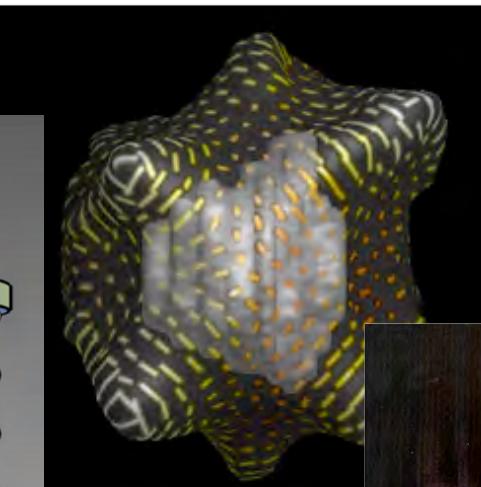
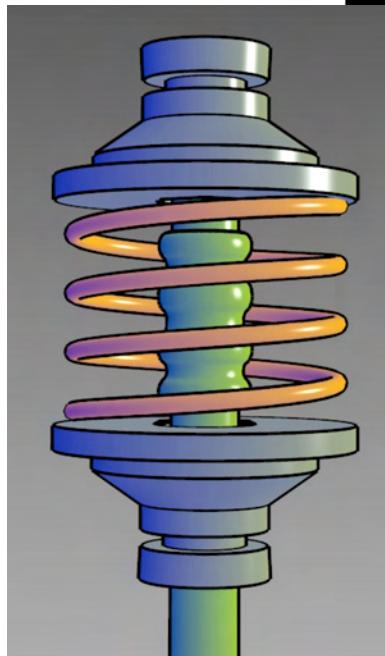




# NPR & Vis

- Non-Photorealistic Rendering
- Caricature
- Shape/Volume Visualization



# Different Objectives

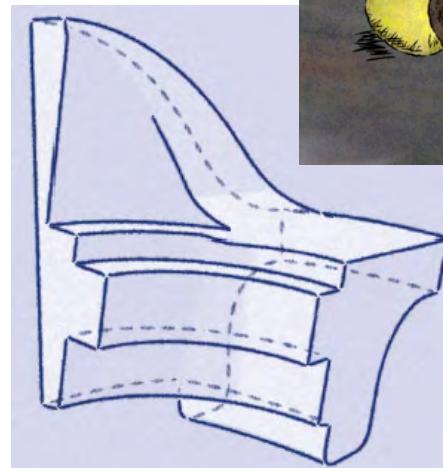
- Realistic: More “correct”



- Artistic: More “interesting”



- Scientific: More “informative”



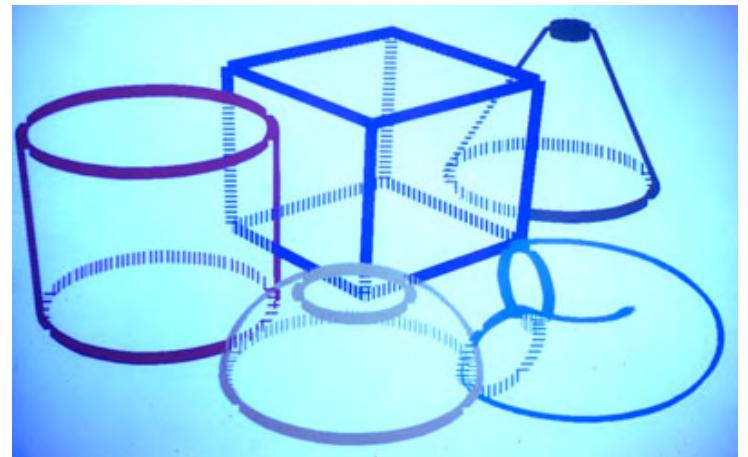
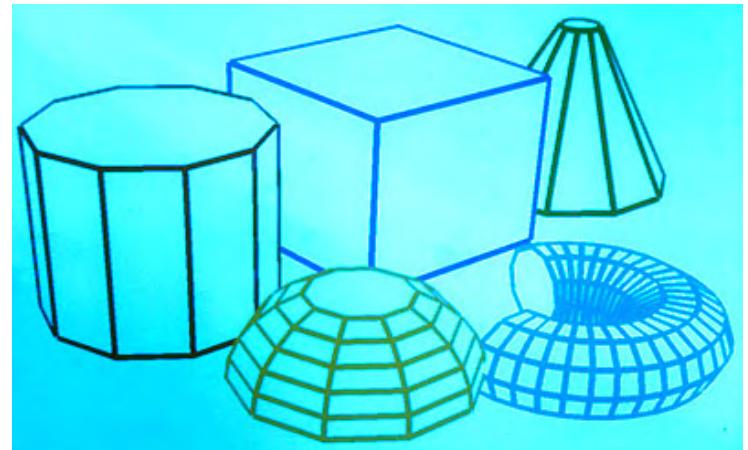
# Terminology

---

- Visualization
  - Interpret geometry/data/information in visual form (metaphor)
- Volume visualization
  - Rendering a 3D scalar or vector field
- Rendering
  - Mechanics of computing pixel colors from a graphic model
- Photorealism
  - Attempt to reproduce physics of light
- Non-Photorealistic Rendering (NPR)
  - Stylistic rendering effects
- Caricature
  - Extract & exaggerate distinguishing features

# Edge Attributes

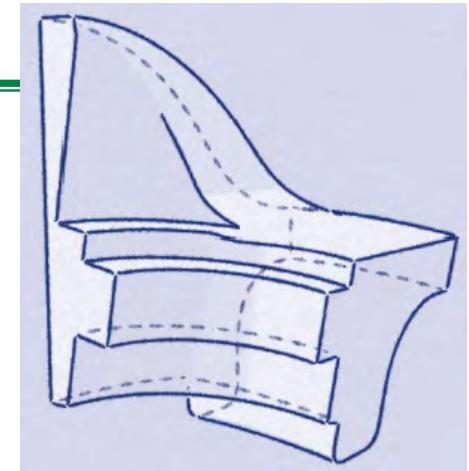
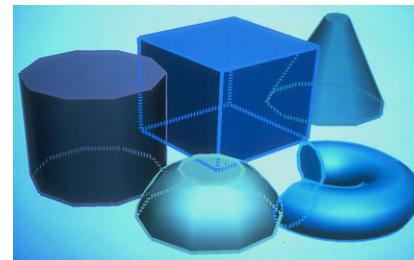
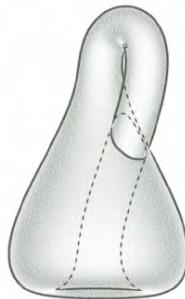
- Sharp edges (creases)
  - Surface normal discontinuities
  - Where surfaces meet
  - Tessellation edges are *smooth*
- Silhouettes
  - Separate front and back facing parts
  - Form closed loops
- Visible
  - Bounding at least one front faces
  - Not occluded from the viewpoint



Which edges are shown?  
Which are dashed?

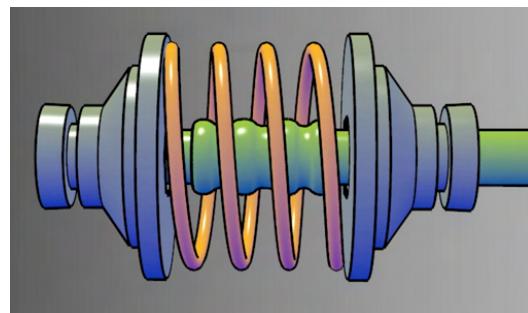
# Technical Illustration

- Silhouettes



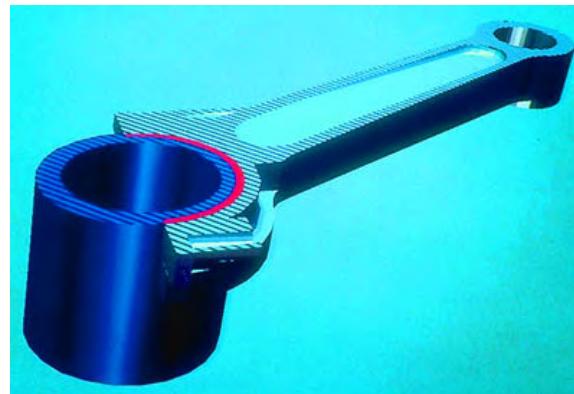
- Hidden Parts

- Color cues



- Hatching

- Cross-sections

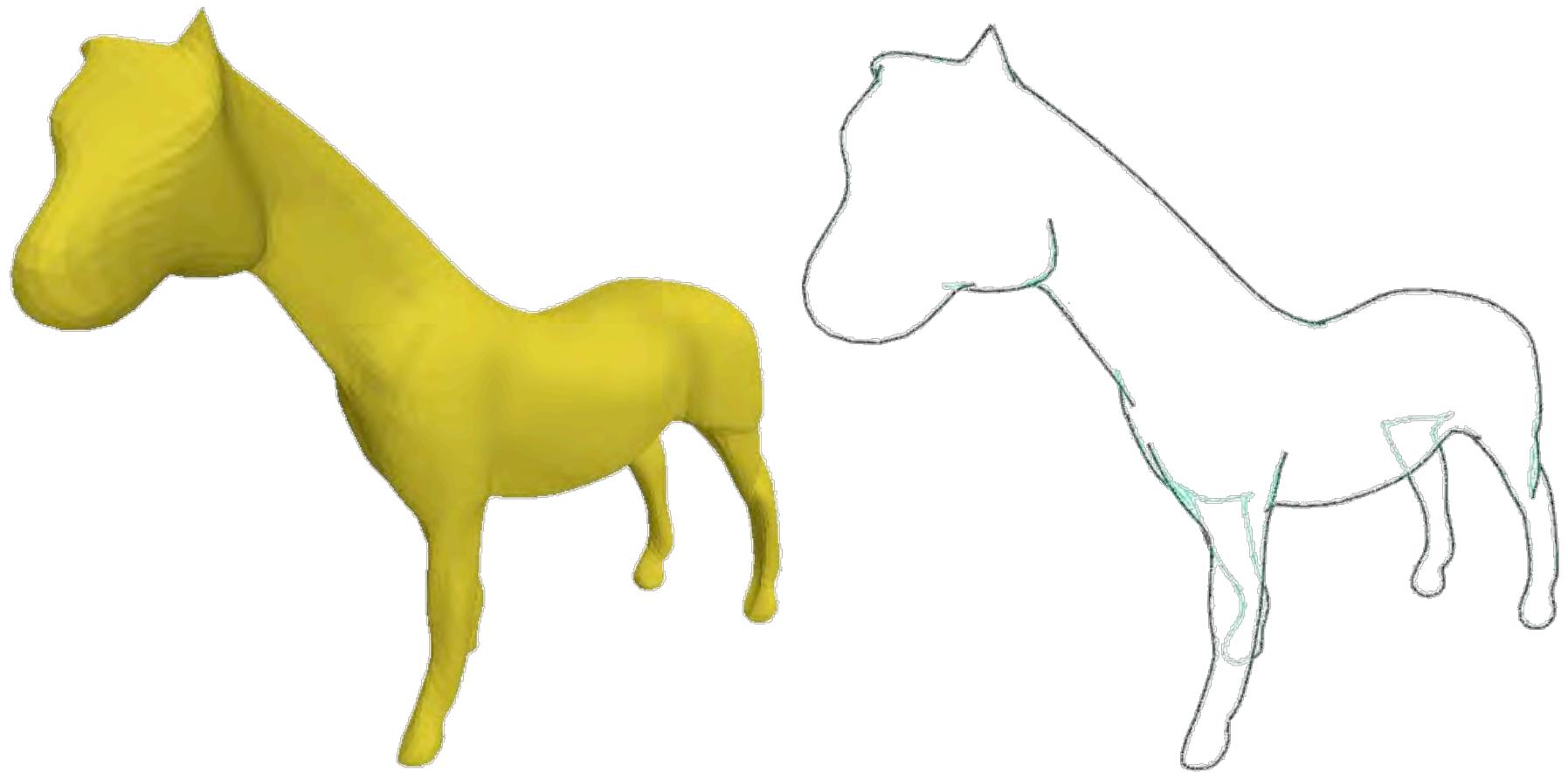


- Interferences

# How to find the silhouettes?

---

- Edges that separate front and back faces



# How to render hidden silhouettes

---

Render the shape, then disable the z-buffer and render silhouettes

```
M.showFrontTriangles();
hint(DISABLE_DEPTH_TEST); // show on top
stroke(dgreen); M.drawSilhouettes();
hint(ENABLE_DEPTH_TEST); // show silhouettes
```

```
class Mesh {...}
void drawSilhouettes() {for (int c=0; c<nc; c++) if (c<o(c) &&
frontFacing(t(c))!=frontFacing(t(o(c)))) drawEdge(c); }
```

```
Boolean frontFacing(int t) {return !cw(E,g(3*t),g(3*t+1),g(3*t+2)); }
```

