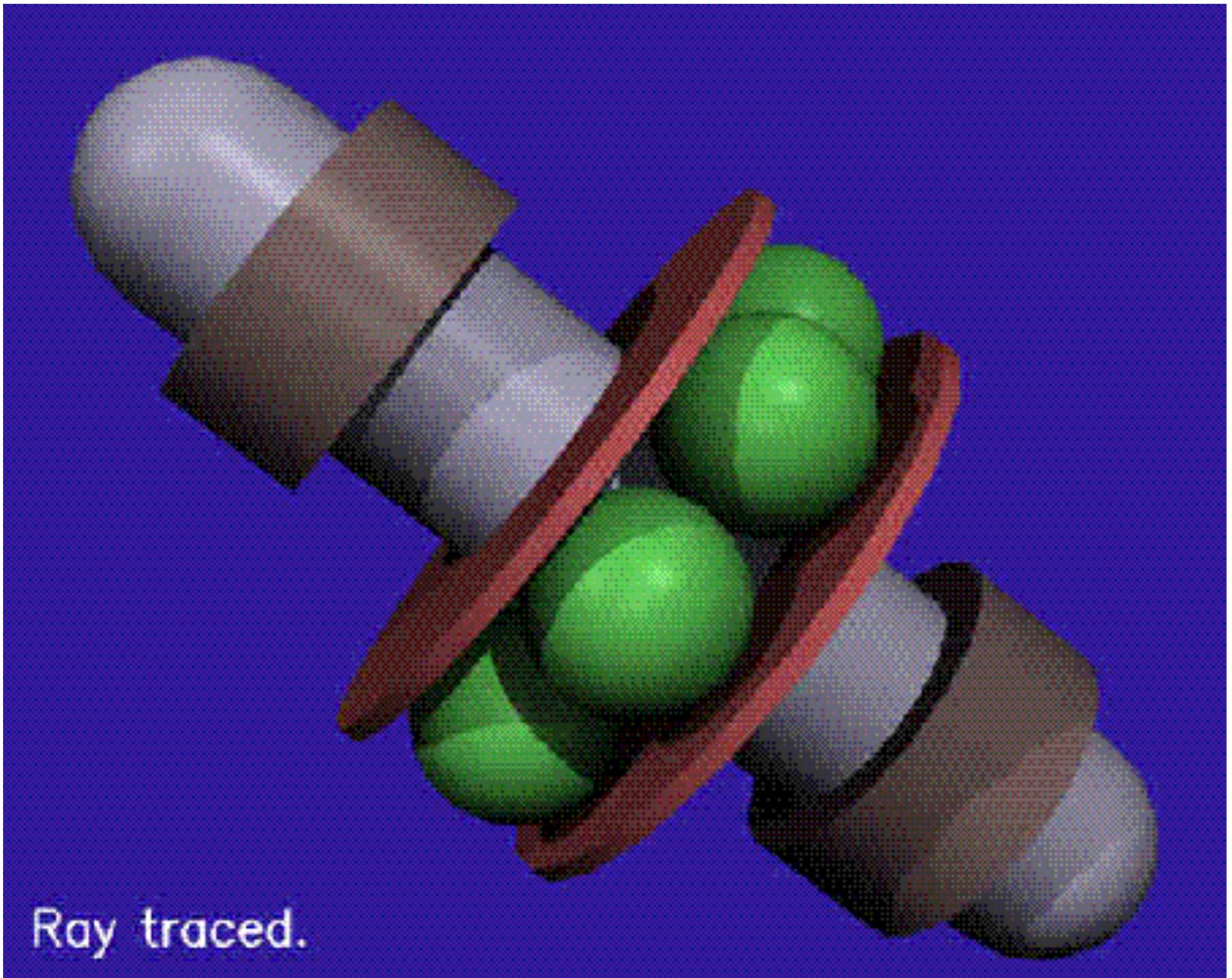
- Rendering techniques - visibility computation, illumination models, realistic imaging algorithms



