Introduction

- Getting acquainted - teams
- Current studies or major
- Hometown
- A interesting data problem

Outline

- Scientific Visualization
  - Data Topologies and Data Sources
  - 1D and 2D Visualization Algorithms
  - Overview of 3D Visualization techniques
    - Iso-contour surfaces
    - Volume Rendering
  - Transfer functions and segmentation (2D)
  - Flow Visualization Algorithms (2D)

Outline (con’t)

- Volume Rendering
  - Optical Models
  - Algorithms
  - Transfer Functions
- Global Vector Field Visualization
- Virtual Environments
  - The CAVE
- Data or Information Visualization
  - Overview of perceptual issues
  - Brushing
  - Focus + context
  - Successes
What is Visualization?

- Understanding of data
- Insight into information
- Presentation and sharing of insights.

Data Sources

- Computational Science
- Data Acquisition / Imaging
- Historical Observation
- Survey, Census, etc.

Data Topologies - Structured

- Cartesian
  \[ x_{j+1} = x_j + \Delta \]
- Regular or Uniform
  \[ x_{j+1} = x_j + \Delta x \]
- Rectilinear or Perimeter
  \[ x_{j+1} = x(i) \]

Curvilinear

- Curves may intersect in i or j
- Curves may not cross in i or j
Data Topologies - Unstructured

- Unstructured or cell data or finite-element data
  - Tetrahedral

Data Topologies - Unstructured

Hexahedral

New Data Topologies

- Improved data topologies offer huge potential for savings in computational science
- Hierarchical models are becoming more common
New Data Topologies

- Hierarchical
- Multi-Block Curvilinear
- N-sided Polyhedron where n>6
- Multi-Grid or Adaptive Mesh Refinement

Working with data

- Reconstruction is critical
- Useful Image Processing operations
  - Histogram
  - Data mappers
  - Region of interest selection
  - Edge detection
  - Noise removal or blurring

1D and 2D Visualization Techniques

1D Visualization

- \( y = f(x) \)
- Line Charts
- Curve Fitting
- Smoothing or Approximation
1D Visualization

- Non-cartesion coordinate systems

2D Visualizations

- Contour Lines - $f(x,y) = \text{constant}$

Basic 2D Visualizations

- Scalar Data on a Regular Grid
  - Surface plots
    (2D graphics)

2D Visualizations

- Psuedo Coloring
2D Computer Graphics

- Image formats and pixel limitations
- Color Tables
  - grey-scale
  - hot to cold
  - perceptual

Transfer Functions

- Besides the basics, most tools allow you to define your own color mappings.

2D Visualization

- Vector Fields
  - Hedgehogs
  - Streamlines

1D Visualization

- Vector?
2D Contouring

- Continuous $f(x,y)$
  - Use steepest decent to find zero crossing (root) of the function $f(x,y)-c$
  - Follow contour from this seed point until we reach a boundary or loop back.
  - Direction close to $\nabla f \otimes z$
  - Problems?

2D Contouring

- Discrete Data
  - Assume the Mean Value Theorem
  - Assume monotonicity?
- 1D Analogy
  - 5 Points

Three-dimensional Visualization Techniques

Given a quadrilateral

- $f(x,y) = 0.5$

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**Visualization Algorithms**

- 2D Slice planes in 3D

**2D Slice Planes**

- Orthogonal to a coordinate axis
  - Uniform Grids => image
  - Arbitrary
    - Specify the normal and a point
    - Produces a 2D unstructured grid

2D Slice Planes

- Mesh with colors at vertices
  - 128x128x128 volume can produce over 50,000 triangles.
- Mesh with 2D texture coordinates
  - Very slow if no hardware support
  - More precise transitions
- Mesh with 3D texture coordinates

2D Flip book of slices

- Rather than view the 2D slice in 3D, rapidly play a sequence of orthogonal slice planes in a movie loop.
- