Visualization

What is Visualization?

- Definition: visual representation of data
- Connotations
  - Computer generated
  - Lots of data
- Transform the abstract and symbolic into the geometric

Raw Data (Lots of it)

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22.5 5 0.4790 35 0.2750 113 14.12 15 0.0320
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0.9610 118 5.34 110 1.0000 1 0.7376 60 0.8125 38
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22 0.7920 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
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0.2135 21 0.1232 92 0.0000 94 73223 128 341876 127
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0.4444 16 107168 102 531030 102 19.8 69 0.3770 83
0.2712 115 16.64 106 0.0417 0.5076 58 335019 124 1924
36 1.0000 1 4 55 0.7417 63 69.00 78 3
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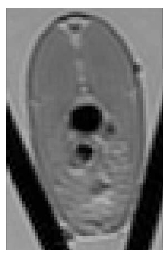
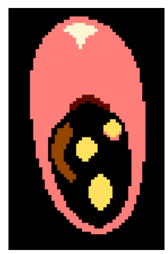
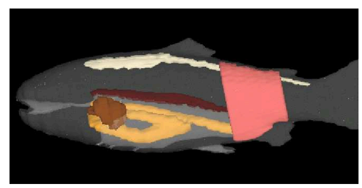
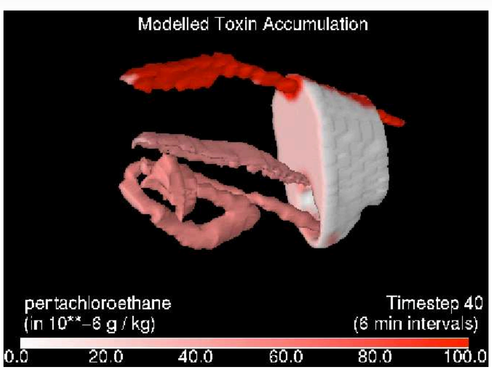
Data Visualized







Data Visualized



Why Visualize?

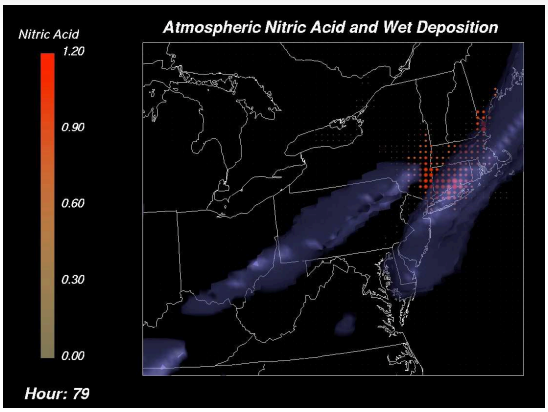
- Harness the human visual perception system
- Presentation
  - Communicate concept to peer, student, policy makers
- Exploration
  - Rapidly construct and test many informal hypotheses

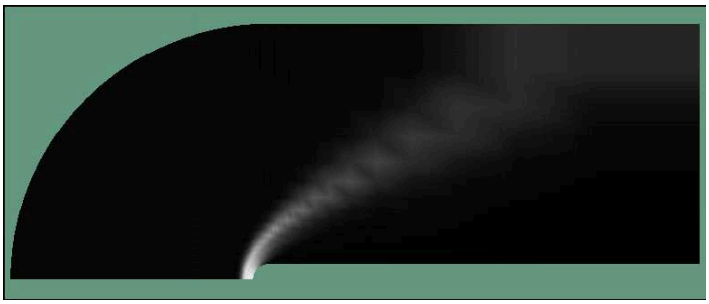
Lots of Numbers

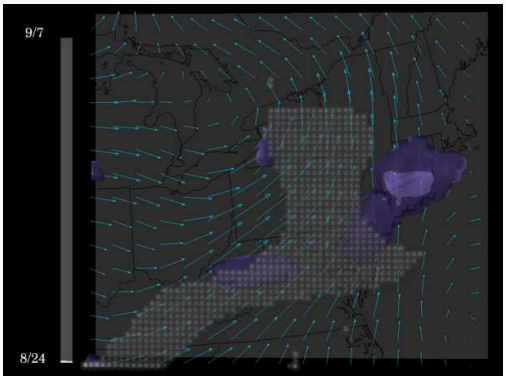
- Simulations
- Sensors
- Scanners
- Surveys
- Equations