# Antonio Haro (class project)

---

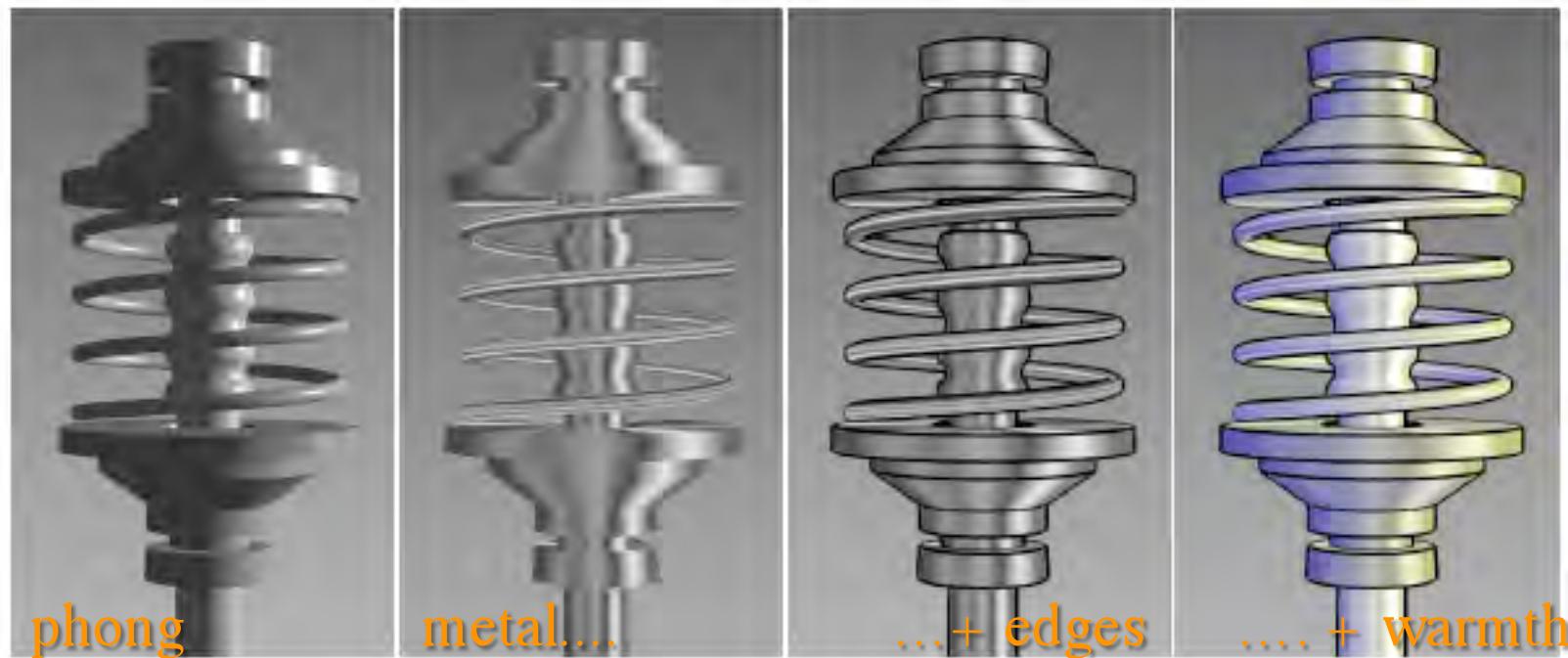
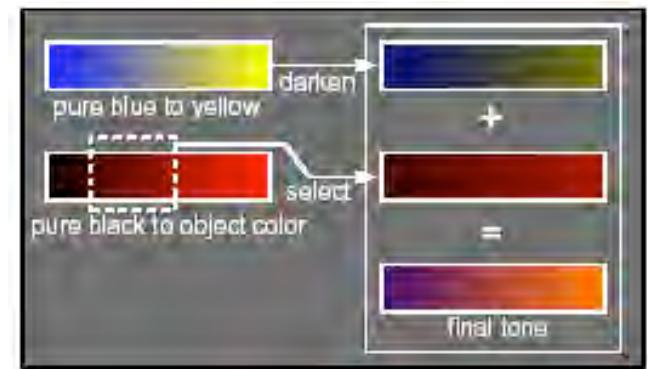
- Approach
  - Find the (visible) silhouette edges
  - Parameterize them
  - Offset along tangent & normal
  - Draw using 'sketched' style



# Amy Gooch - Bruce Gooch - Peter Shirley - Elaine Cohen

<http://www.cs.utah.edu/~gooch/SIG98/abstract.html>

- Use hue shift to enhance orientation
  - Warmer tones perceived as closer
- Mix with mid part of luminance



<http://www.cs.utah.edu/~shirley/papers/gooch98.pdf>

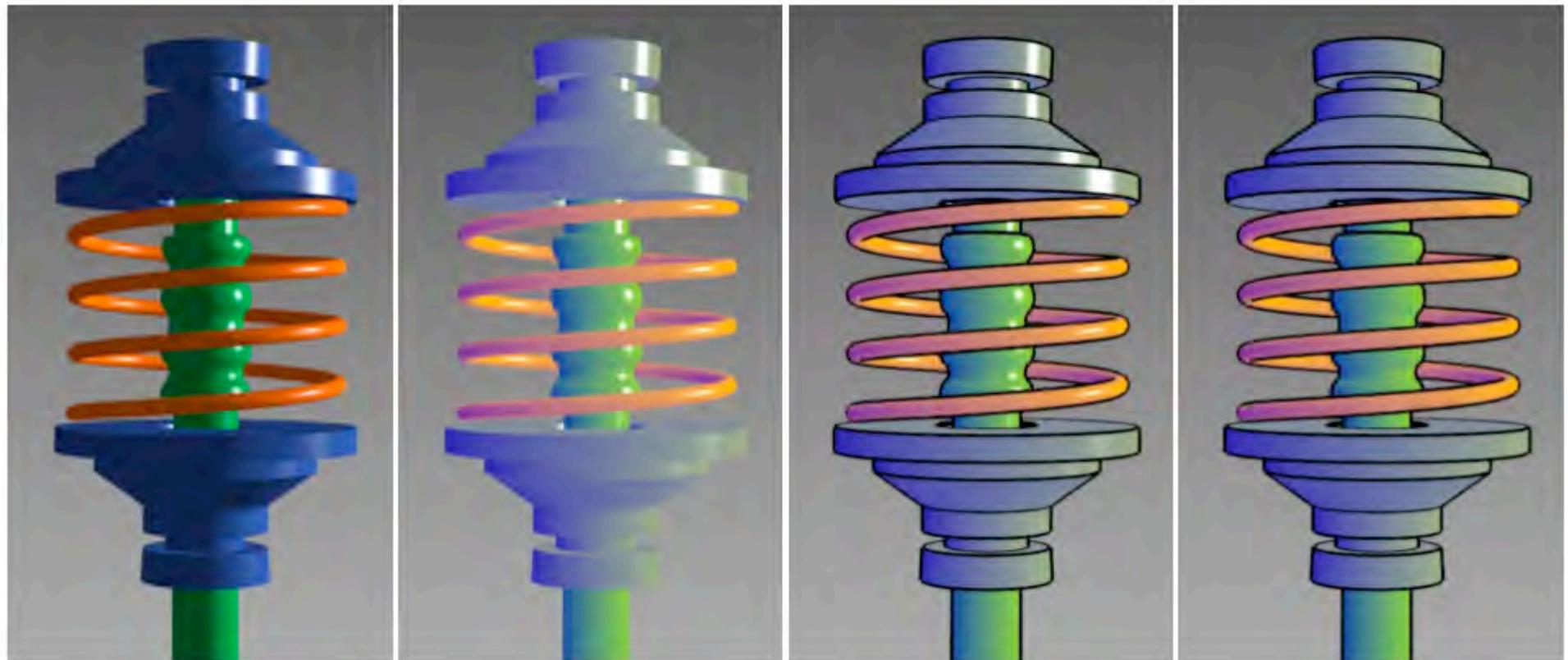


Figure 11: Left to Right: a) Phong model for colored object. b) New shading model with highlights, cool-to-warm hue shift, and without edge lines. c) New model using edge lines, highlights, and cool-to-warm hue shift. d) Approximation using conventional Phong shading, two colored lights, and edge lines.

# Art Imitation

- Hatching



- Painting



- Toons



---

# **WYSIWYG NPR:**

## Drawing Strokes Directly on 3D Models

*Robert Kalnins*

*Lee Markosian*

*Barbara Meier*

*Michael Kowalski*

*Joe Lee*

*Philip Davidson*

*Matthew Webb*

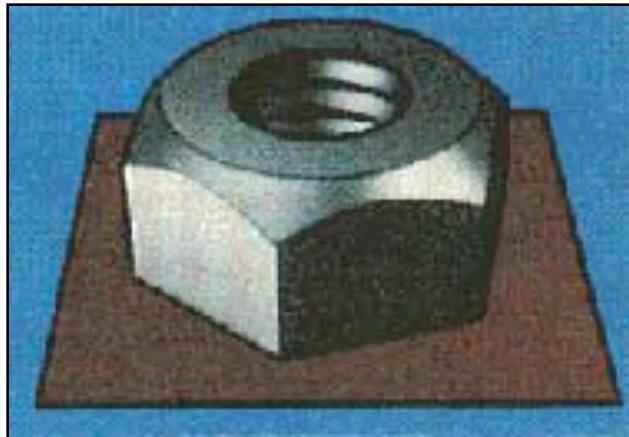
*John Hughes*

*Adam Finkelstein*

Princeton University   Brown University



# NPR: Simulating Various Media



Technical Illustration [Saito 90]



Pen & Ink [Winkenbach 94]



Watercolor [Curtis 97]



Paint [Hertzmann 98]

# Long-Range Goal

---

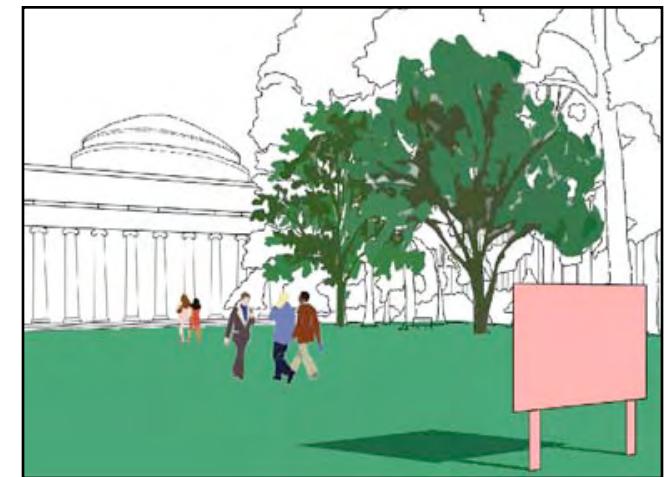
Create full scene by drawing



[Cohen 00]



[Bourguignon 01]



[Tolba 01]

# NPR: Dynamic Imagery

---

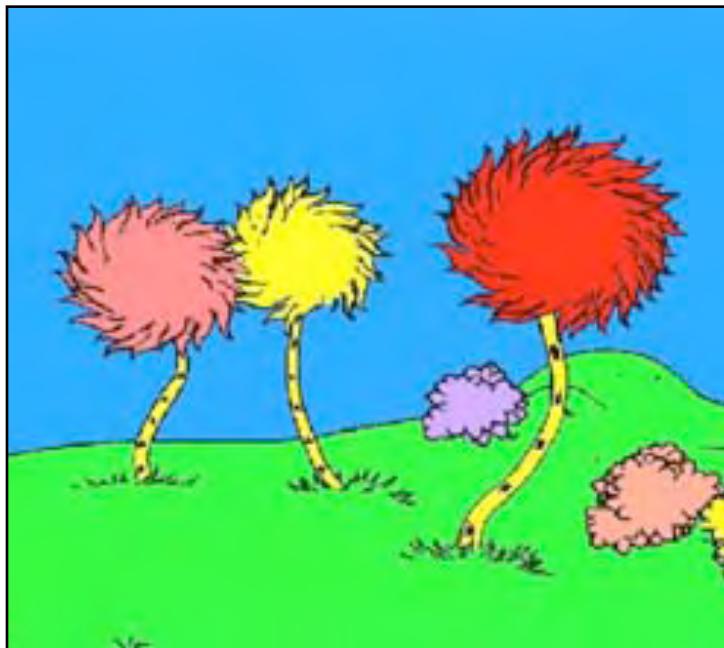


Painterly rendering for  
3D models [Meier 96]

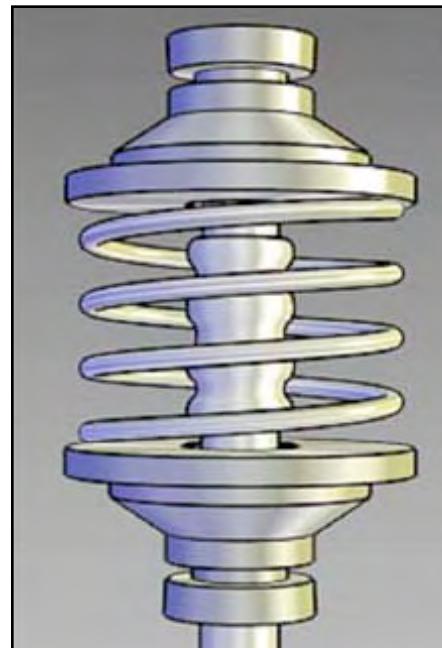


Painterly rendering for  
video [Litwinowicz 97]

