CMSC 491A/691A
Artistic Rendering

Penny Rheingans
UMBC

Announcements

- Upcoming
  - Thurs: John K and Jesus
  - Next Tues: Marc Olano
  - Next Thurs: Sean, Nick, Jeremy
  - Tues Nov 7: Chris
- Beta Release: Nov 21

The purpose of computing is insight, not numbers.

Hamming

What is Visualization?

- Def: visual representation of data
- Connotations:
  - computer generated
  - LOTS of data
- Transforms the abstract and symbolic into the geometric
- Harnesses the human visual perception system

Text Representation

0130 3.00 3.00 5658.00 4360.00 0.7706 1296.00 0.2291 0.00 0.00 2.00 0.0004 0.00 0.0000 4905 33 0.0411 110 32903 14 0.8271 103 0.1729 50 0.0774
149 0.0000 94 213478 38 1167274 30 19.3 82 0.3070 116 0.4165 19 16.33 90 0.0195 0.7073 101 1823573 7 2940 14 1.0000 1
6 22 0.8139 23 83.50 49 5 0.0491 4.32 0.0317 111 0.9765 28 19.50 18 1.0000 1 0.7405 58 0.5670
141 90

0200 5.00 5.00 3803.00 192.00 0.0505 3594.00 0.9450 8.00 0.00 9.00 0.0024 0.00 0.0000 4453 68 0.0219 13 21279 49 0.8948
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0.3159 16 503237 90 677 110 0.7740 133 8 11 0.8273 17 117.50 9 4 0.1184 12.00 0.1530 3 0.9804 9
24.00 7 0.6188 68 0.7406 57 0.7518 74 63.00

0220 5.00 5.00 1910.00 717.00 0.3754 1178.00 0.6168 3.00 0.00 10.00 0.0052 2.00 0.0010 4962 27 0.0381 95 26063 30 0.8764
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118 5.34 110 1.0000 1 0.7376 60 0.8125 38 34.00

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131 0.2080 23 0.0823 147 0.0000 94 76293 125 471250 111 18.8 95 0.2980 122 0.2817 104 14.81 27 0.0250
0.8172 123 806829 56 1970 34 0.9900 104 3 83 0.7380 66 65.50 87 1 0.2203 1.00 0.0146 136 0.9545
135 8.60 86 1.0000 1 0.5927 107 0.9213 3 17.00

0400 3.00 3.00 1439.00 1010.00 0.7019 429.00 0.2981 0.00 0.00 0.00 0.0000 0.00 0.0000 5265 10 0.0344 77 18554 71 0.8411
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0.7346 107 475567 96 1438 61 1.0000 1 4 55 0.7965 31 71.00 75 0 0.0000 0.60 0.0129 139 0.9645
103 10.67 64 0.2500 102 0.7957 45 0.7073 105 34.00

0420 4.50 4.00 2246.00 1076.00 0.4791 1164.00 0.5183 1.00 0.00 4.00 0.0018 1.00 0.0004 3919 140 0.0325 71 21774 44 0.8939
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92 6.83 101 0.0000 116 0.8831 26 0.5140 147 46.00

0612 2.30 2.00 324.00 310.00 0.9568 10.00 0.0309 4.00 0.01 0.00 0.0000 0.00 0.0000 6004 1 0.0680 152 41521 6 0.7385 152
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0.00 N/A N/A N/A 1.0000 1 N/A N/A 1.00

0613 2.10 2.00 1205.00 1190.00 0.9876 11.00 0.0091 4.00 0.00 0.00 0.0000 0.00 0.0000 4693 46 0.0552 144 10336 145 0.7784
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0.9152 145 513682 87 1205 74 1.0000 1 3 83 0.7137 88 42.50 136 0 0.0000 1.00 0.0257 120 0.9740
35 6.00 105 1.0000 1 1.0000 1 0.7500 75 21.00

0614 3.00 3.00 4460.00 3193.00 0.7159 1229.00 0.2756 21.00 0.00 16.00 0.0036 1.00 0.0002 4296 89 0.0354 82 19313 64 0.8031
126 0.1969 28 0.1414 61 0.1053 78 285811 24 1203057 27 19.7 73 0.4960 32 0.4412 10 16.38 97 0.0391
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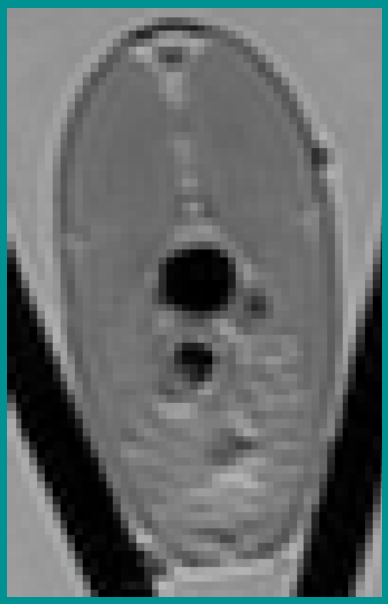
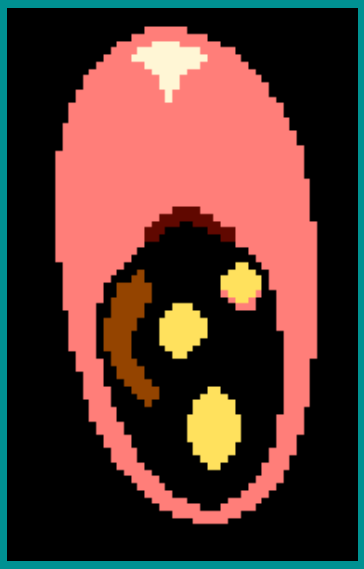
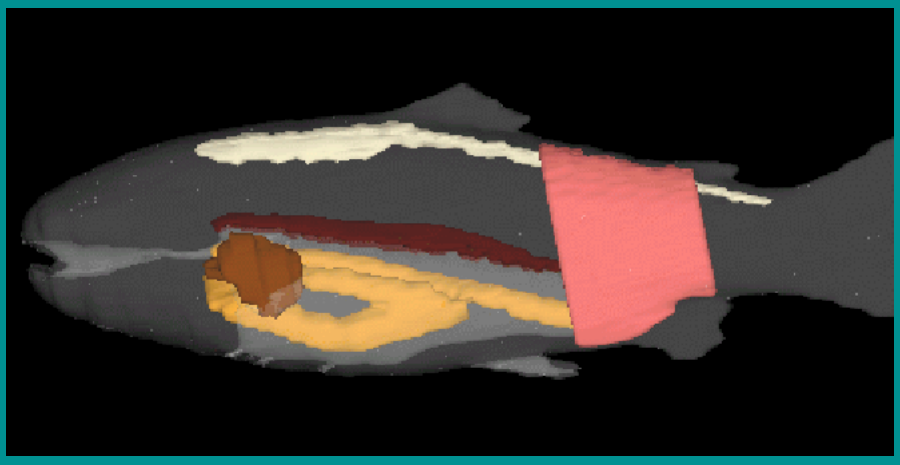
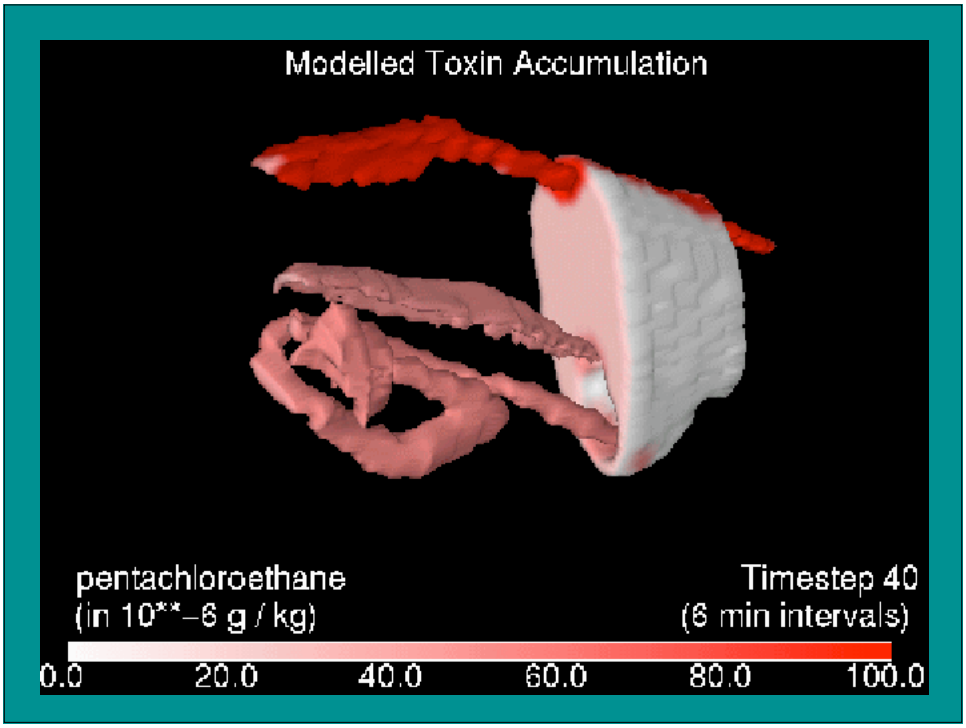