Visualization Tasks

- See values
  - Extrema
  - Anomalies
  - Boundaries/Thresholds
  - Distribution/Structure
- See multiple variables
  - Relationships
- See flow/change
- Understand process



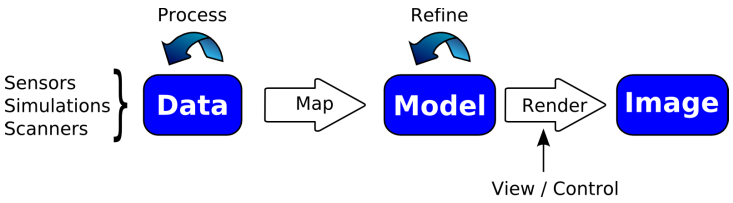




Visual Vocabulary

- Position
- Shape
- Color
- Density
- Glyphs
- Motion
- Interaction

The Visualization Process



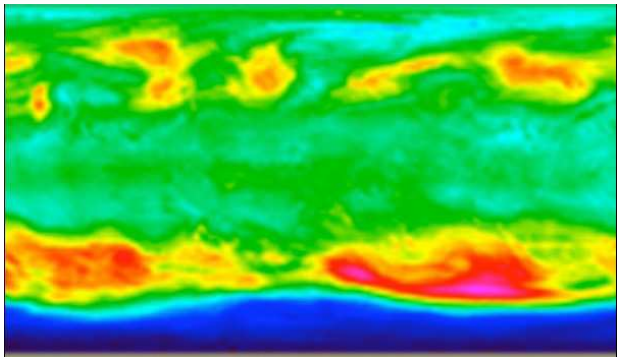
Categories of Visualization

- Data Visualization
  - Spatial
  - 2D/volume
  - scalar/multivariable
- Information Visualization
  - Non-spatial
  - HD Data
  - Structures
- Program/Performance Visualization

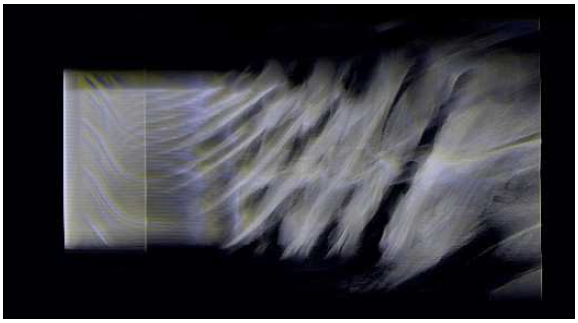
Application Areas

- Environmental modeling/monitoring
- Computational fluid dynamics
- Medical diagnosis
- Treatment planing
- Drug design
- Chemistry/Physics
- Public Health
- Sociology/Economics