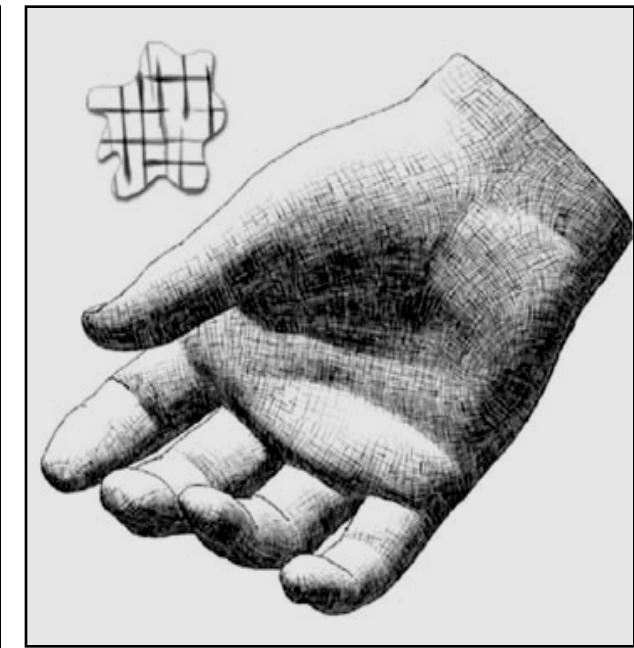
# NPR: Interactive Rendering



[Kowalski 99]



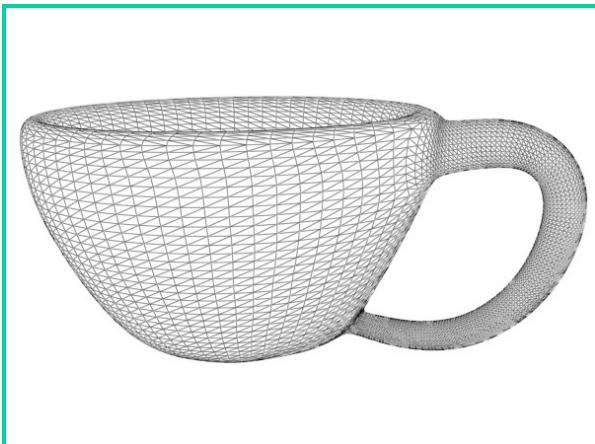
[Gooch 98]



[Praun 01]

Algorithms for aesthetic qualities.

# WYSIWYG NPR



- Draw on 3D model
- Retain stylization for new views
- Stylistic flexibility

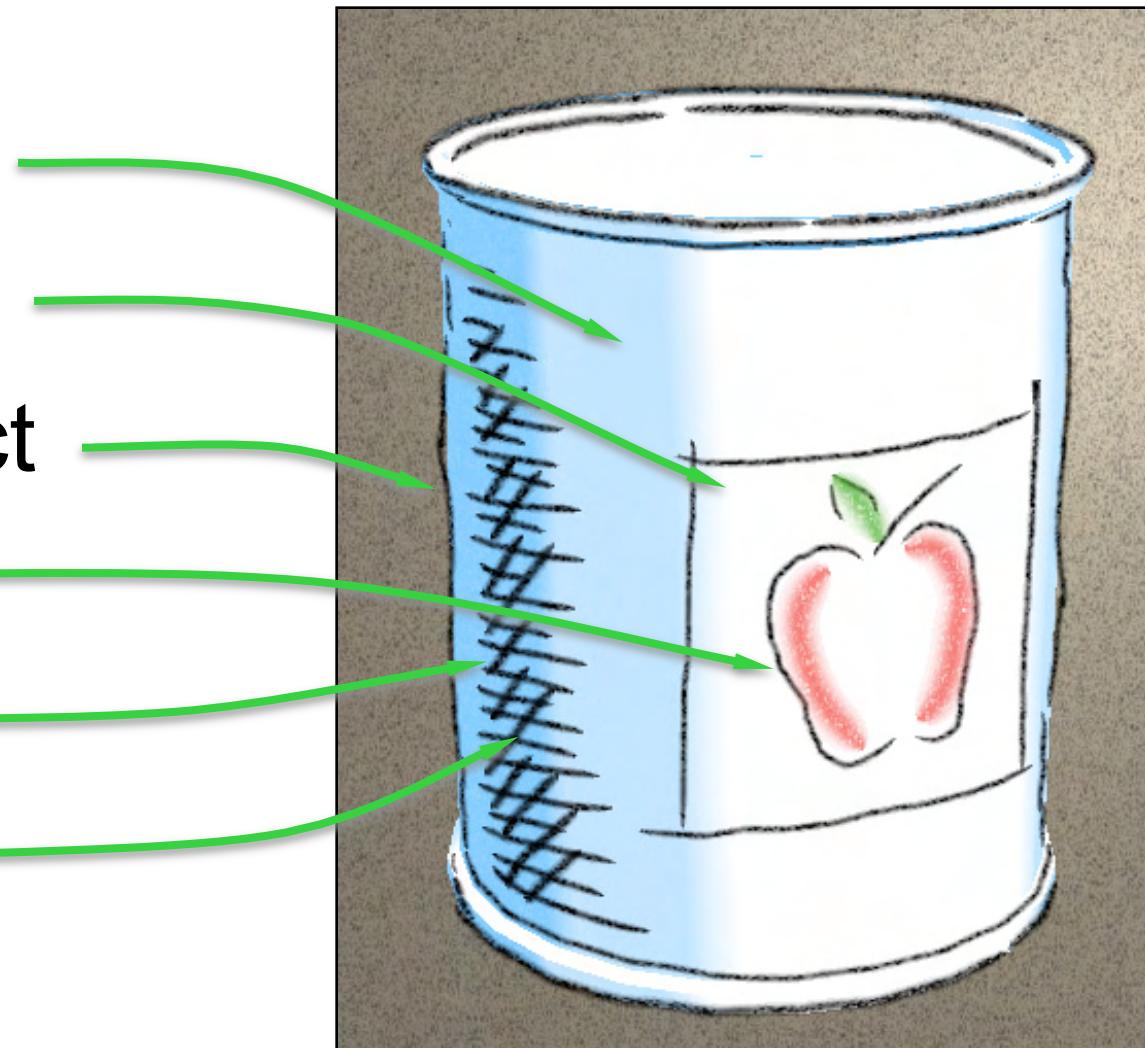


# Stylistic Flexibility



# Overview of Components

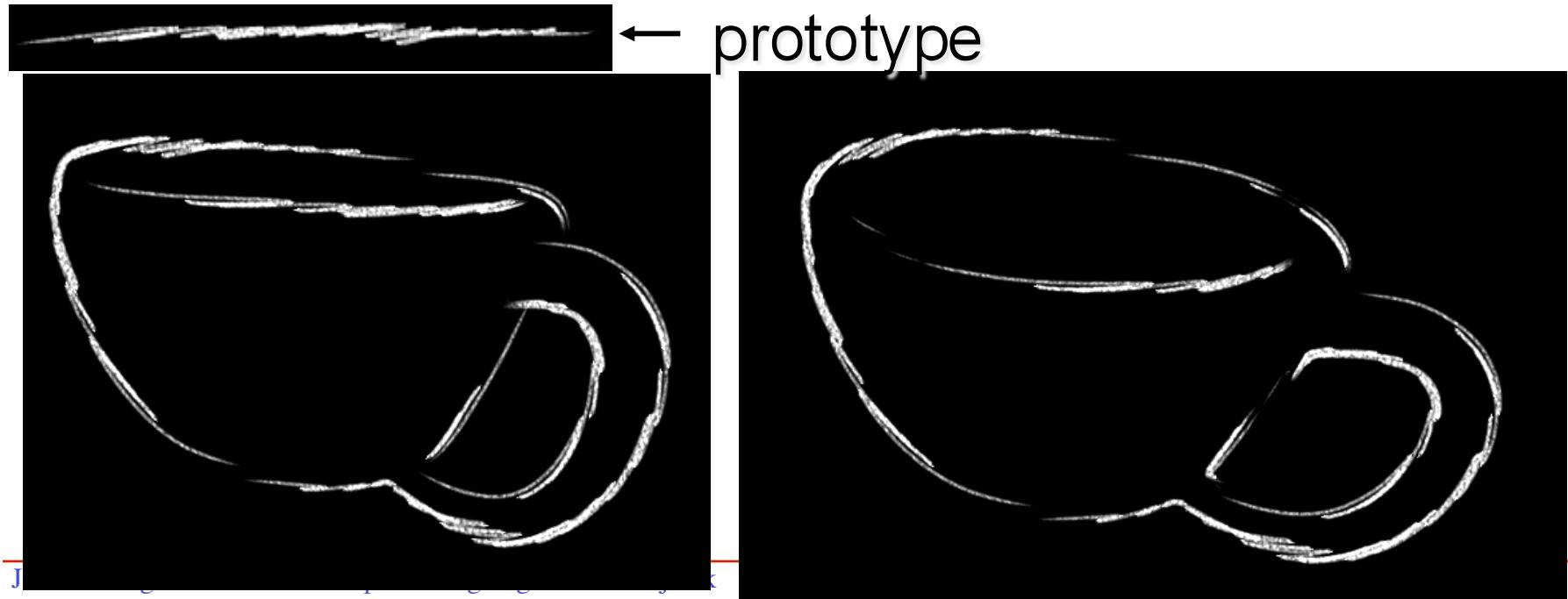
Base Coat  
Brush Style  
Paper Effect  
Decals  
Outlines  
Hatching



# Silhouette Stylization

Silhouettes are view-dependent.

- Problem #1: localized stylization?!?
- Solution: “rubber-stamp” globally

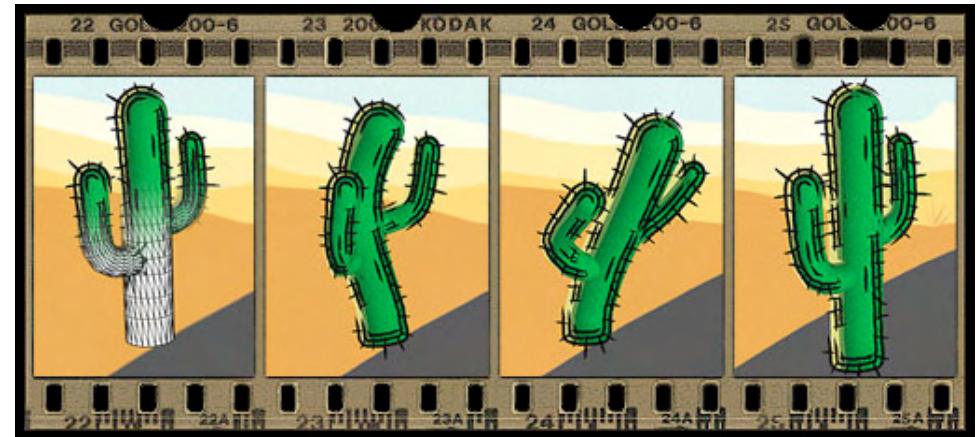


Robert Kalnins, Philip Davidson, Lee Markosian,  
Adam Finkelstein

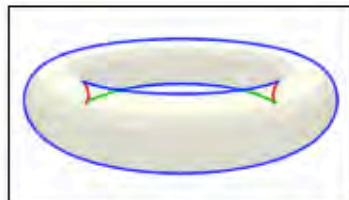
[http://www.cs.princeton.edu/gfx/pubs/Kalnins\\_2003\\_CSS/index.php](http://www.cs.princeton.edu/gfx/pubs/Kalnins_2003_CSS/index.php)

## Coherent Stylized Silhouettes

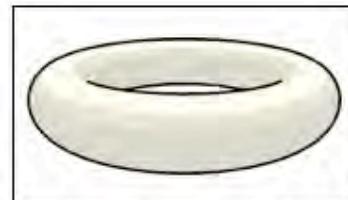
- Silhouettes correspondence
  - in consecutive frames
- Track silhouettes in 3D



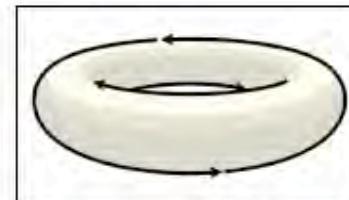
(a) mesh in frame  $f_i$



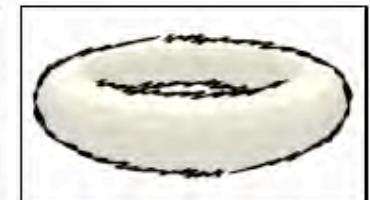
(b) silhouette loops



(c) silhouette paths



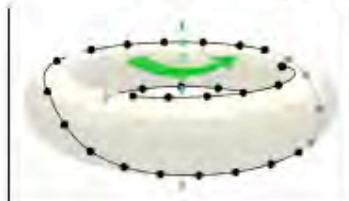
(d) brush paths



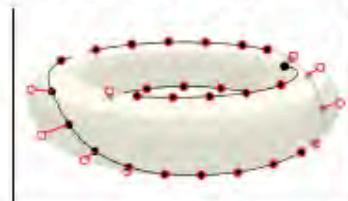
(e) strokes in  $f_i$



(f) samples on (d)