Why Visualize?

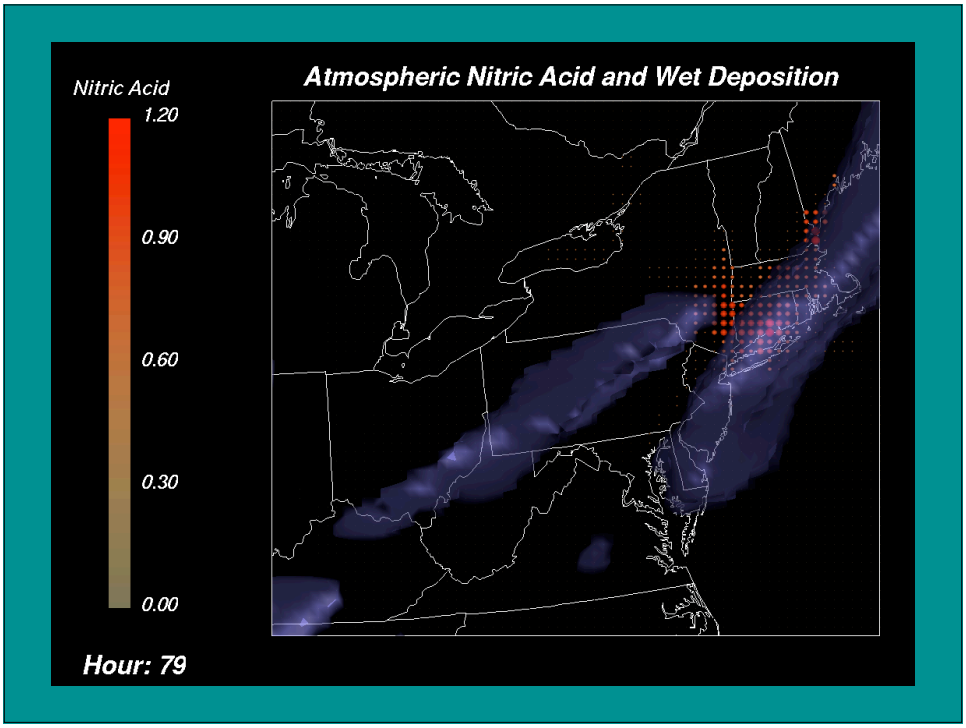
- Harness power of human visual system
- Presentation
  - communicate concept to peer, student, policy - maker
- Exploration
  - rapidly construct and test many informal hypotheses