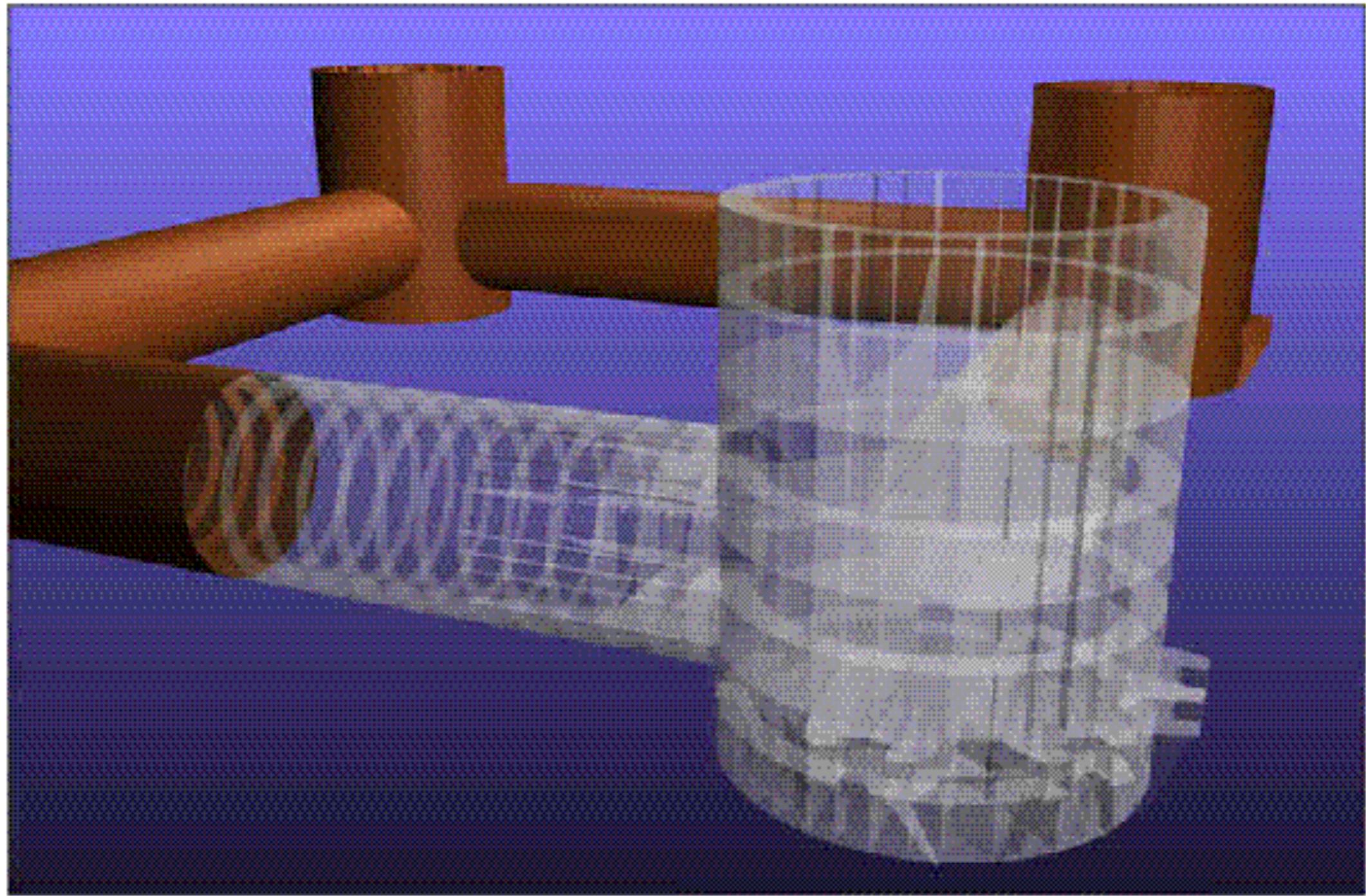
Flat shaded.



Z buffered.



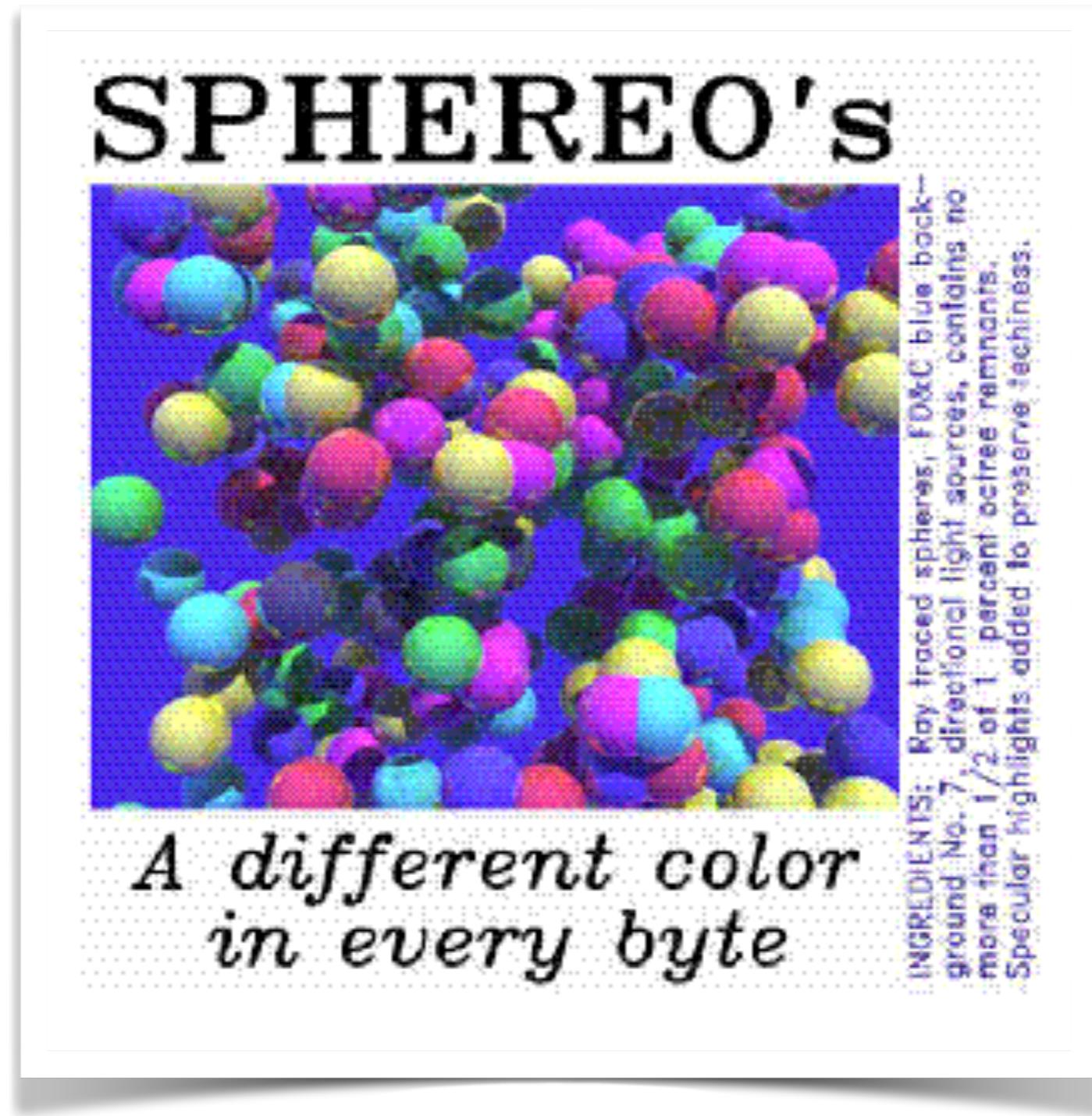
Ray traced.