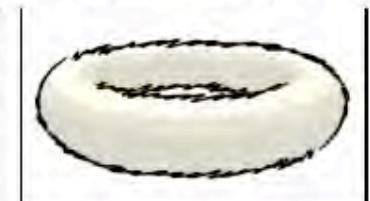
(g) new camera for  $f_{i+1}$



(h) propagation



(i) new brush paths



(j) new strokes in  $f_{i+1}$

# Hatching: Level of Detail

## *Free hatching*

- User-defined LOD



## *Structured hatching*

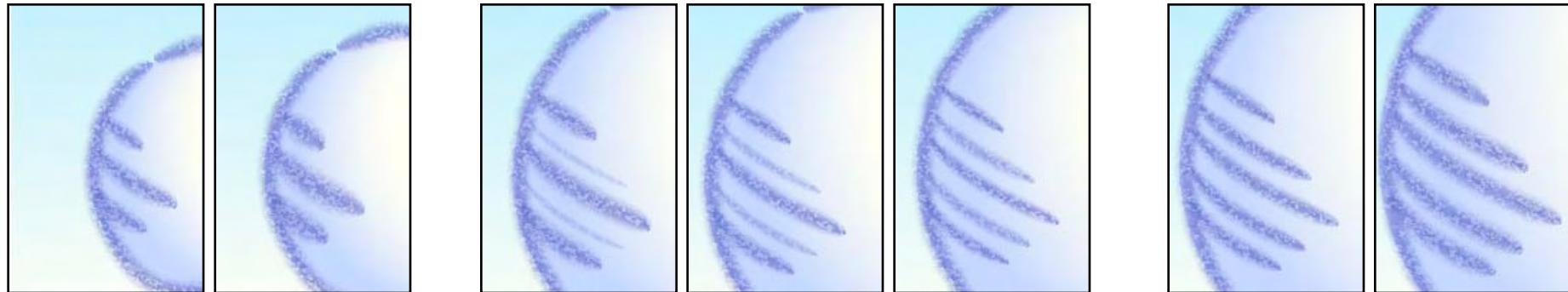
- Automatic LOD



# Structured Hatching LOD

LOD based on size of group

- Double size: double strokes
- In between: adjust widths
- At transition: animate



size=1    1.25    1.6    1.6    1.6    1.75    2

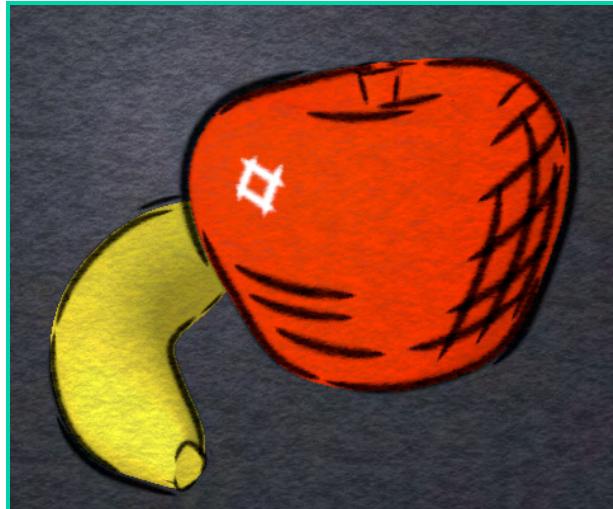
# Hatching: Lighting Scheme

## Fixed Hatching

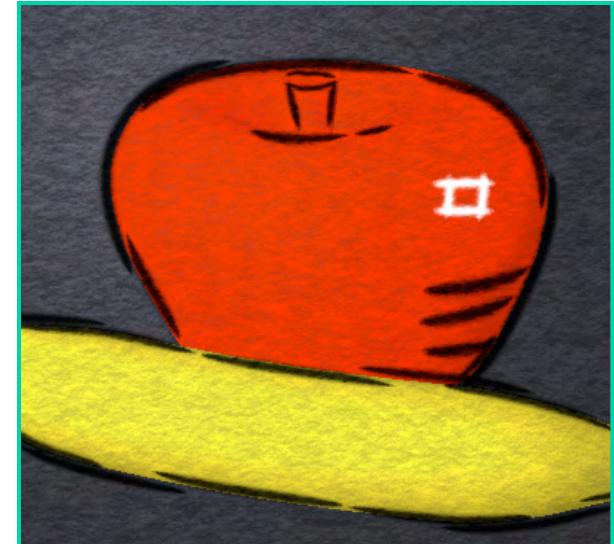
- Light fixed in world frame

## Mobile Hatching

- Light moves with camera



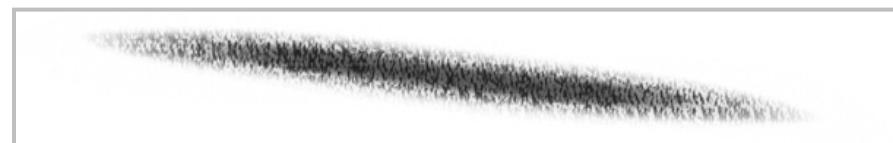
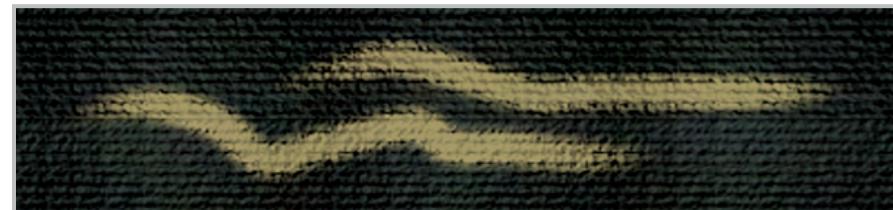
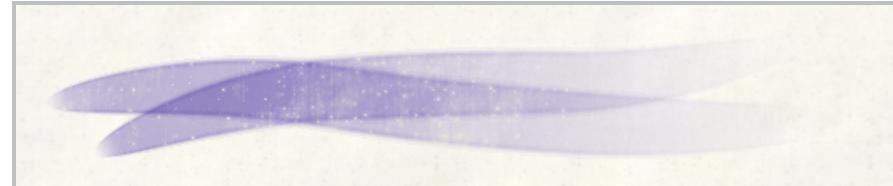
fixed  
mobile



# Brush Style

Per stroke:

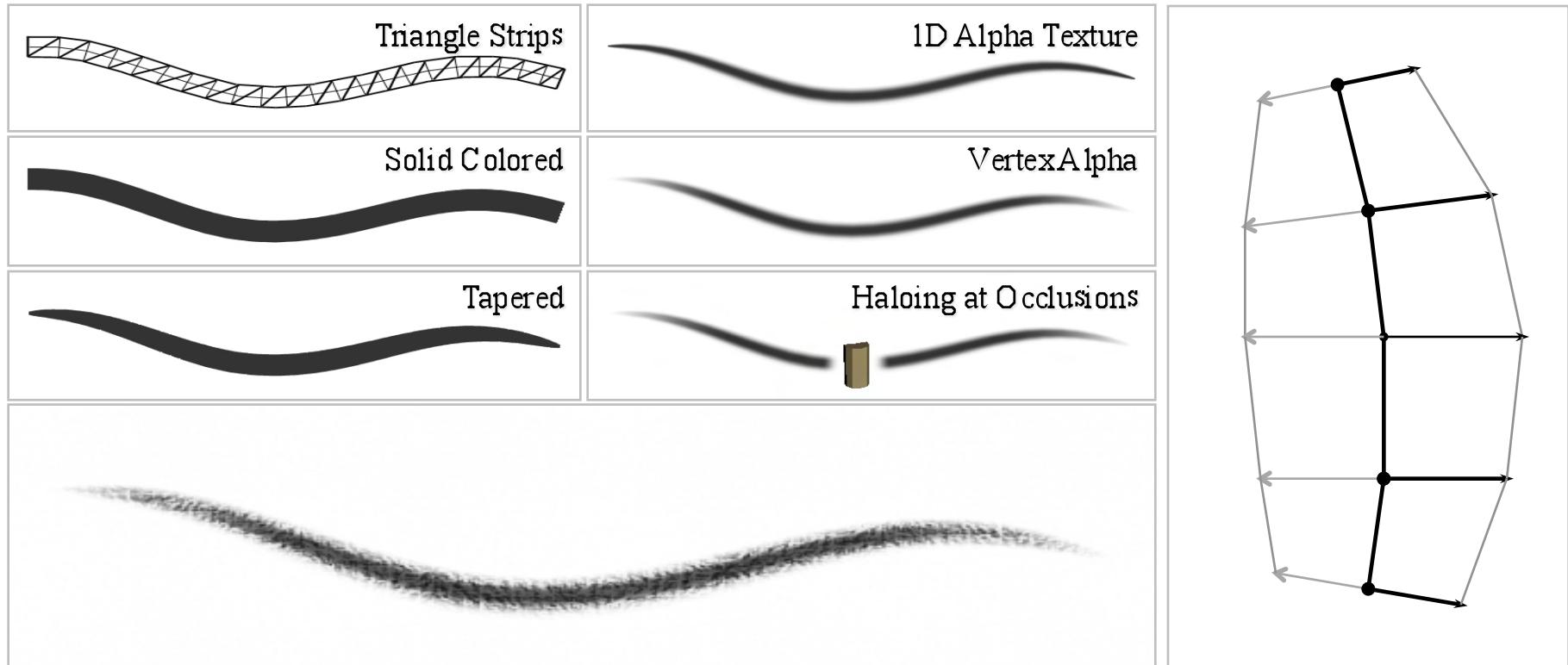
- Color
- Width profile
- Alpha profile
- Paper
- etc.



Rendered as triangle strips.

# Strokes

[Northrup 00]



Visibility computed via *ID reference image*.

# 3D Caricatures

---

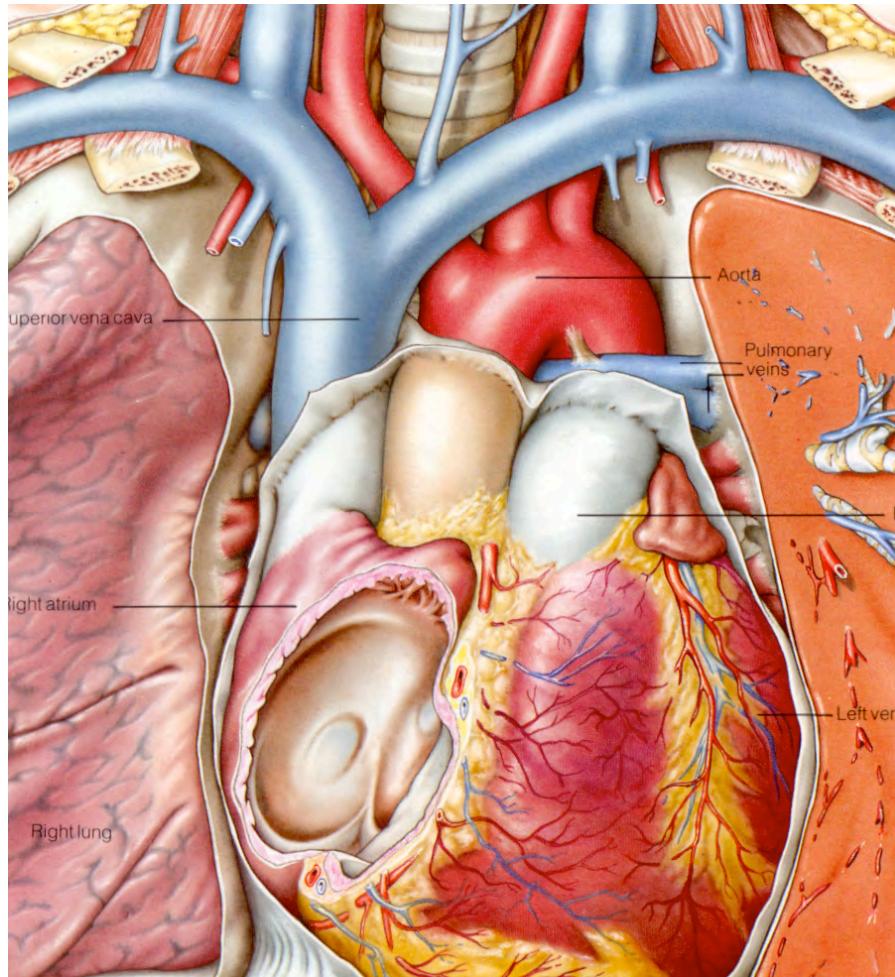


Ergun Akleman & Jon Reisch

Visualization Sciences Program  
College of Architecture  
Texas A&M University

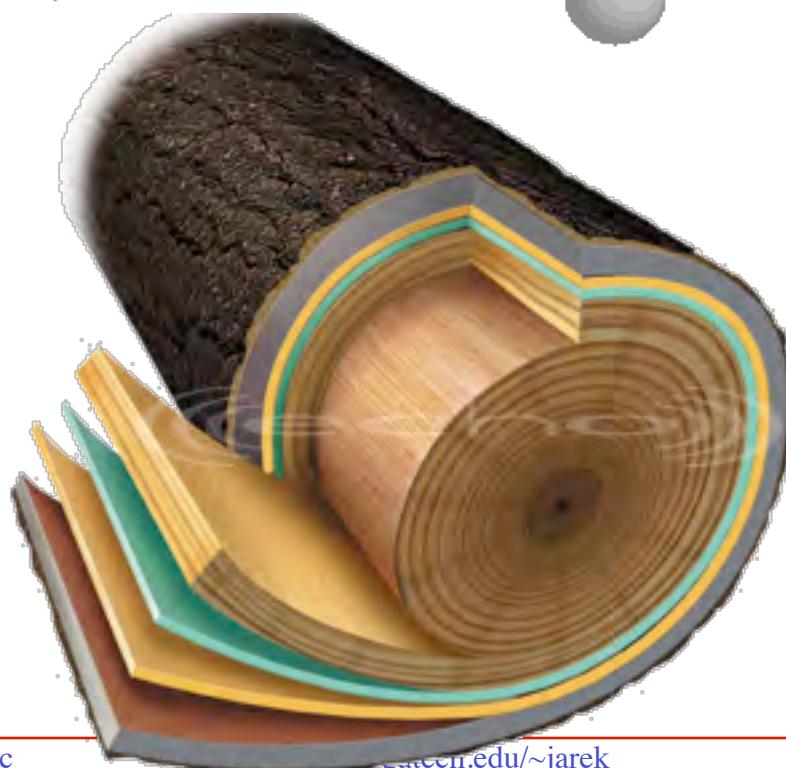
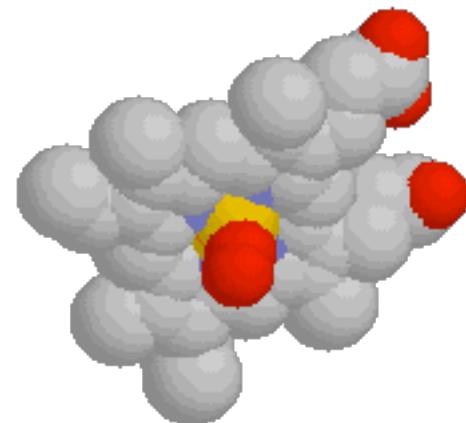
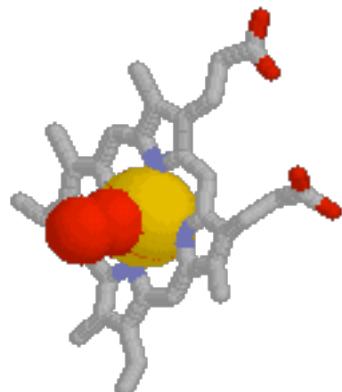