Lots of Numbers

- Simulations
- Sensors/Scanners
- Surveys
- Equations

Visualization Tasks

- See values
  - extrema
  - anomalies
  - boundaries/thresholds
  - distribution / structure
- See multiple variables
  - relationships
- See flow/change
- Understand process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Nitric Acid
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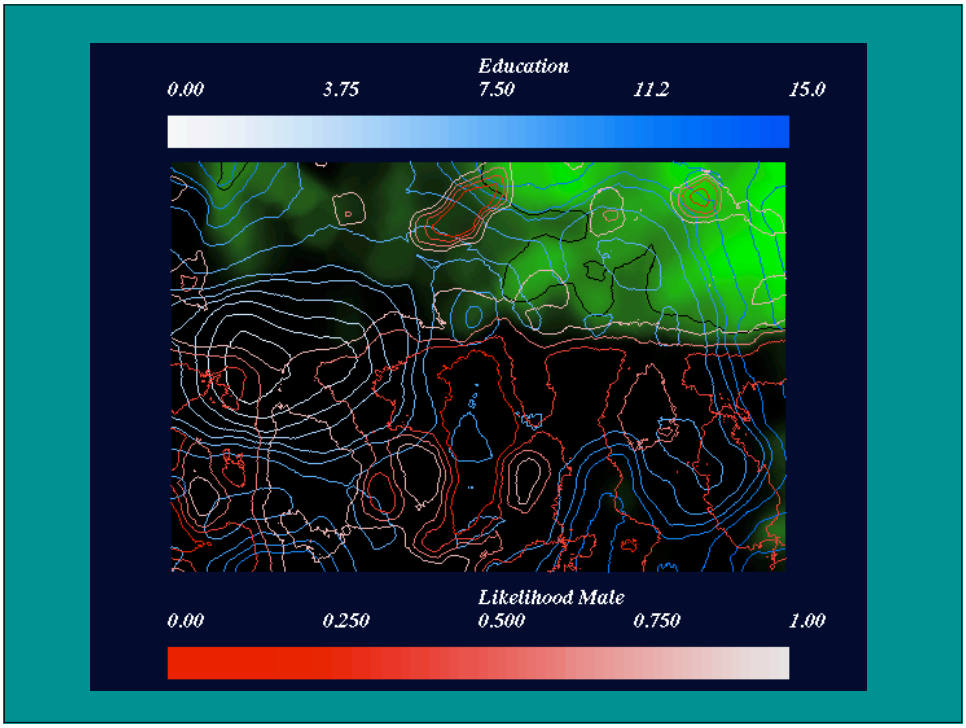
0.60
0.30
0.00
Hour: 79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7.50
11.2
15.0
Likelihood Male
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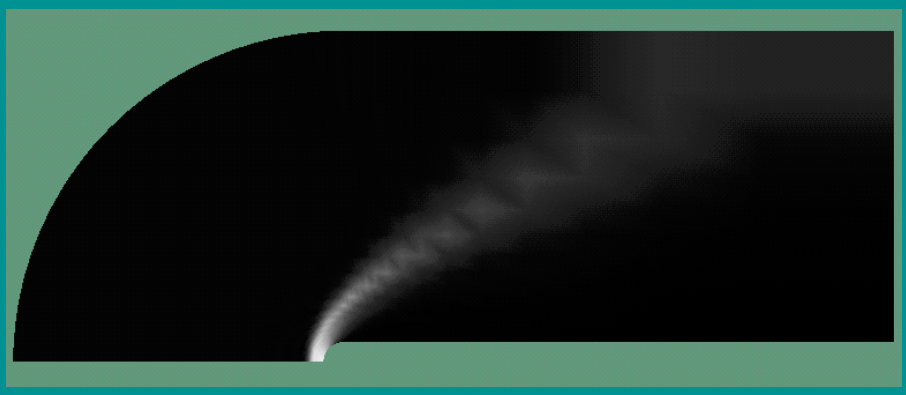
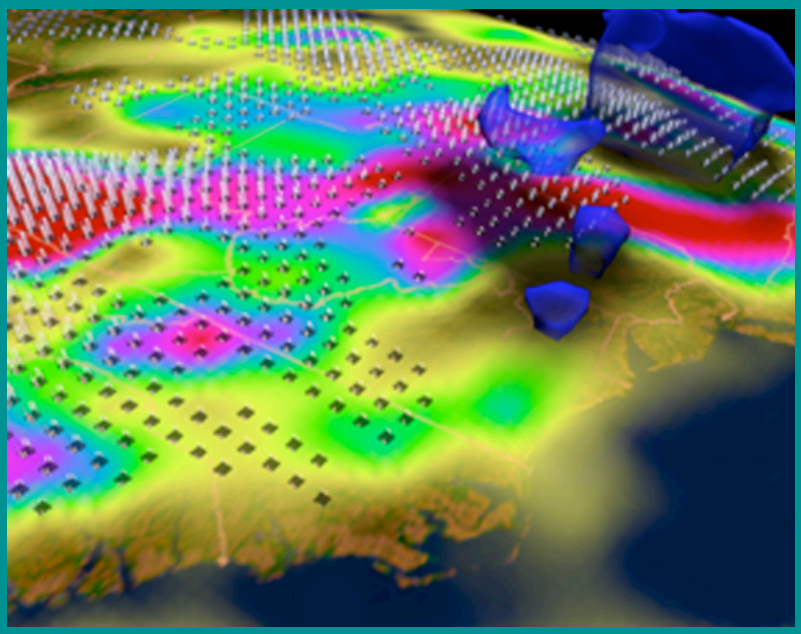
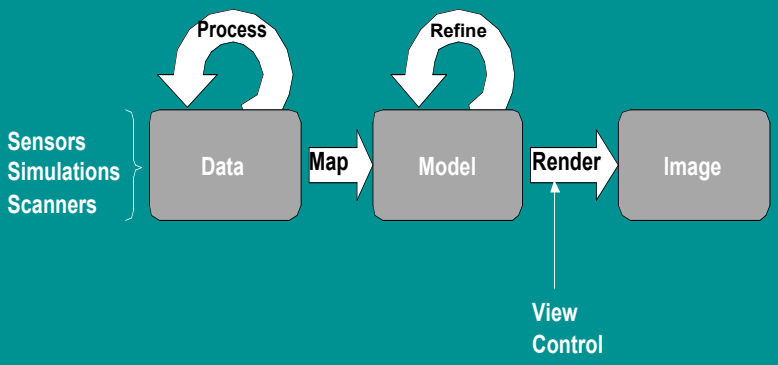
0.500
0.750
1.00