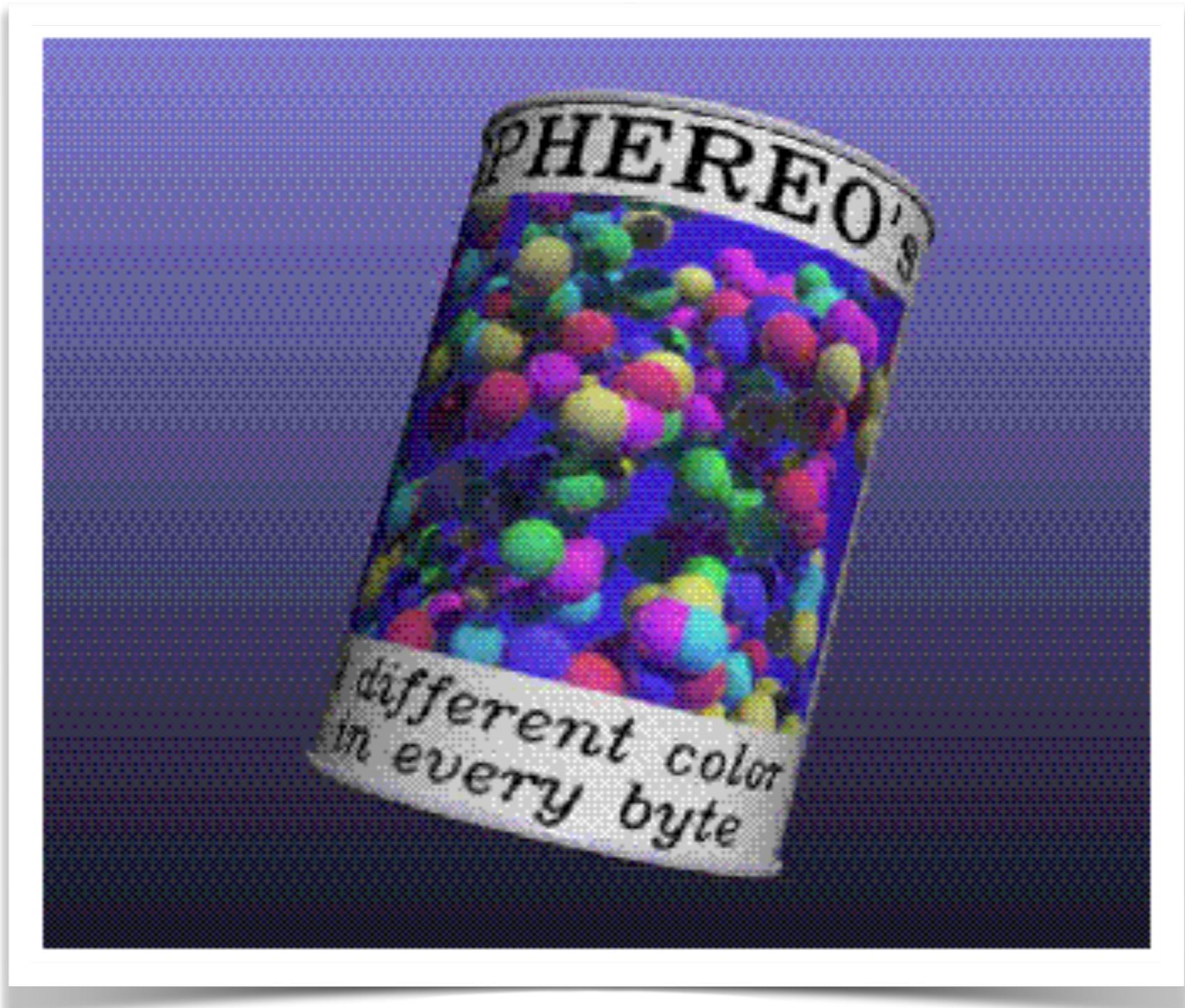


Texture Mapping (Only Brief Overview)