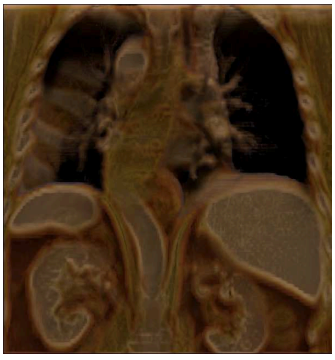
Environmental Modeling/Monitoring



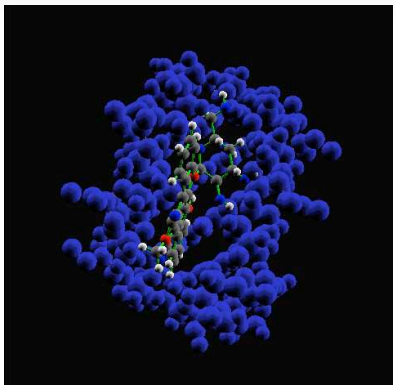
Computational Fluid Dynamics



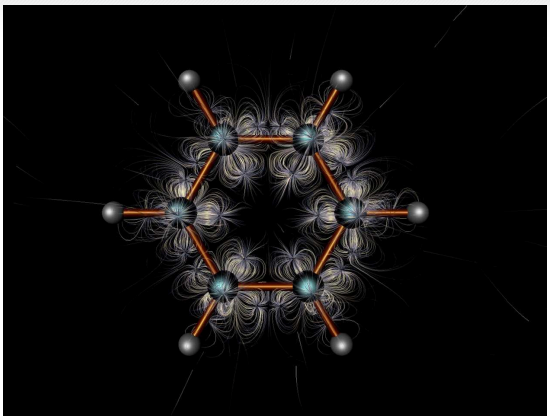
Medical Imaging



Drug Design

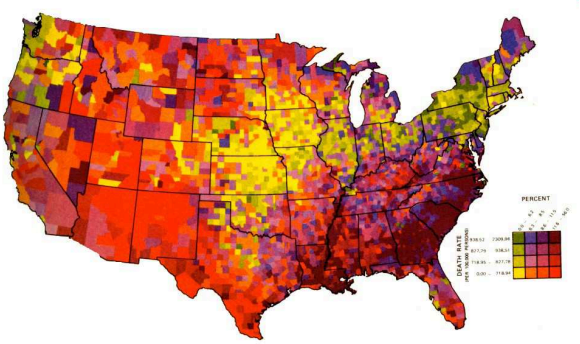


Chemistry



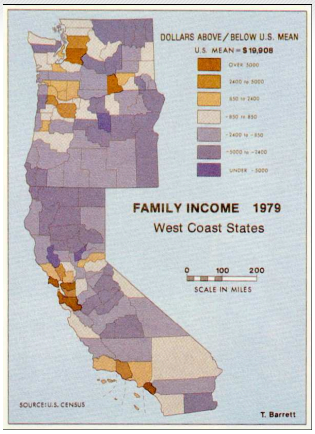
Zoeckler, Stalling, and Hege '96

Public Health



Tufte '83

Sociology/Economics



Olson '97

Case Study – Volumetric Data

- Grid structure common
  - Frequently differing resolutions by dimension
  - Sometimes curvilinear grids
  - Rarely scattered or irregularly structured data
- Sampled from function
  - Volume sampling
  - Partial volume effects
- Categorization an issue

Visualization of Volumes

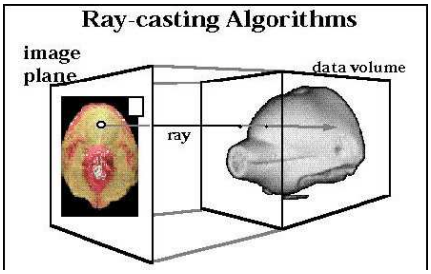
- Surface rendering of significant threshold surfaces in the volume
  - Only threshold elements visible
- Direct volume rendering
  - Each element contributes to final image

Volume Ray Casting

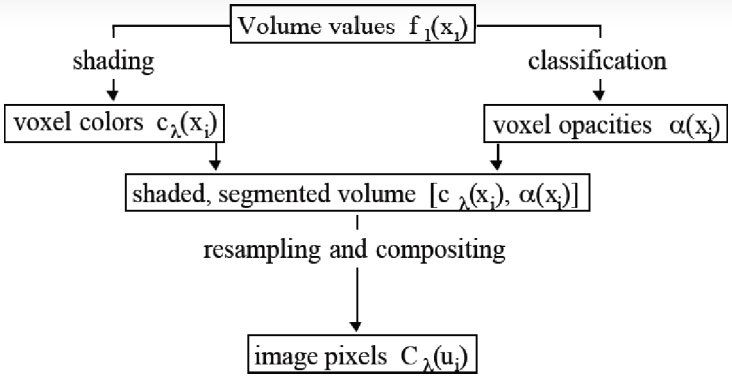
- Mechanism
  - Apply enhancements independently at each sample
- Advantages
  - High quality illumination cues
  - Flexibility to arbitrarily combine enhancements
- Disadvantages
  - Computational load precludes interactive rates
  - Possibly little continuity of volume characteristics

Volume Ray Casting

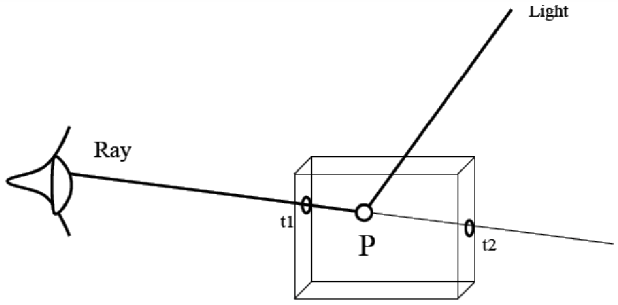
- Kajiya, Von Herzen 1984
- Levoy 1988
- Drebin 1988