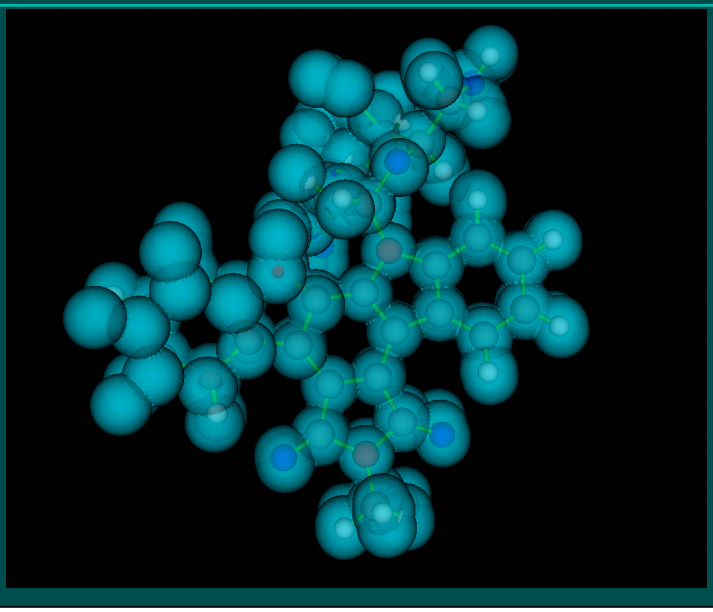




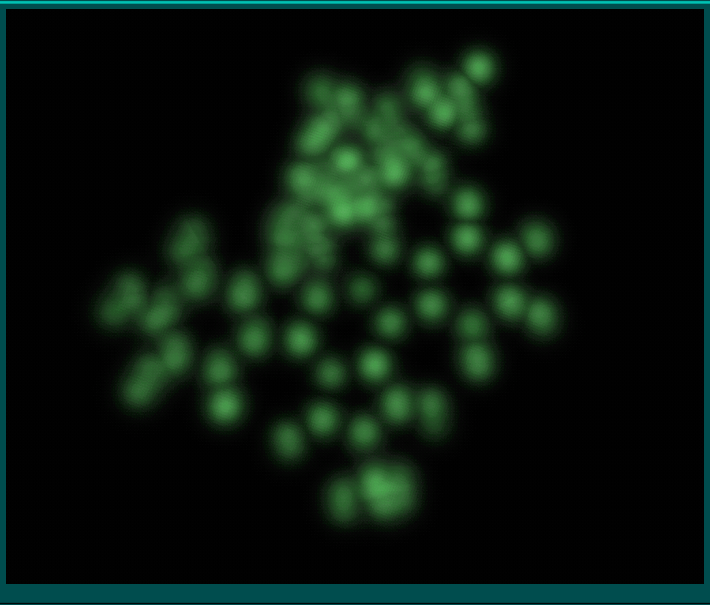
The Visualization Process



Isosurface Rendering

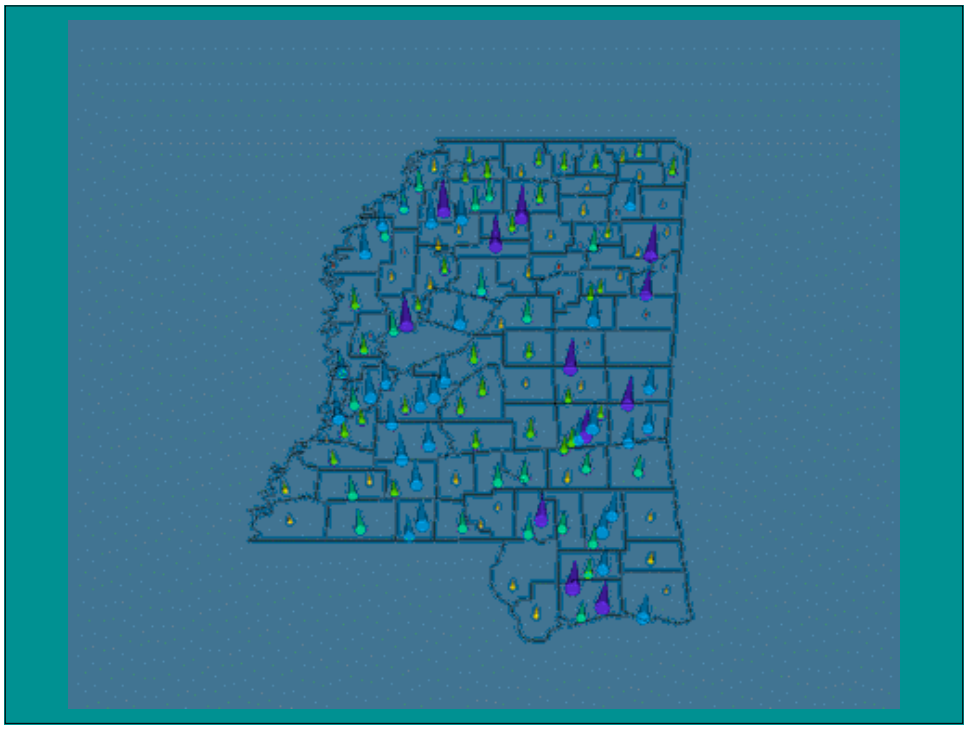


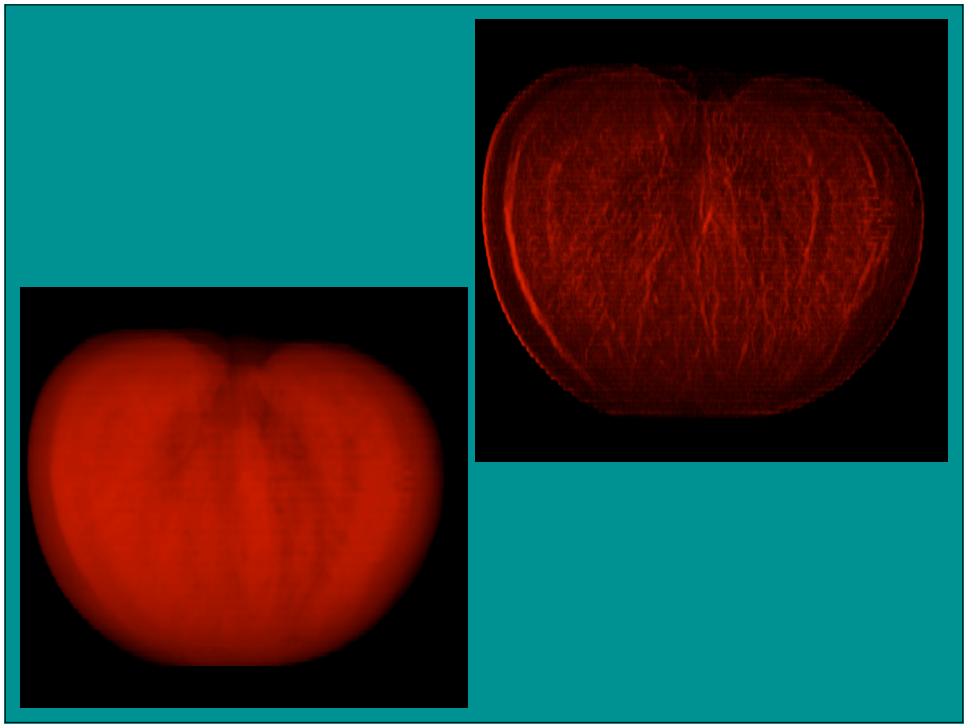
Direct Volume Rendering

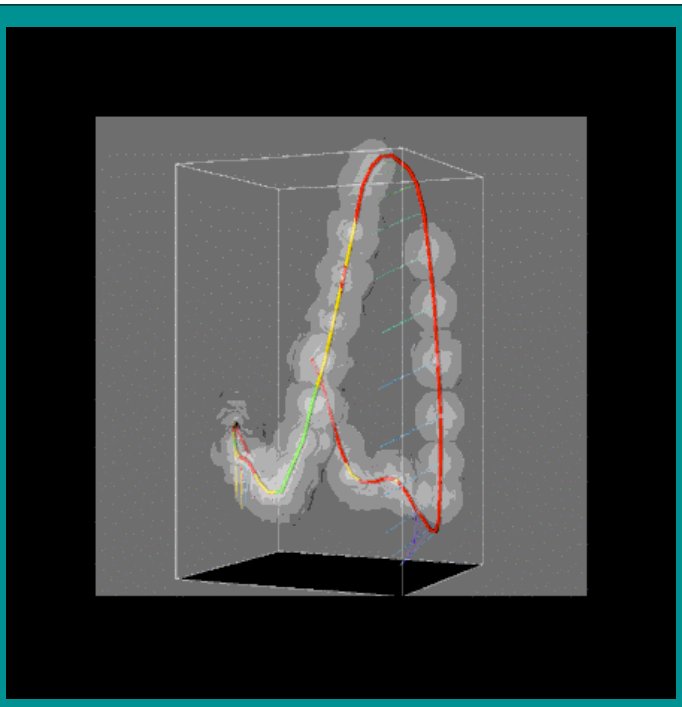


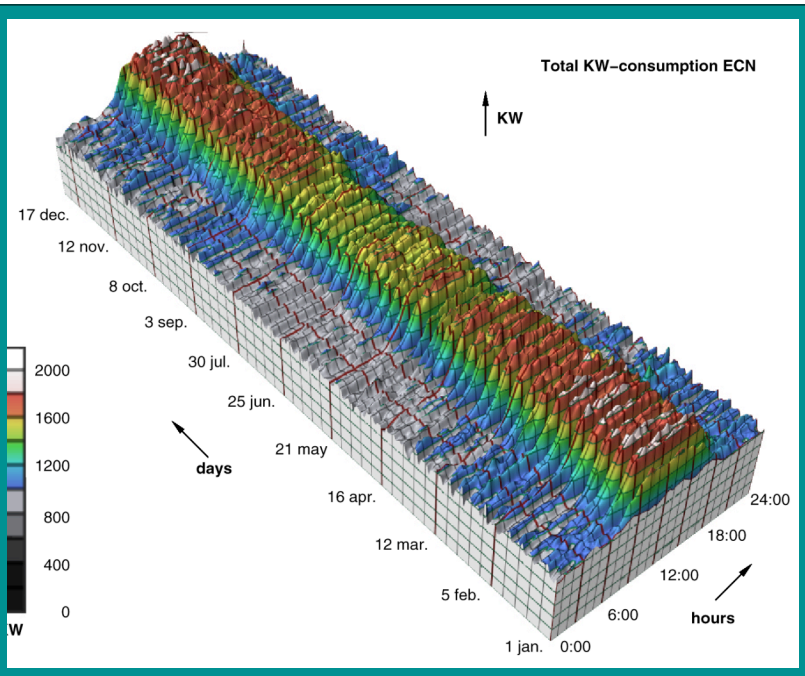
Categories of Visualization

- Data Visualization
  - Spatial
  - 2D / volume
  - scalar / multivariate
- Information Visualization
  - non-spatial
  - hD data
  - structures
- Program/Performance Visualization

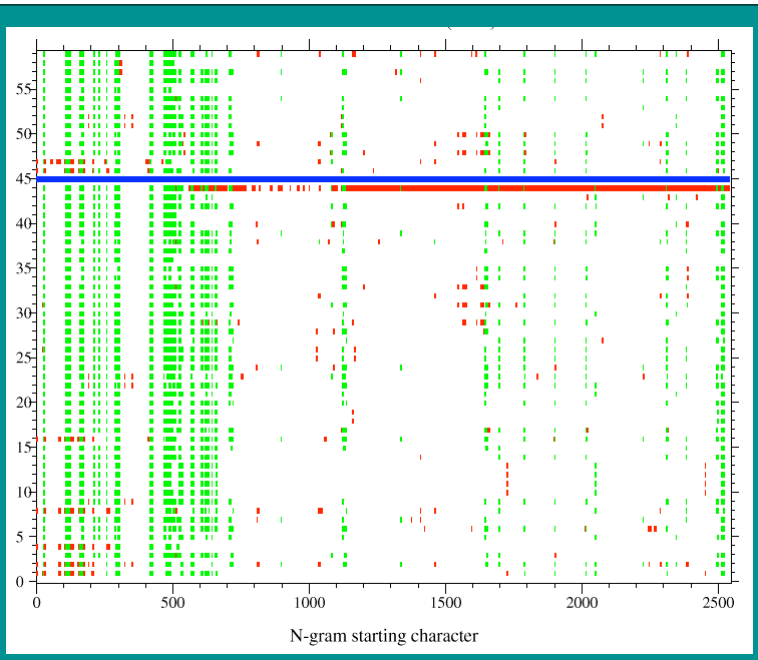




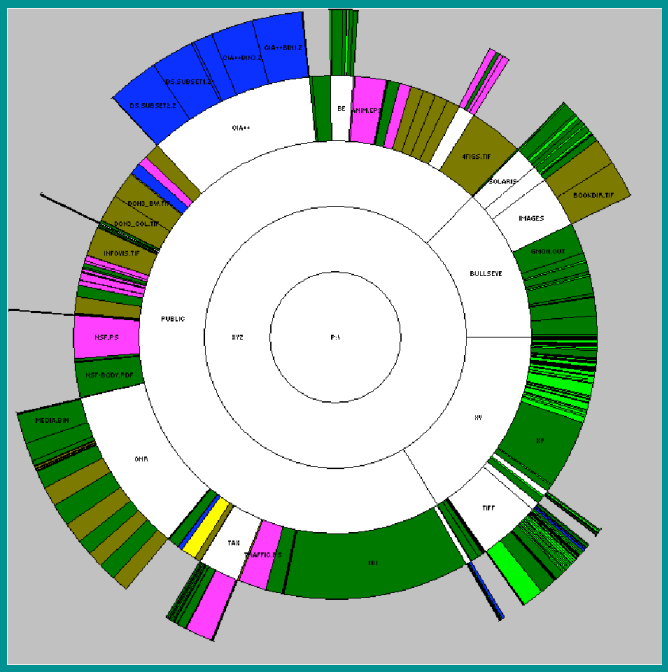




Van Wijk and van Selow ‘99



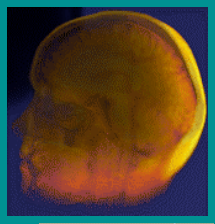
Ribler and Abrams ‘00

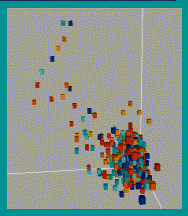


Stasko and Zhang ‘00

Characterization of Visualization Problems

- Characterized by Type of Data and Dimensionality
  - Medical — easiest
  - Scientific
  - Information — hardest





Common Issues

- Accuracy of Results
- Accurate Sampling
- Rendering
- Shading and Illumination
- Perception of Information
- User Interaction

Sampling and Visualization

- Sampling Performed Multiple Times
  - Data acquisition
  - Segmentation / data pre-processing
  - Surface generation
  - Visualization / rendering
- This Information Is Vital to Generating Accurate Images

Shading and Illumination

- Shading: Determining the Color of each Pixel
  - Includes: pseudo-coloring, illumination, transparency, texturing, and shadowing
- Illumination: Simulating light reflectance, absorption, and transmission

Perception in Visualization

- Generating Images for Humans to View
- Visual Cues can Increase Effectiveness
- Correct Use of
  - Color
  - Lighting / shading
  - Shape / texture
  - Motion

Interactive vs. Non-Interactive

- Interaction vs. Image Quality
- Interaction vs. Information Quantity
- Best choice:
  - System that allows interactive preview and exploration combined with non-interactive realistic rendering

Data Taxonomy

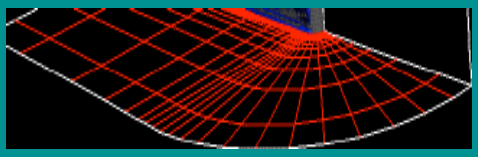
- Can characterize data by its characteristics
- Can generalize about data with similar characteristics
  - potential problems
  - natural visualization techniques
  - ease of implementation