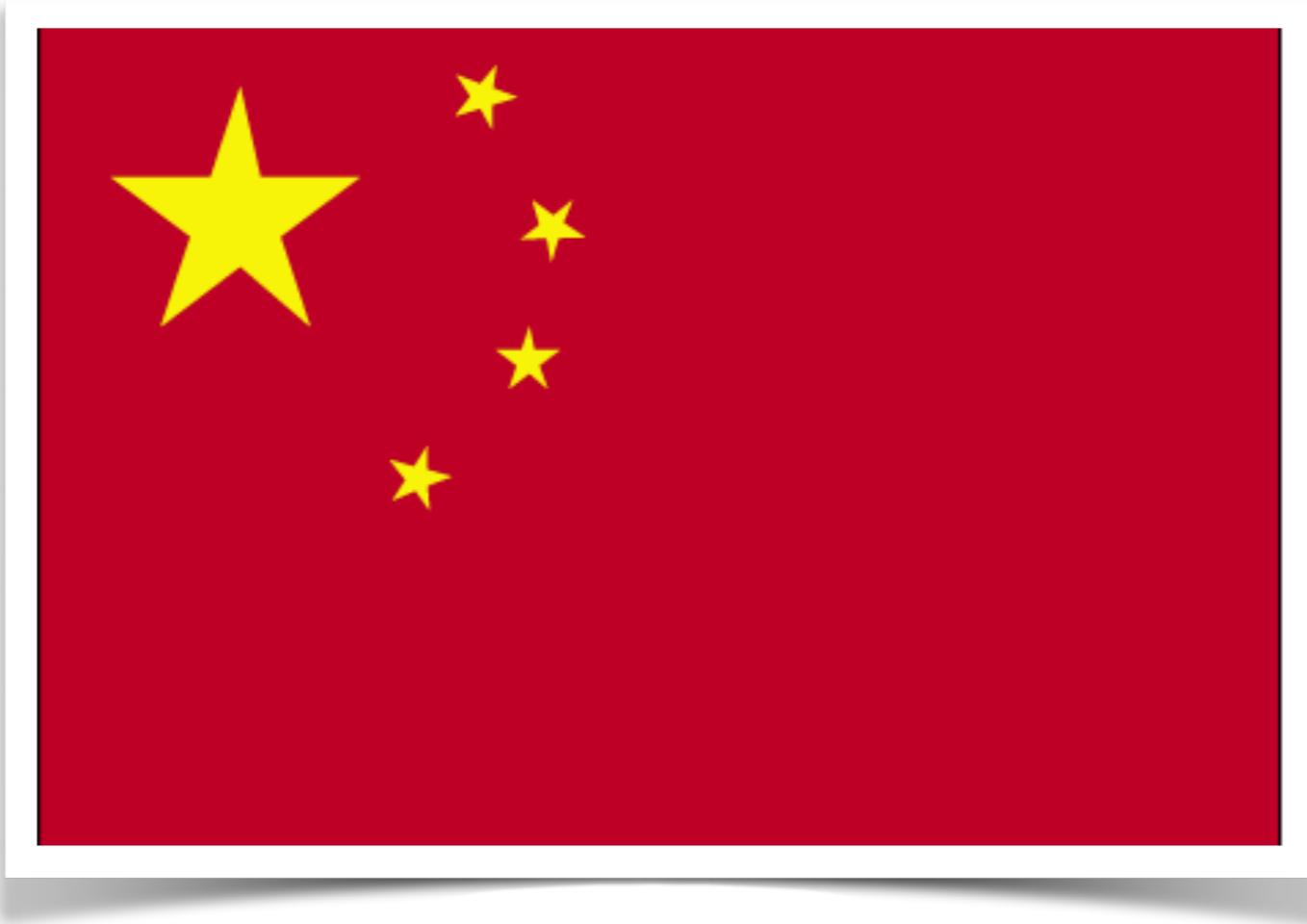
Texture Mapping



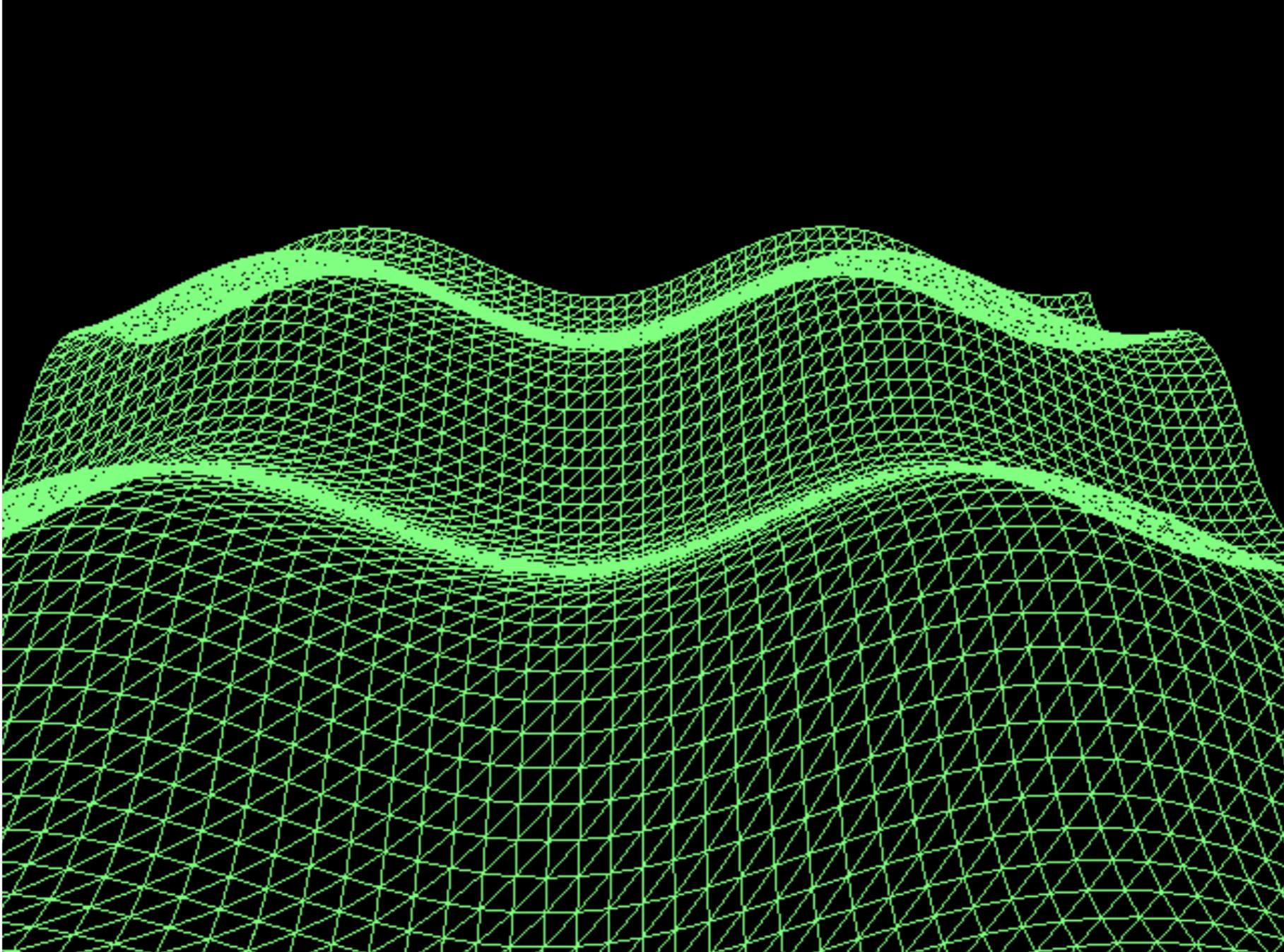