# Illustration vs. Volume Rendering

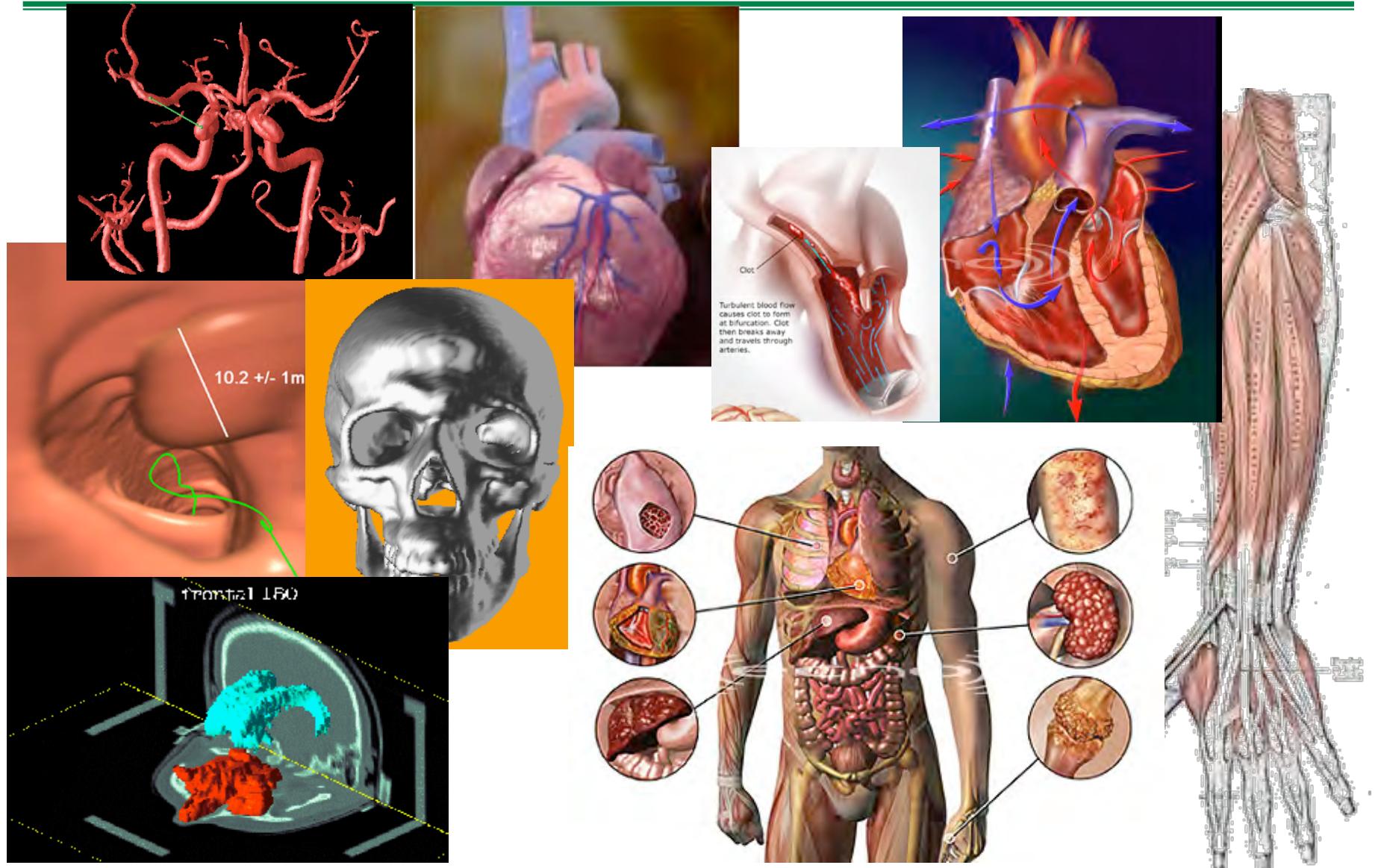


# Biology

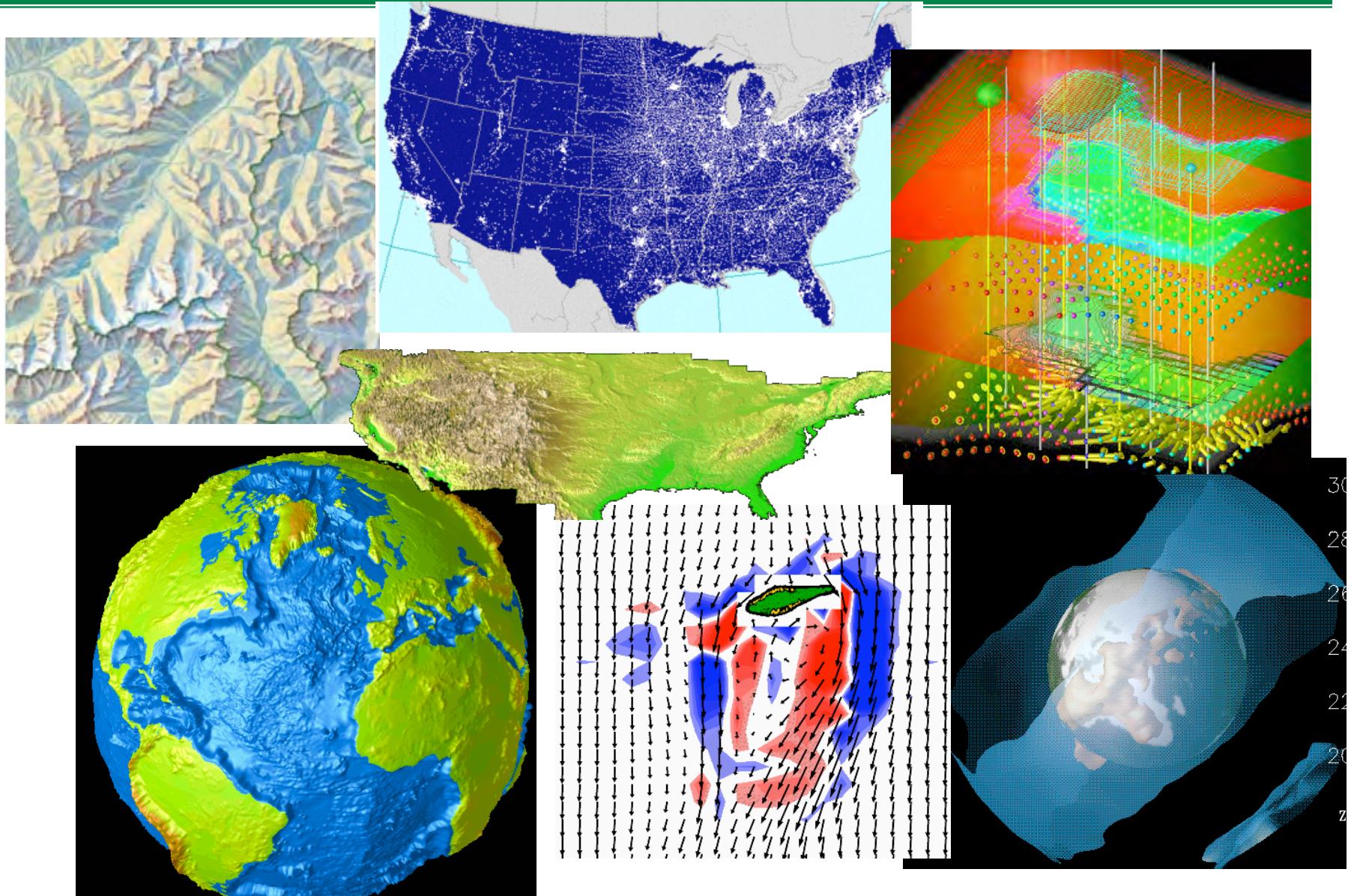
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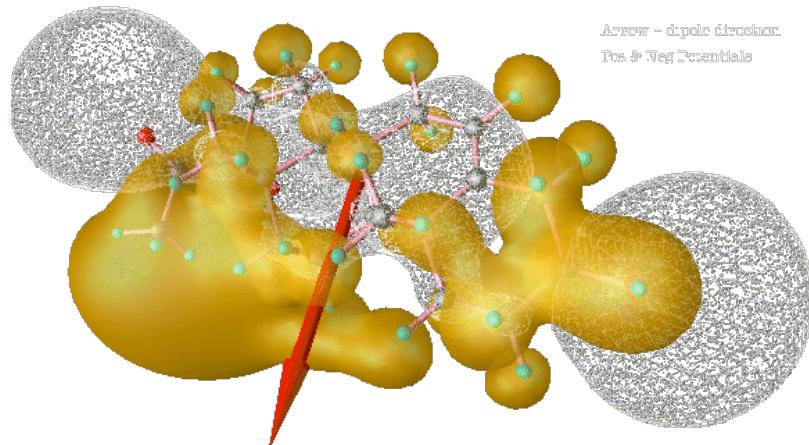
# Medicine



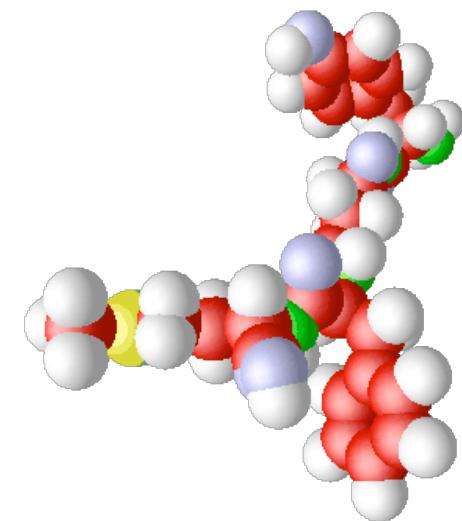
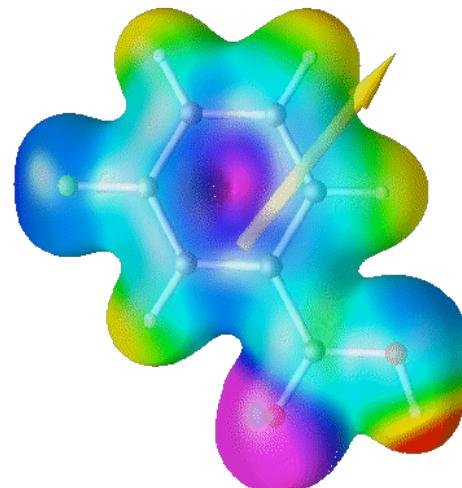
# GIS