Data Characteristics: Continuity

- Continuity
  - discrete: anything sampled or stored
    - ex: computational model, CT scan
    - issues:
      - representation error
      - possible aliasing
      - artifacts of sampling
  - continuous: only implicitly defined
    - ex: mathematical functions, predictive model

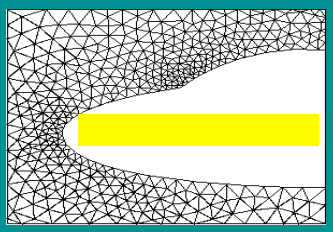
Data Characteristics: Structure

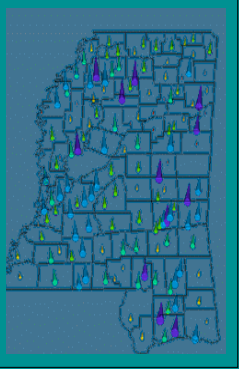
- Geometry vs Topology
- Topological Structure
  - Structured
    - Inherent spatial relationship among points (gridded)
    - Common grid types
      - Regular
      - Rectilinear
      - Curvilinear
    - Advantages
      - easy computation
      - possibly efficient storage (for densely populated grids)



Data Characteristics: Structure (cont)

- Structure
  - Irregularly structured
    - non-grid connectivity
    - ex: FEM results, surface meshes
    - advantages:
      - flexibility
  - Completely unstructured
    - no known spatial relationship among points
    - ex: pollution monitors, documents, atoms
    - advantages:
      - flexibility
      - efficient storage (for sparsely populated grids)





Data Characteristics: Dimension

- Dimensionality
  - # independent variables (usually # spatial/temporal variables)
  - commonly:
    - 2D
      - ex: weather info at ground, xray
    - 3D
      - ex: weather info in atmosphere, CT/MRI scan
    - *n* D
      - ex: census info, stock market conditions, document word frequency
  - Grid dimensions may differ from spatial dimensions

Data Characteristics: Multiple

- Number of variables per position
  - scalar
    - one value
      - ex: temperature, rainfall, or wind speed
  - multivariate:
    - multiple scalars
      - ex: temperature, rainfall, and wind speed
    - vector
      - ex: wind direction
    - tensor
      - ex: stress and strain forces
- Multivariate vs multidimensional

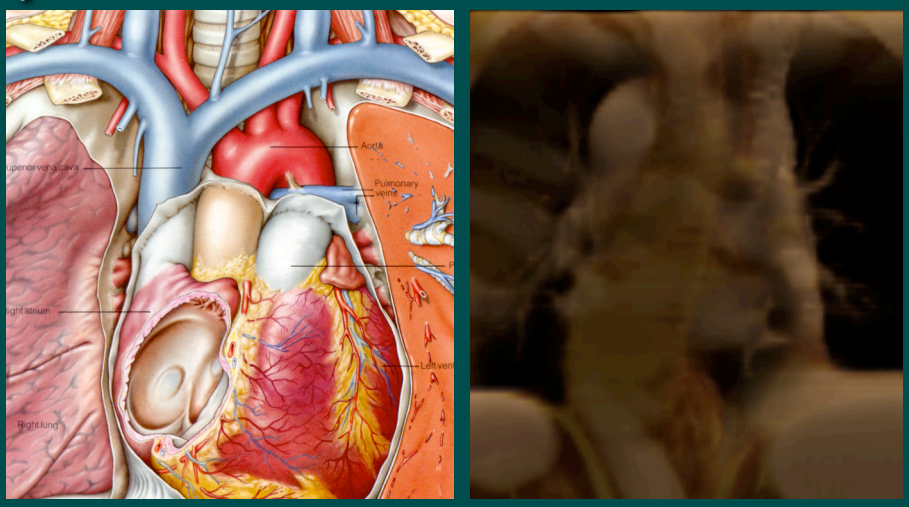
Data Characteristics: Scale

- Types
  - nominal
    - categories or identifiers
    - ex: county, land use, ethnicity, tissue type
  - ordinal
    - ordered values
    - ex: preference, ranking
  - integer
    - constant step size
    - ex: test scores, degrees Fahrenheit
  - ratio
    - meaningful zero
    - ex: degrees Kelvin, income, wind speed

Photo by Pavel Machotka, painting by Paul Cézanne, in Machotcha96, pgs 96-97.

Photo by Pavel Machotka, painting by Paul Cézanne, in Machotcha96, pgs 108-109.

Illustration vs. Volume Rendering

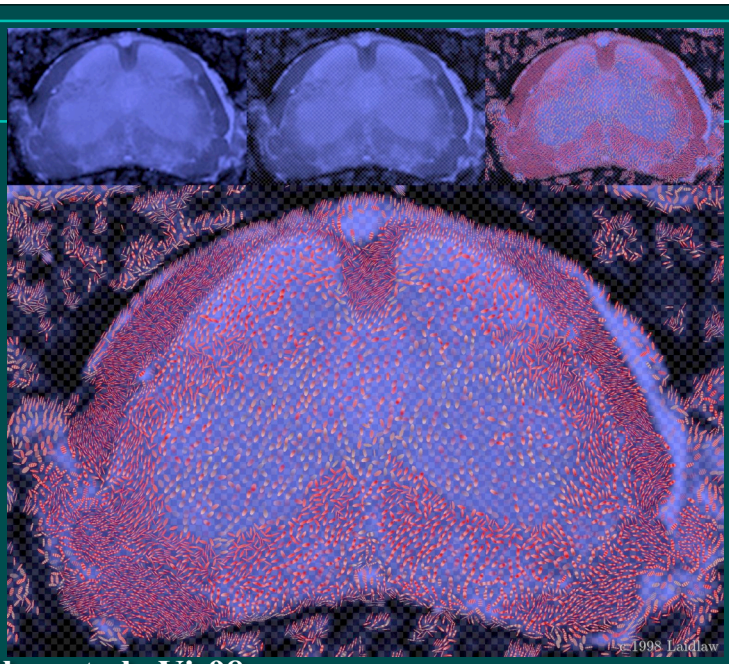


NPR Visualization

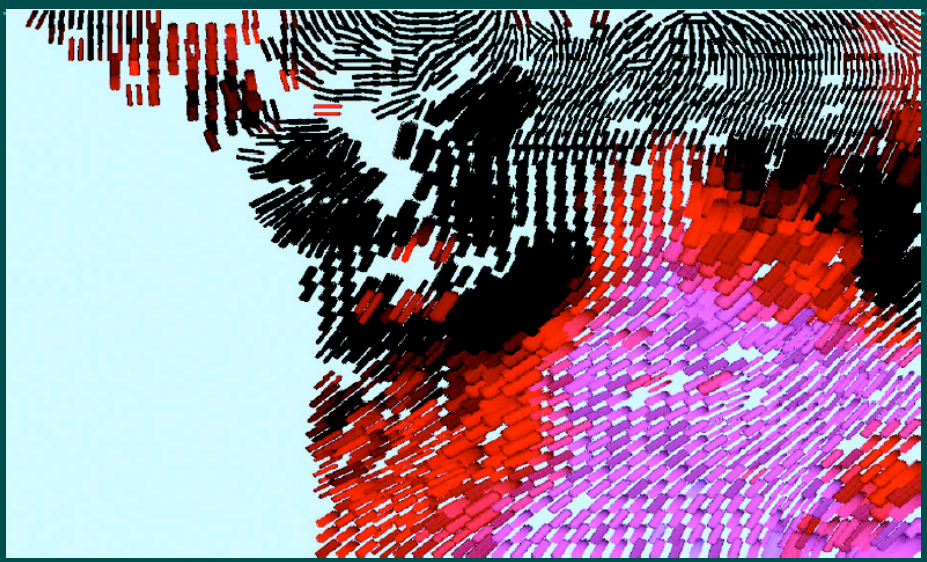
- Isn't all visualization non-photorealistic?