Texture Mapping



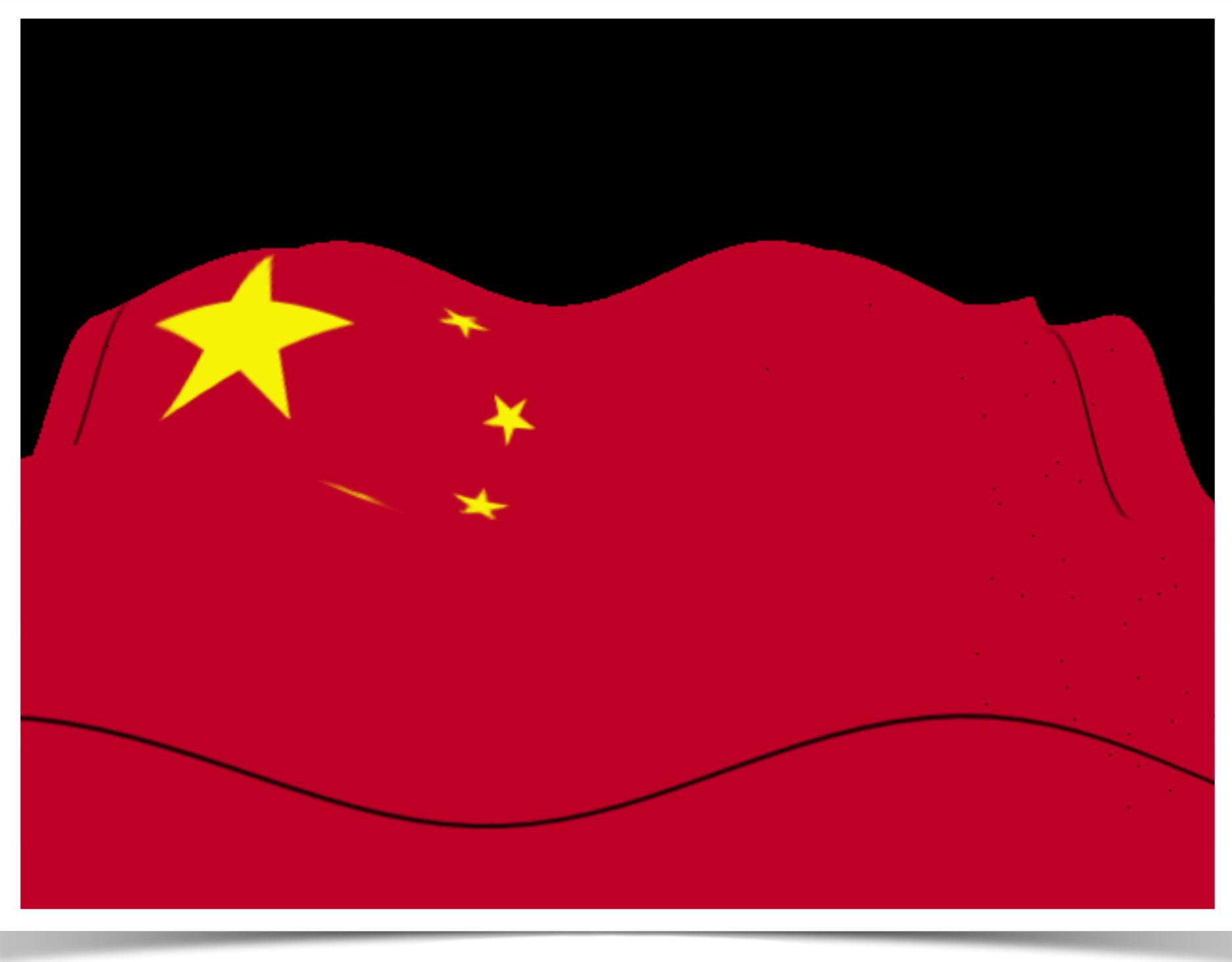
Texture Mapping



Texture Mapping



Texture Mapping