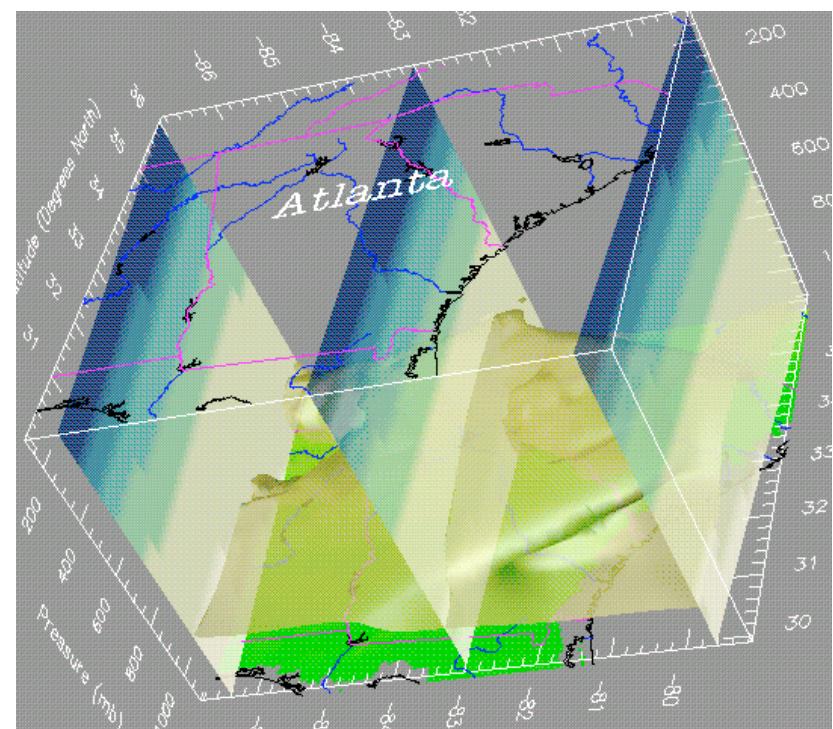
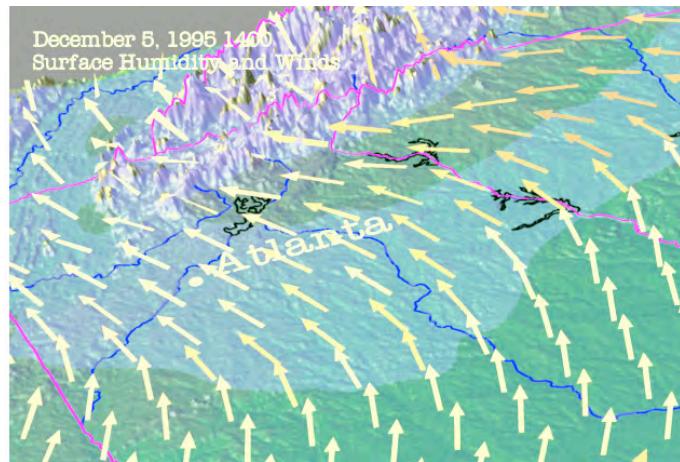
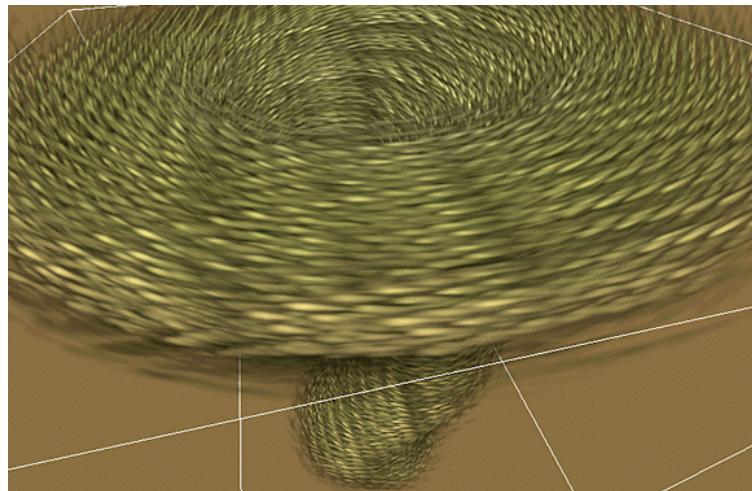
# Chemistry



Arrow - dipole direction.  
Pos & Neg Potentials

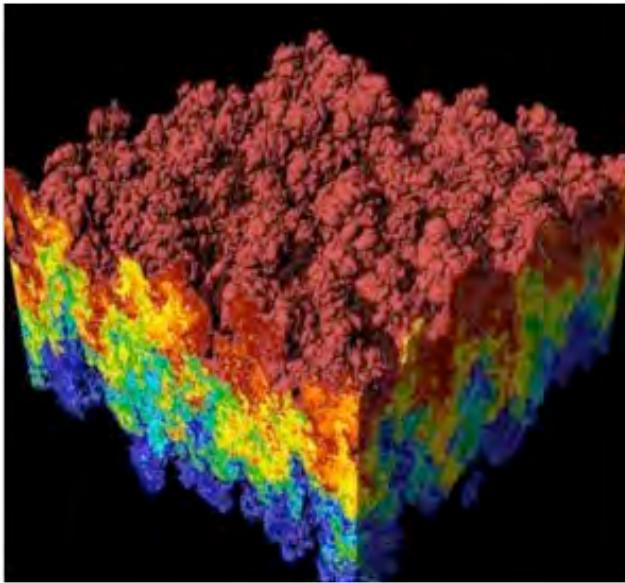


# Weather

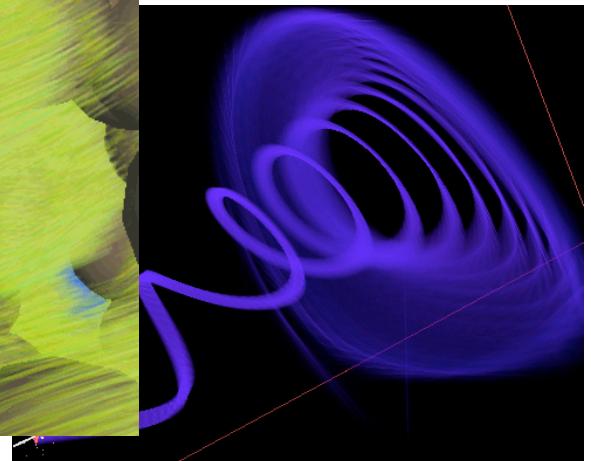
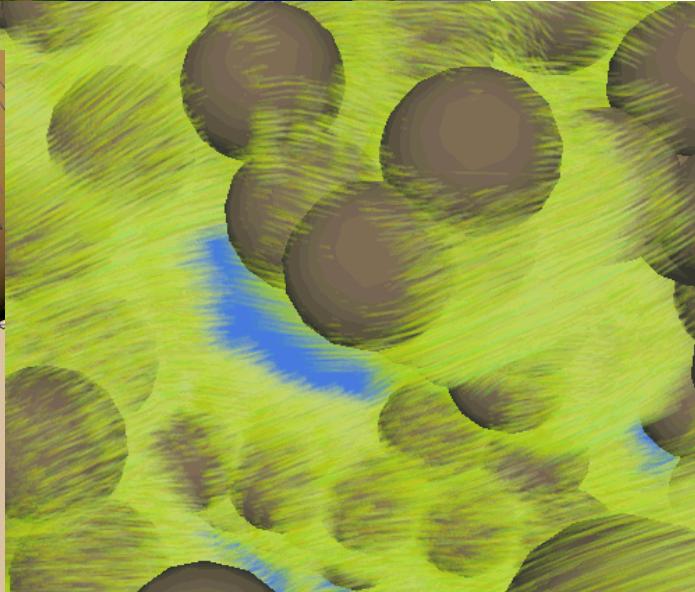
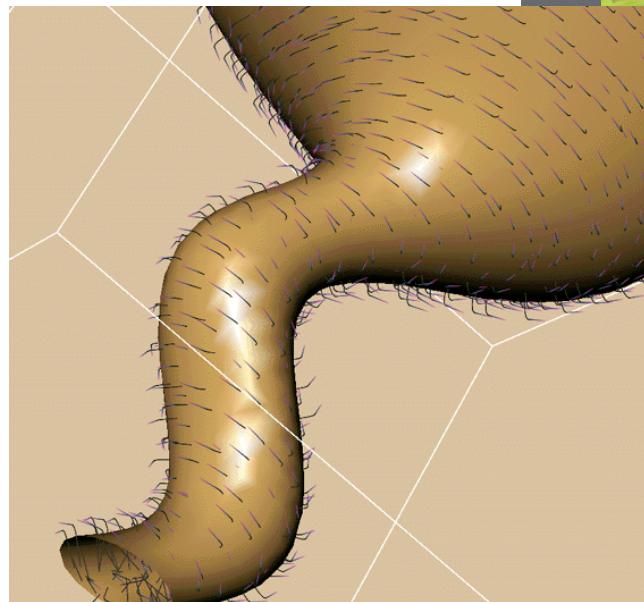
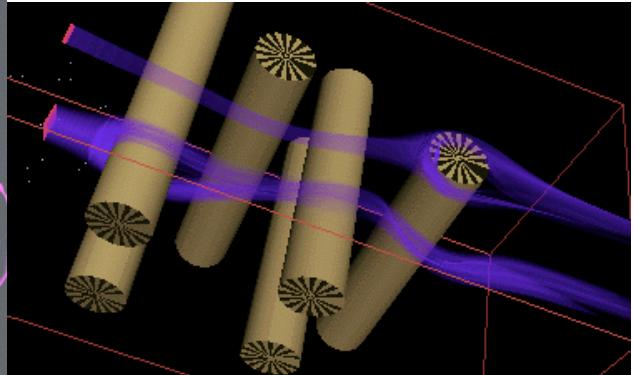
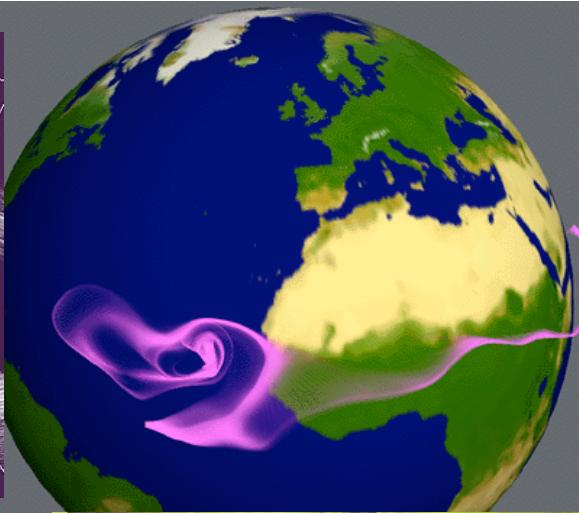
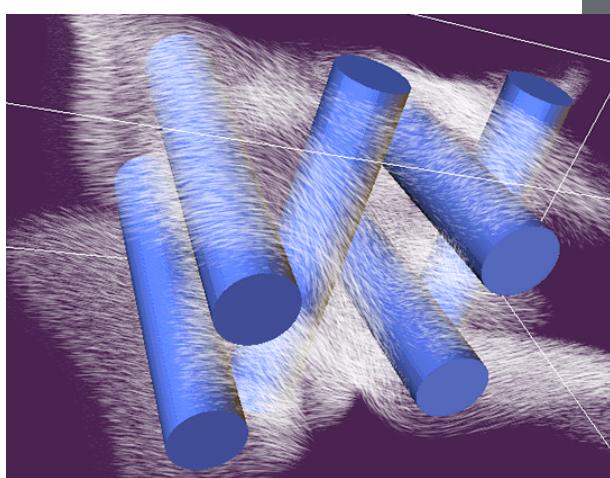


# Simulation

---

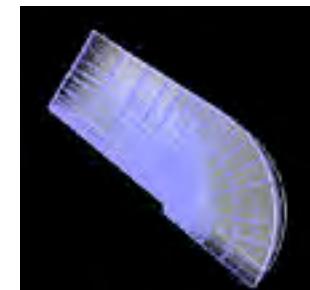
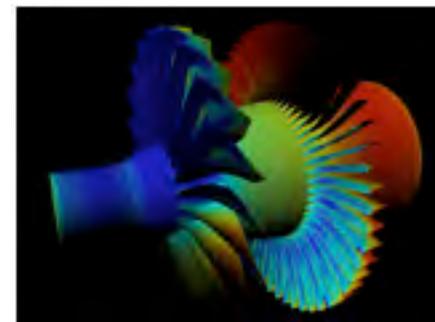
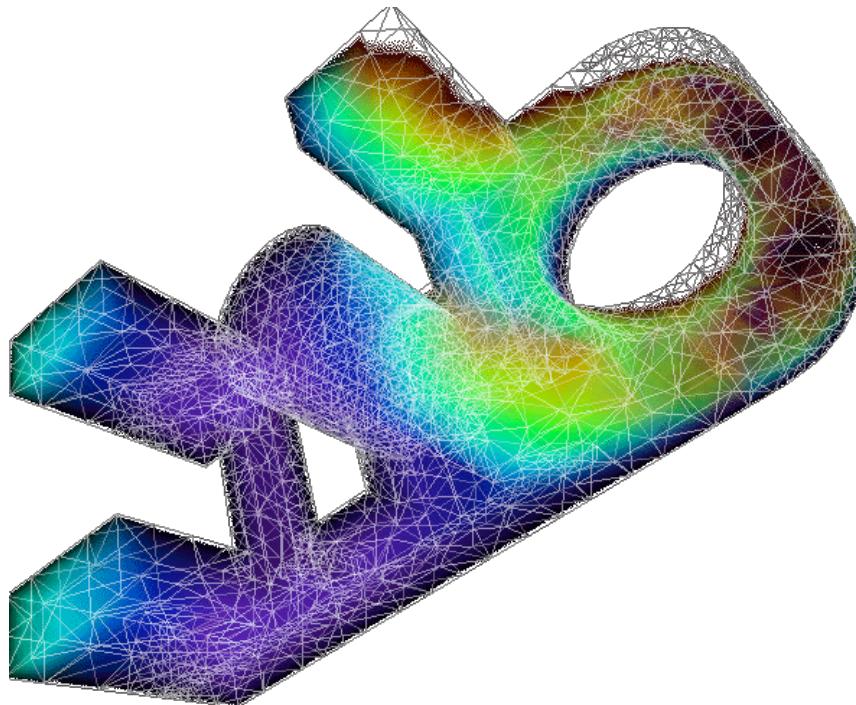