NPR Visualization

- 2D visualization
  - 2D oriented brush strokes (Laidlaw98, Kirby99, Healey02)
- 3D visualization
  - Comprehensible rendering (Saito90)
  - Illustrated surfaces within volume (Treavatt00)
  - Textures on surfaces (Interrante95,97; Rheingans96)
- Volume visualization
  - Stroke-based volume previewing (Saito94)
  - Flow volumes (Interrante98, Stompel02)



• Laidlaw et al., Vis98



• Healey, CGA02

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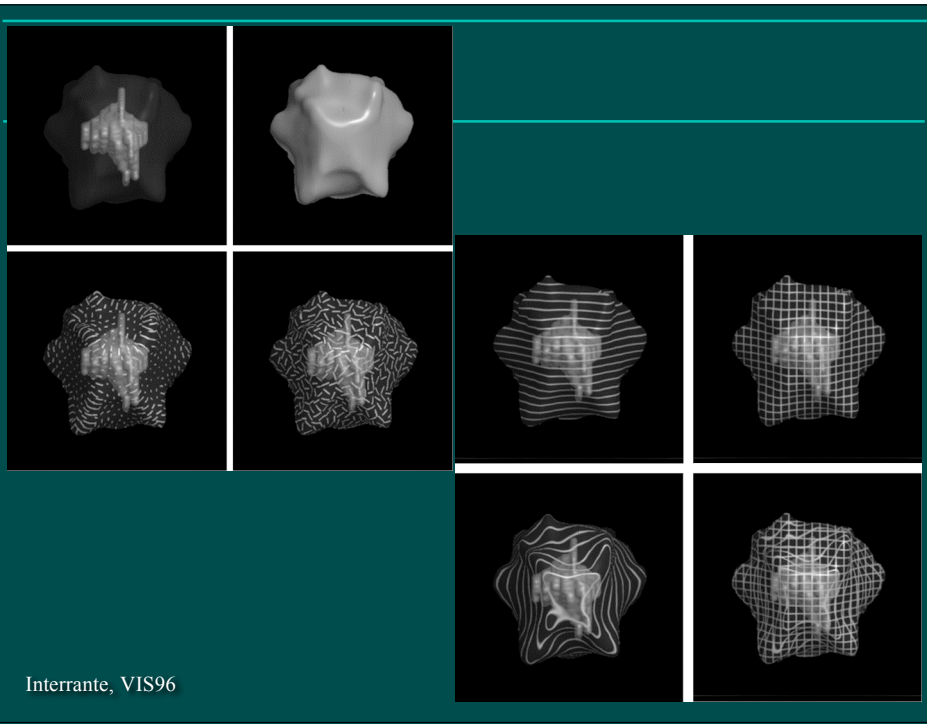
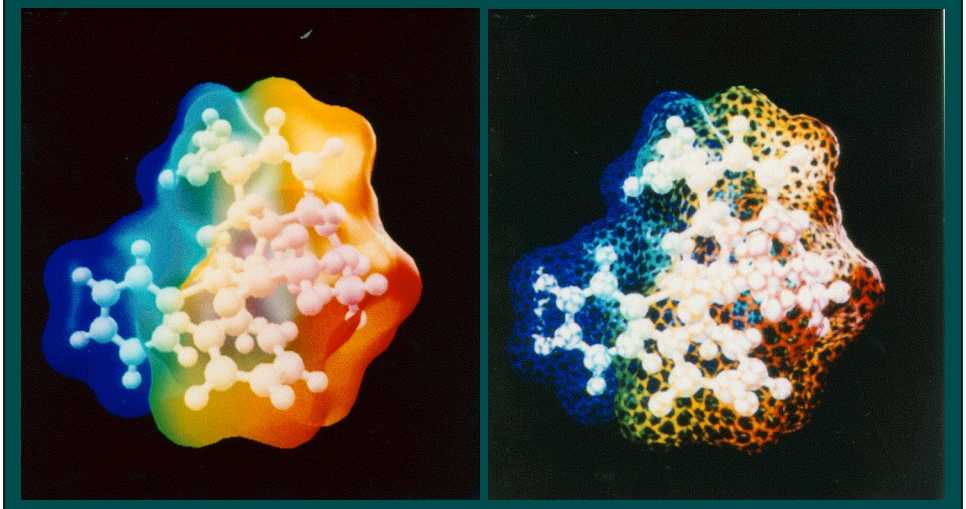
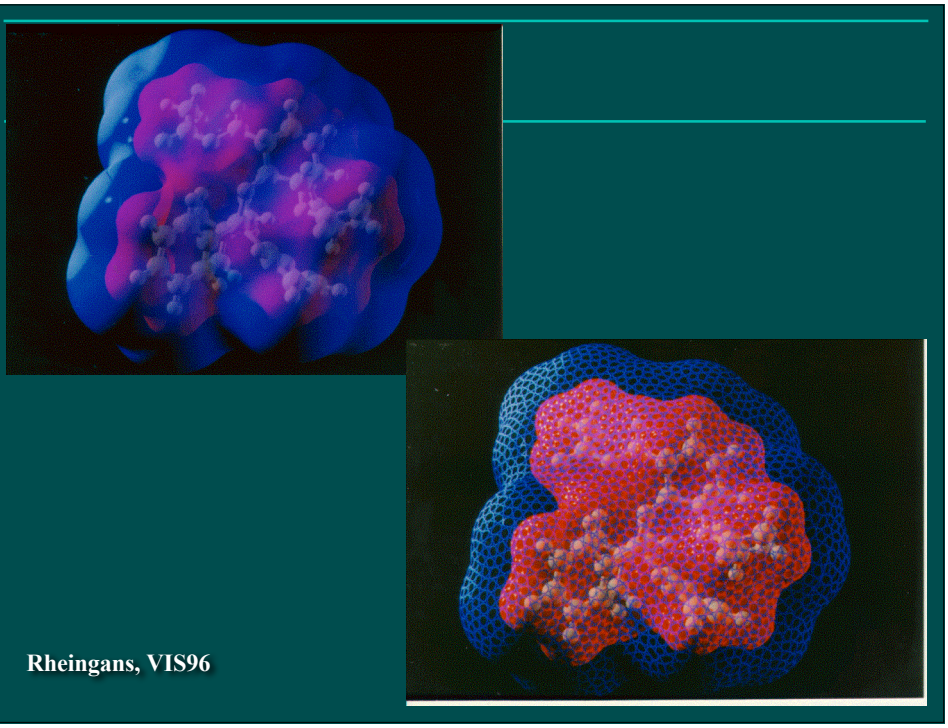