Realtime Ray Tracing

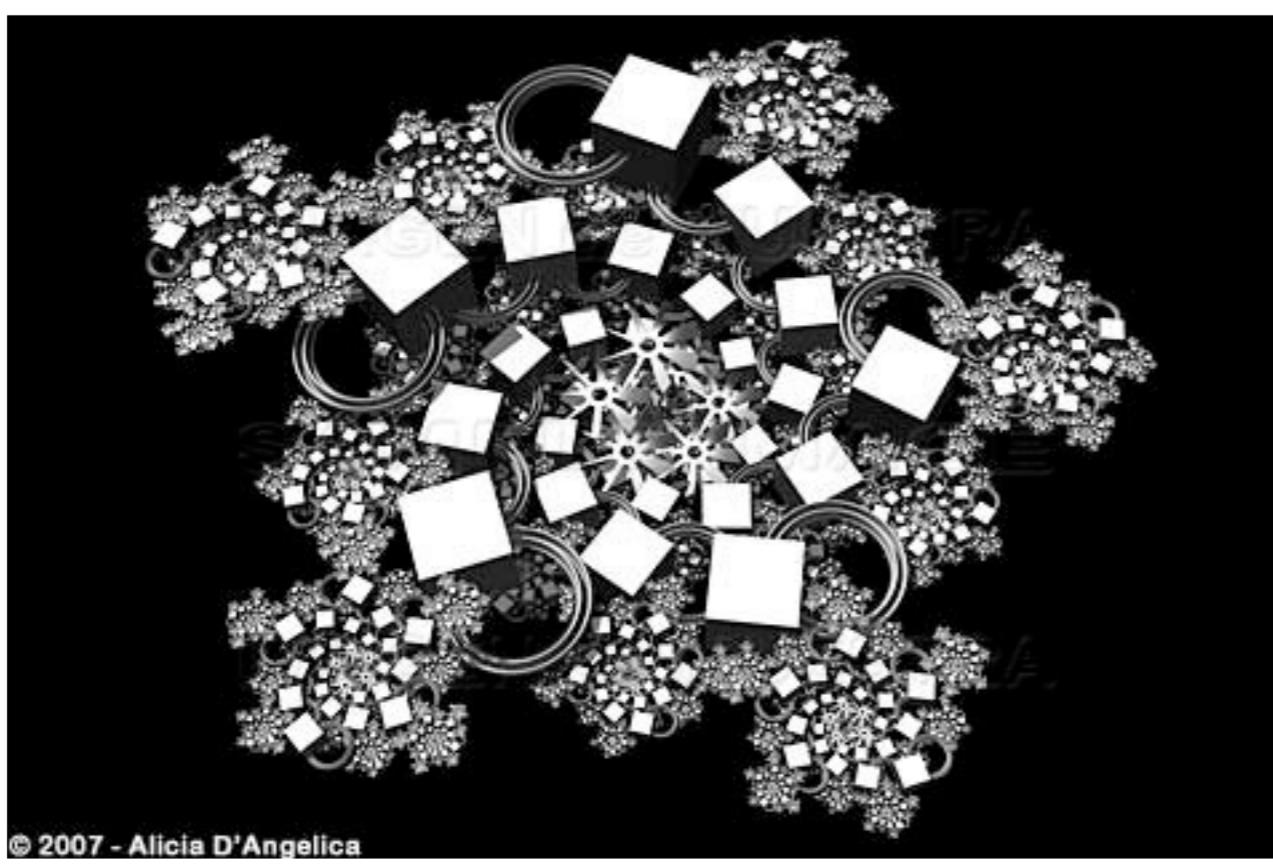
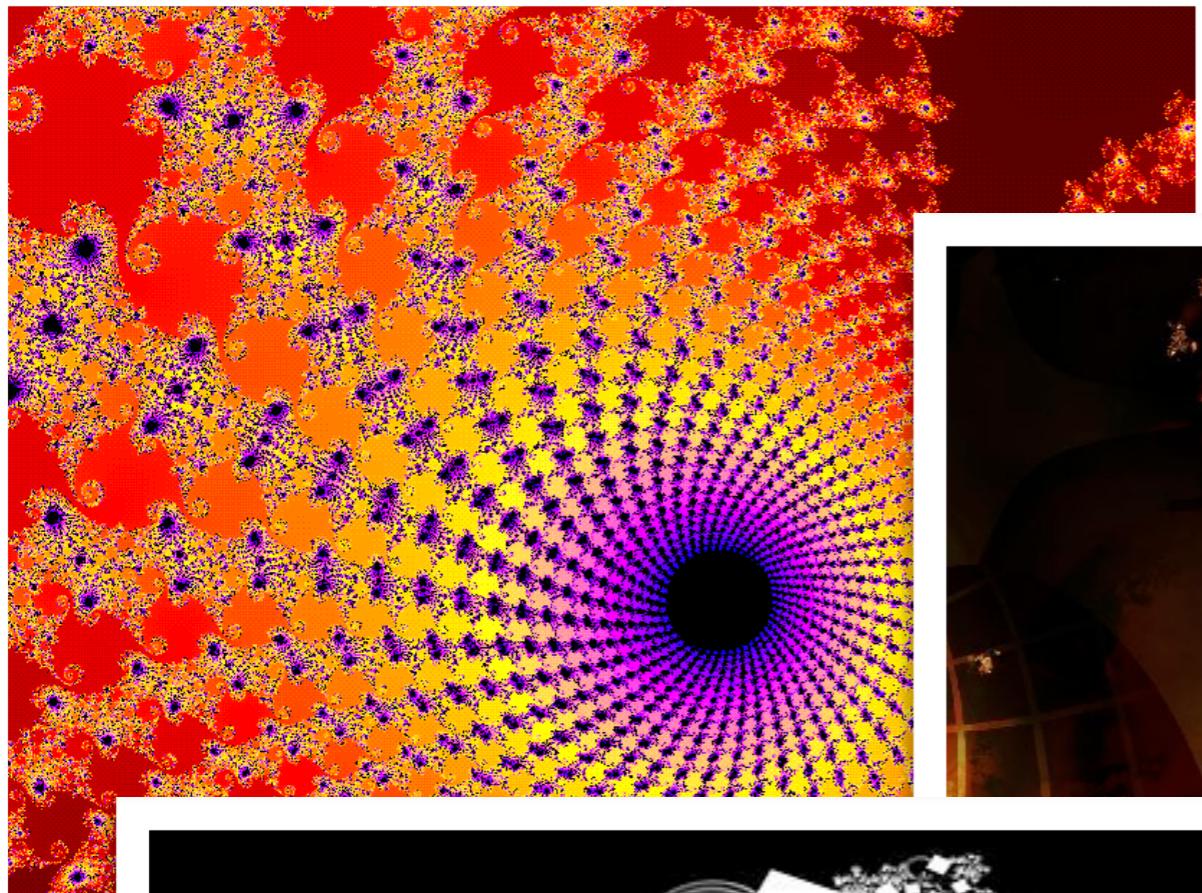