Raycast Volume Rendering Pipeline



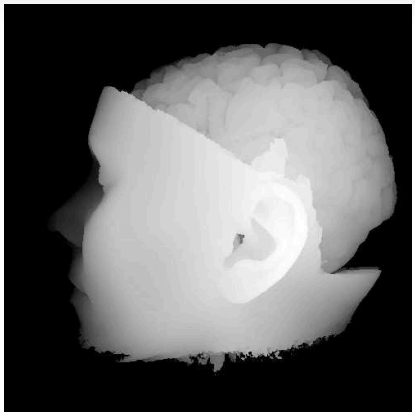
General Concept



Volume Ray Casting – Algorithm

for each pixel **do**
    Intersect ray with volume
    from t1 **to** t2 **do**
        step through each voxel
        calculate opacity and color of each voxel
        accumulate these

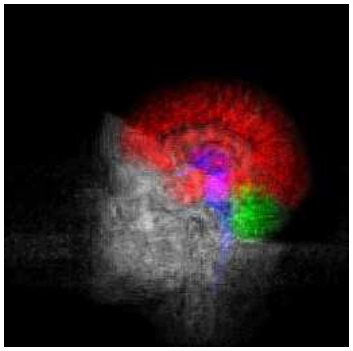
Example Depth Rendering



Classification, Coloring, Opacity

- Accomplished through use of look-up tables
  - Store texture values as look-up table indices
  - Allows some coloring of different data types
  - Can implement interactive transfer function variation in this manner

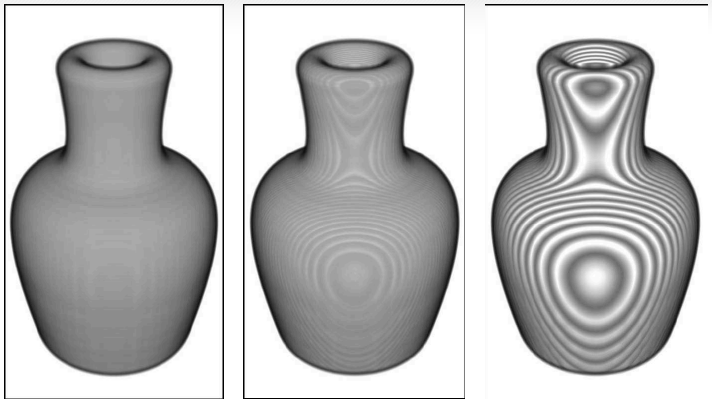
Segmented Colored Rendered



Issues: Sampling Along Ray

- How do we step through the voxels?
  - Use 3D digital difference analyzer
  - Resample at regularly spaced interval the voxel color and opacity
  - Adaptively resample the information based on frequencies in the data
- How frequently do we sample?

Various Sampling Rates



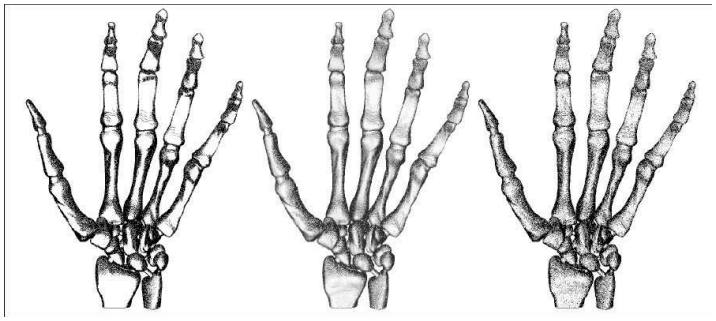
Issues: Accumulating Opacity

- How do we accumulate the opacity?
  - Kajiya's atmospheric attenuation
  - Levoy: modify opacity by gradient, de-emphasize tissue interiors
  - Linearly

NPR Volumetric Rendering - Stippling

- Approach
  - Generate point primitives based on volume distribution
  - Enhance based on gradient, orientation, etc
  - Supplement with curve strokes
  - Accelerate with fragment program
- Results
  - Interactive rates for modest volumes on PC

Stippled Volume Rendering



Lu et al., TVCG 2003

Common Issues for All Types of Visualization Techniques

- 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's Role 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

- Interactive vs. image quality
- Interactions vs. information quantity
- Best Choice:
  - Systems that allows interactive preview and exportation combined with non-interactive realistic rendering

More Data Visualization

- CMSC 635: Advanced Computer Graphics
  - Covers volume rendering in more detail
- CMSC 636: Data Visualization
  - Geo-spatial Visualization
  - Volume Visualization
  - Vector Visualization
  - Visualization of High-dimensional Data
  - Tree and Graph Visualization
  - Visualization Design
  - Evaluation of Visualization