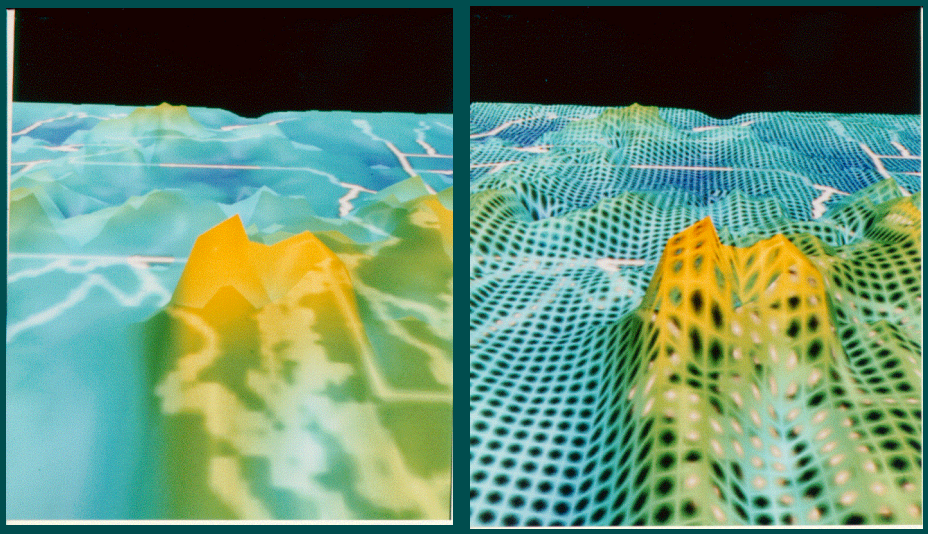
Interrante, VIS96



Rheingans, VIS96

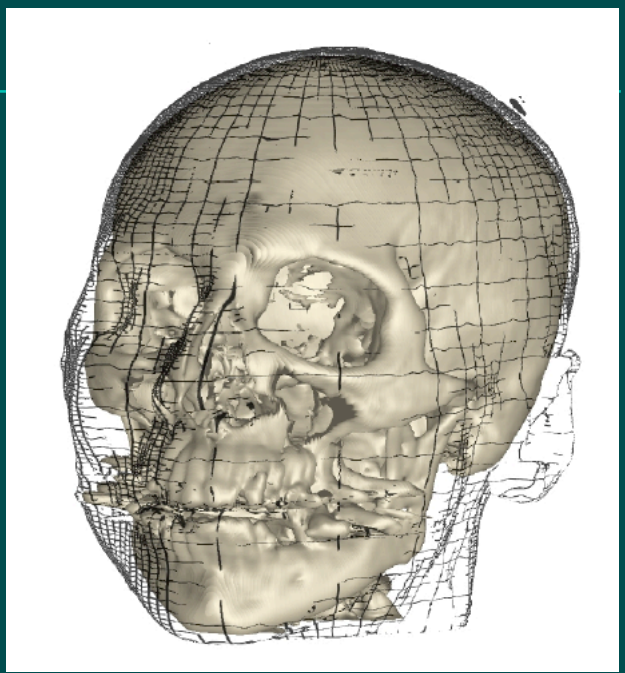


Rheingans, VIS96



Rheingans, VIS96

- Treavett and Chen, Vis00



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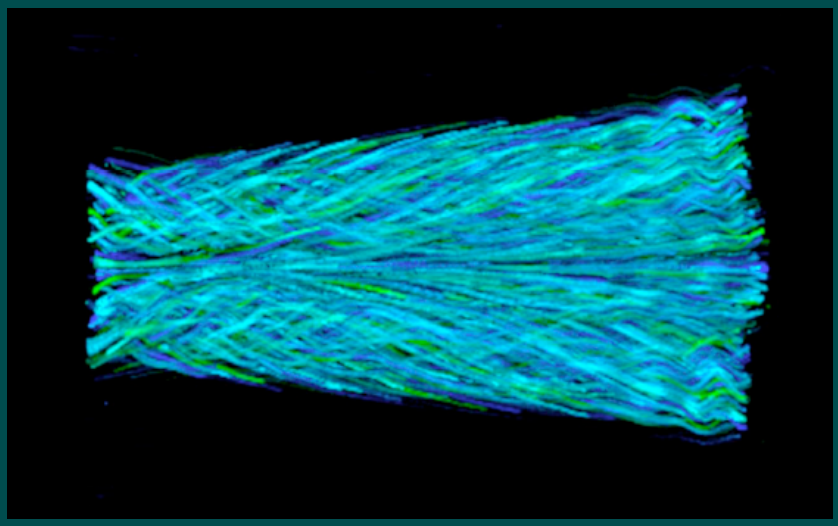
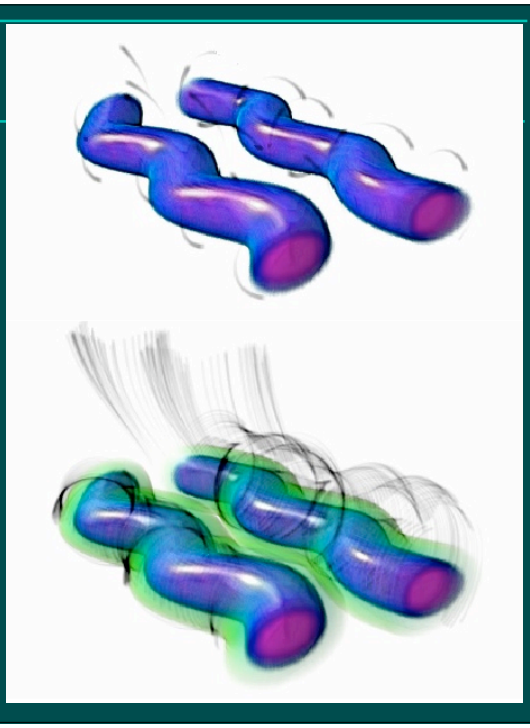


- **Interrante and Grosch, Vis97**



- **Stompel, Lum, and Ma, PG02**

NPR: Graphics vs Vis

- Are they different?

Features

- Surface Rendering
  - Surfaces
  - Silhouettes, high curvature regions, CFD
- Volume Rendering
  - Surfaceness
  - Indicators
    - Gradient, higher-order properties
    - Variability
    - Local structure