Topics Not Addressed

- 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



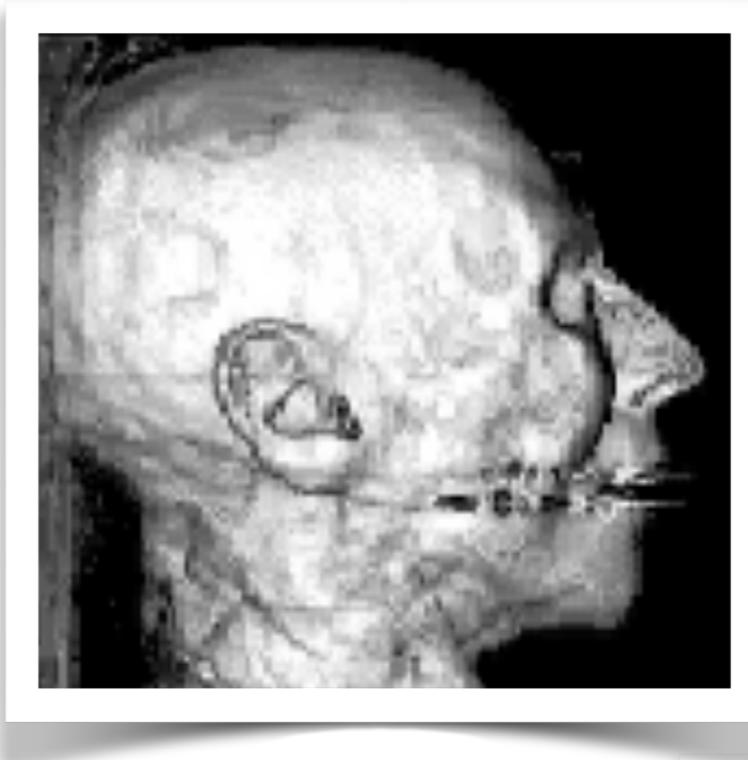
© 2007 - Alicia D'Angelica

fractal images

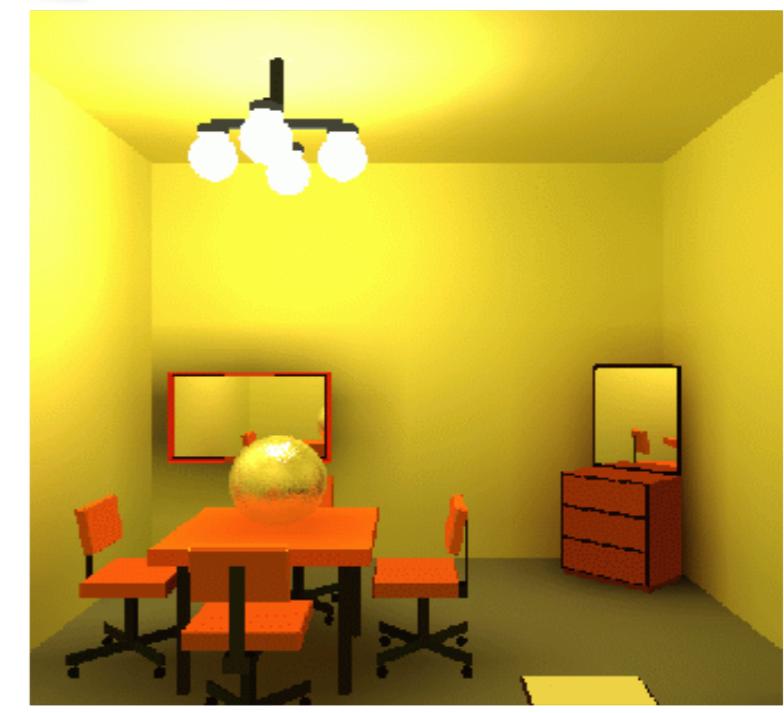


© Ken
Musgrave

Advanced Modeling and Rendering



3D Graphics and
Visualization