# Flow



# Mechanical

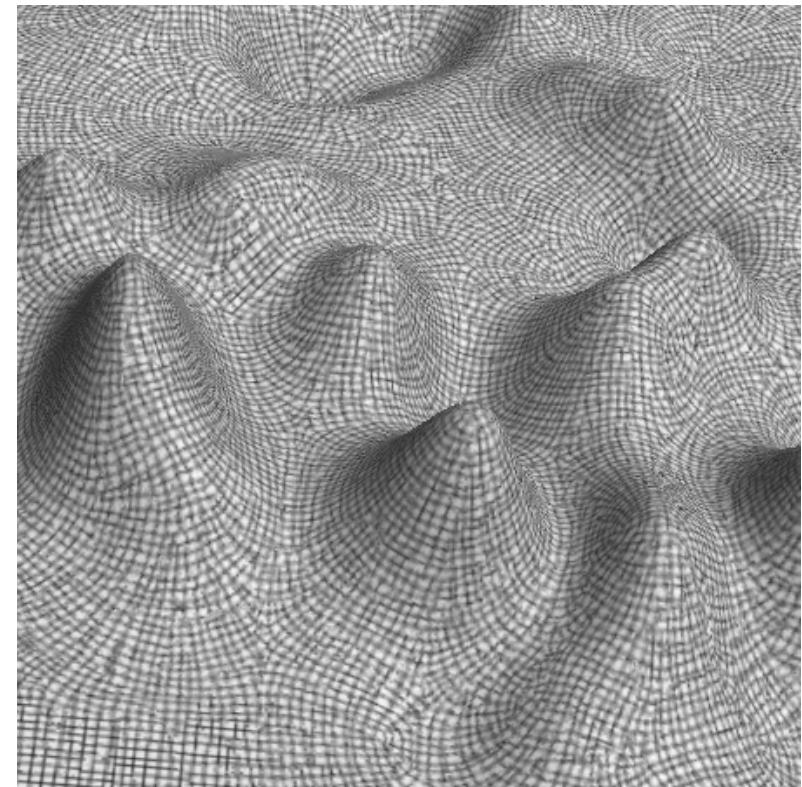
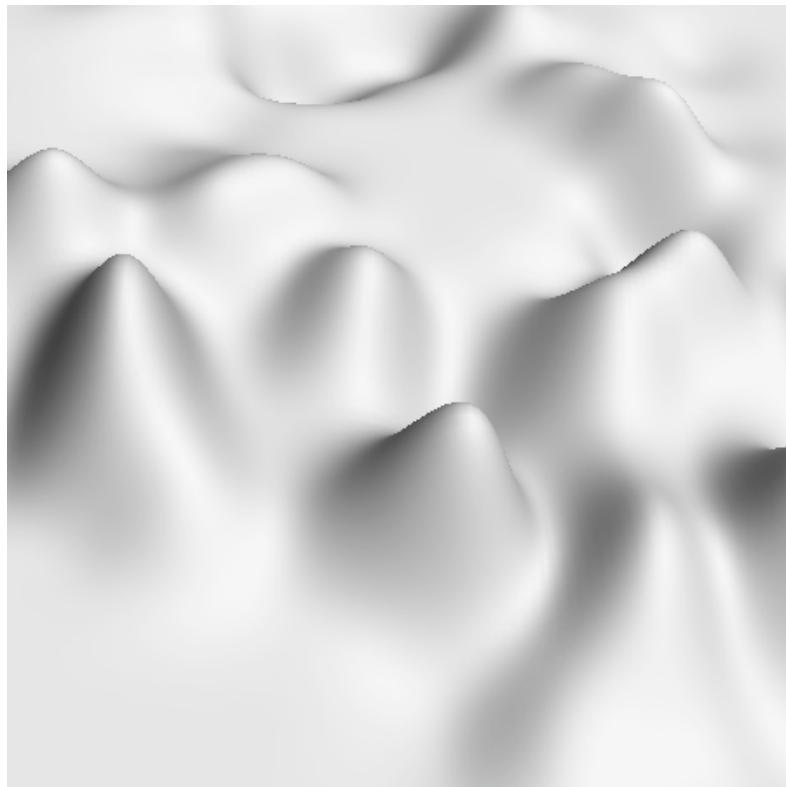
---



# Terrain visualization: Victoria Interrante

---

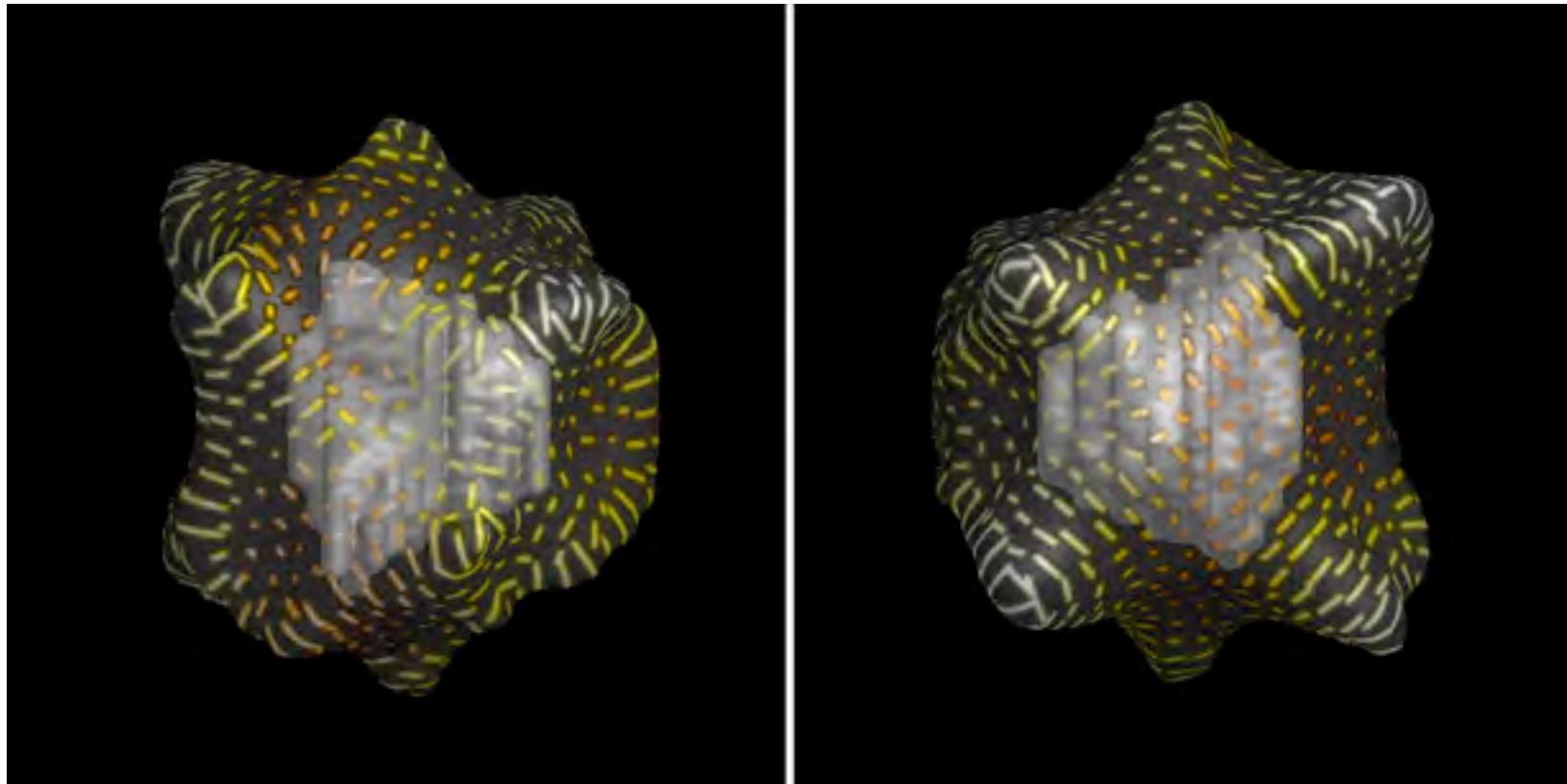
- <http://www-users.cs.umn.edu/~interran/texture/index.html>
- Draw lines of principal curvature



# Hidden surfaces: Victoria Interrante

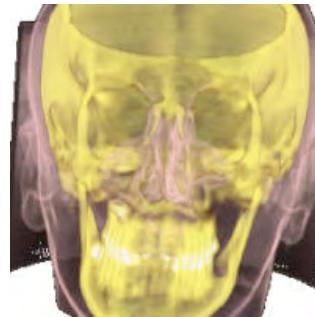
---

- <http://www-users.cs.umn.edu/~interran/3Dshape.html>
- Use principal curvature lines to distribute points on transparent iso-surfaces

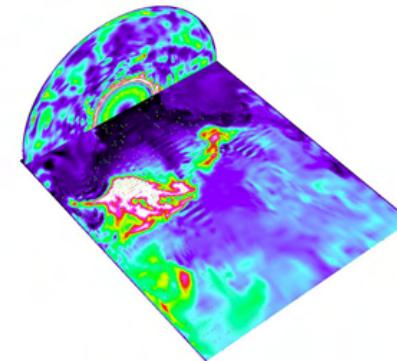


# Volume-Visualization

- Density



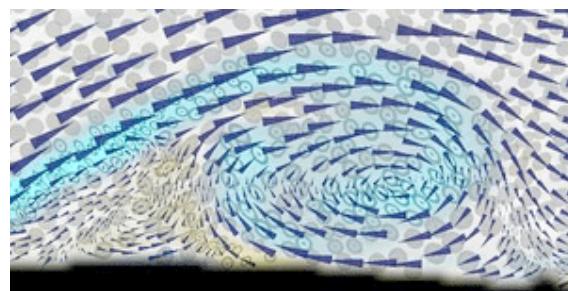
- Section



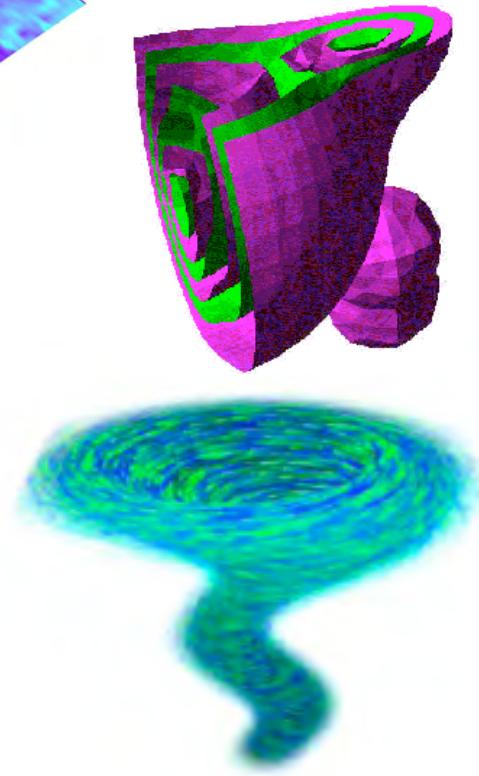
- Isosurface



- Vector field



- Flow



# Traditional Medical Image



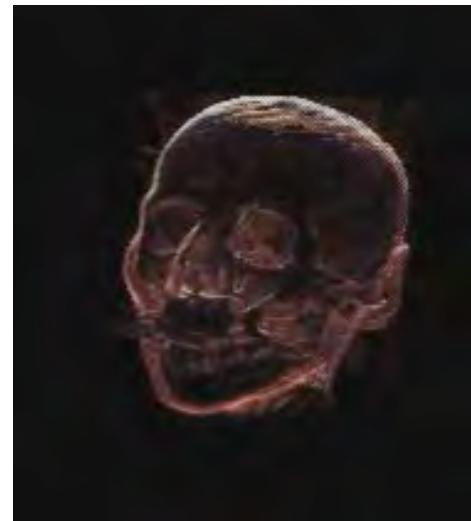
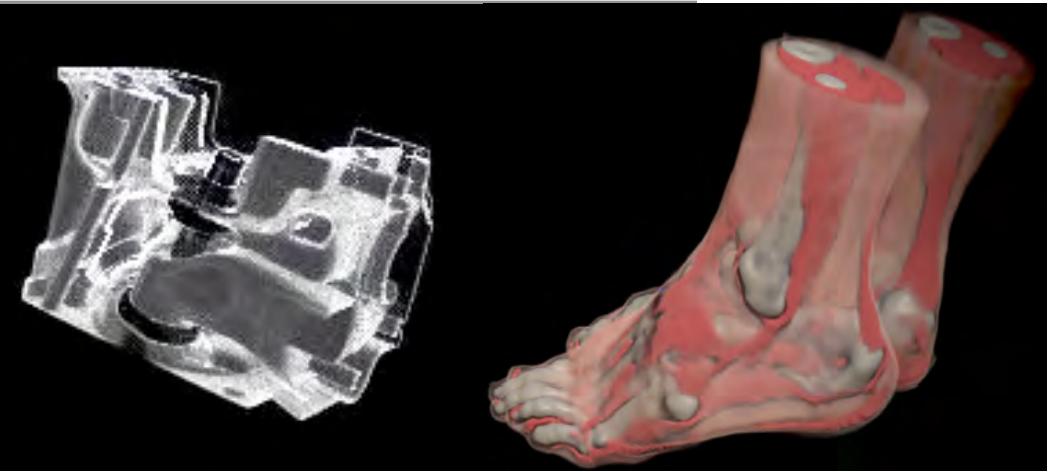
# Where Is Visualization Today?