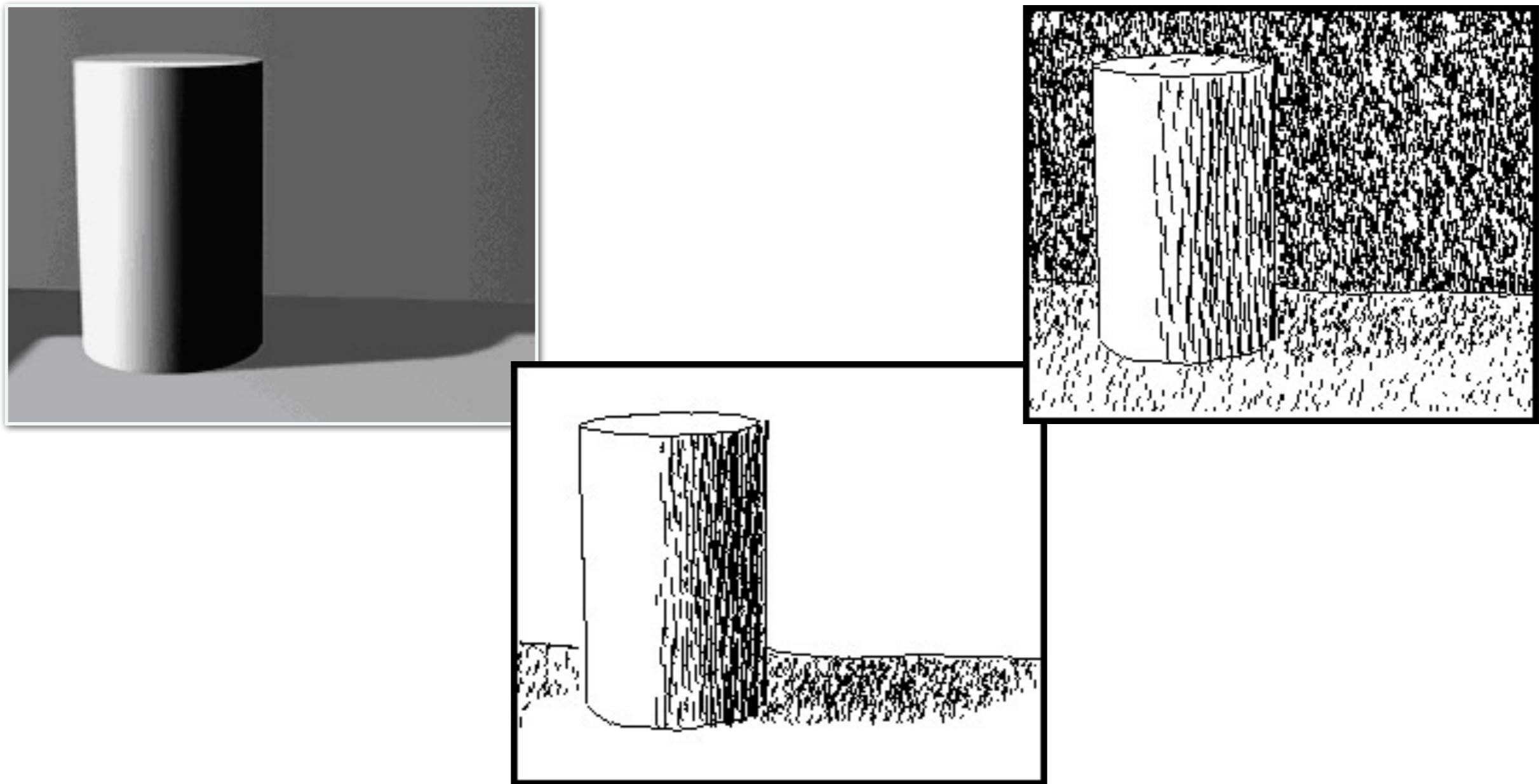


Topics Not Addressed

- Non-photo realistic rendering

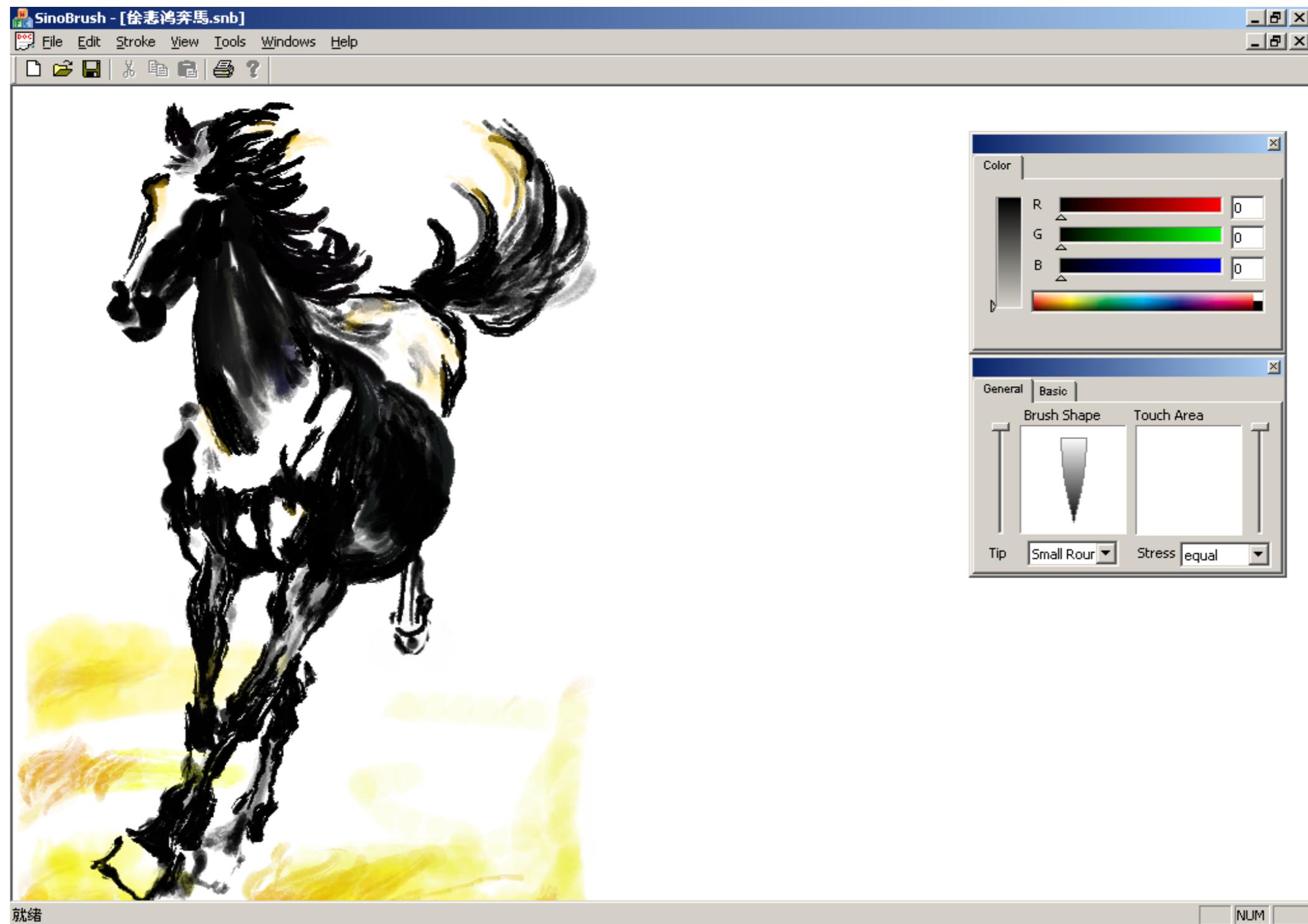


Non-Photorealistic Rendering





Non-Photorealistic Rendering



微博: @浙大张宏鑫

邮件: zhx@cad.zju.edu.cn

主页: <http://person.zju.edu.cn/zhx>

手机: 13958011790

微信: timothykull



谢谢

Thank You