- Realistic visualization  
in real-time is close



Images courtesy of Joe Kniss

# Perceptualization: David Ebert



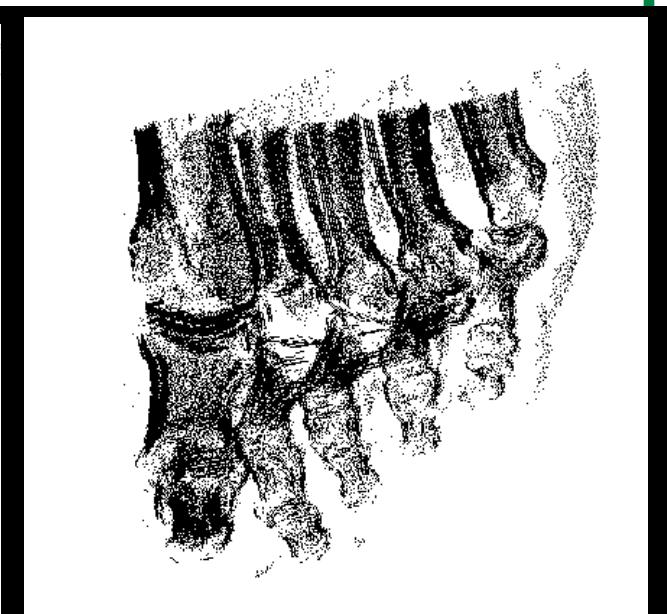
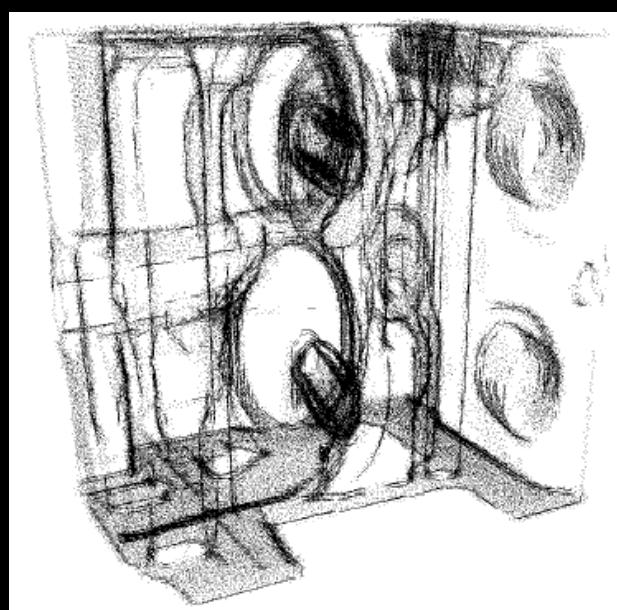
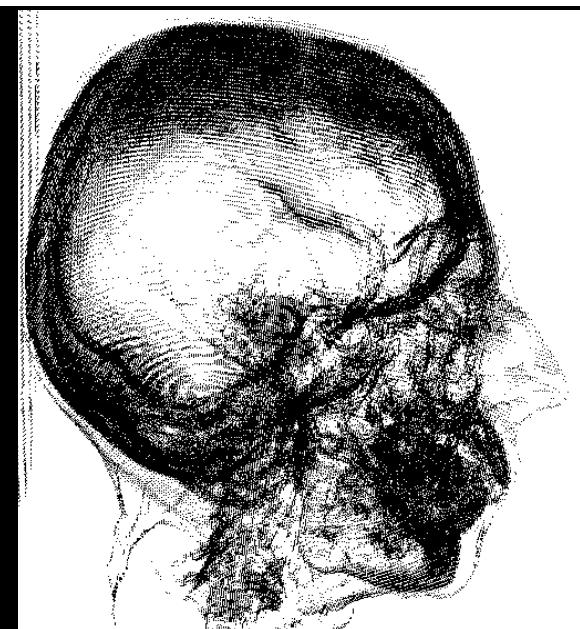
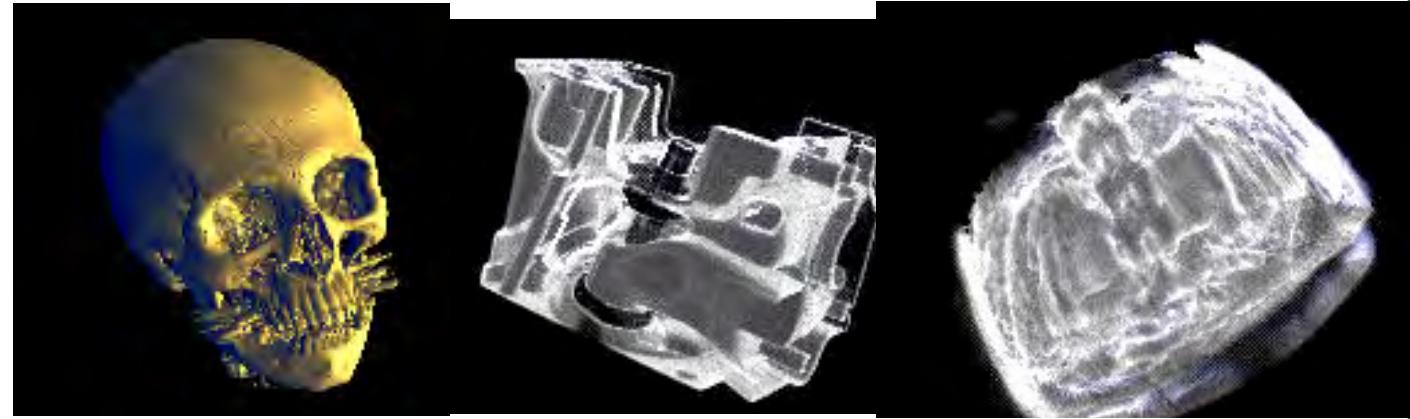
David S.Ebert  
Electrical & Computer Engineering  
Purdue University  
ebertd@purdue.edu

# Advanced Real-time Visualization Examples



Images from Kniss, Premoze, Hansen, Ebert, "Interactive Translucent Volume Rendering and Procedural Modeling," IEEE Visualization 2002.

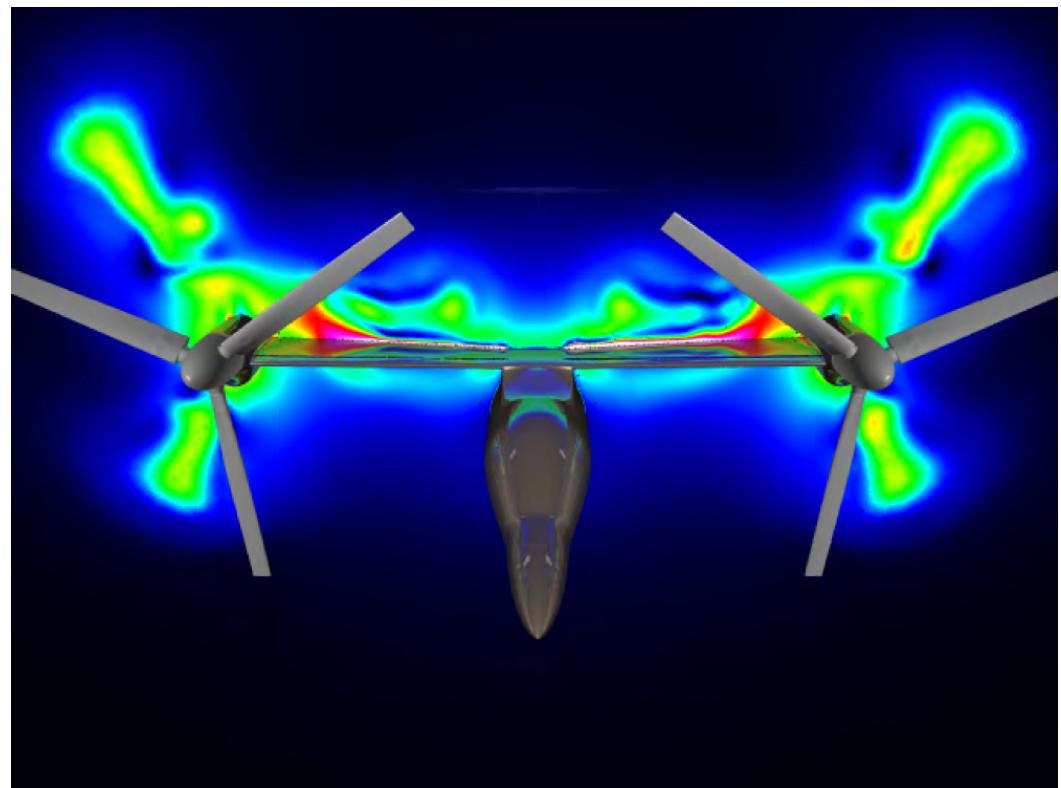
# Interactive Volume Illustration and Stippling



Lu, Morris, Ebert, Hansen, Rheingan, "Non-photorealistic Volume Rendering Using Stippling Techniques," IEEE Visualization 2002.

# The Data Deluge

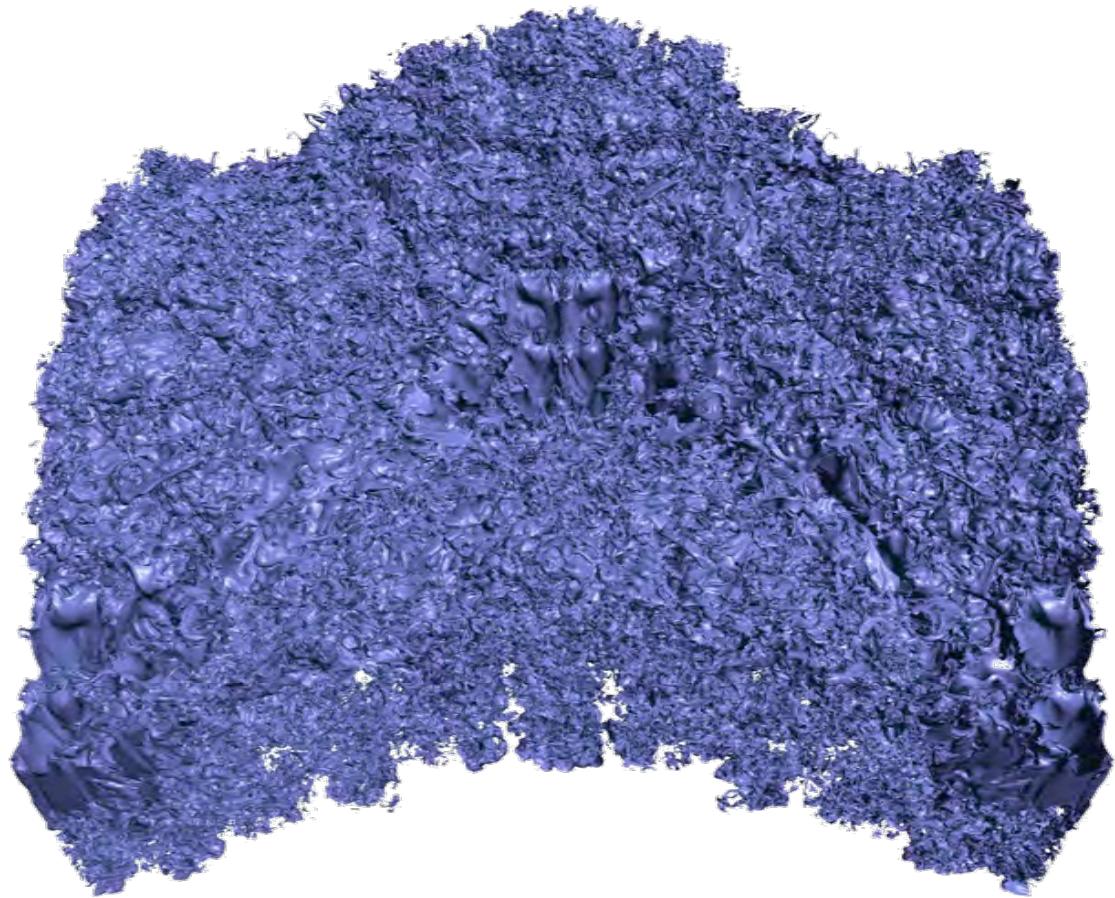
- Example 2: scientific visualization of Osprey-like aircraft
  - 7.4 million tetrahedra in simulation
  - 1362 timesteps
  - Multiple data values per grid point (velocity, vorticity, etc.)
  - Very long simulation and visualization time on large machines



Visualization courtesy of Mississippi State Engineering Research Center

# The Data Deluge

- Example 3: scientific visualization of turbulent mixing
  - 8 billion voxels per timestep
  - 274 timesteps
  - Terabytes of data



Visualization courtesy of Mark Duchaineau, Peter Lindstrom, et al., Lawrence Livermore National Labs

# Selective Enhancement Techniques

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- Most medical and technical illustration uses selective detail to focus the viewer's attention

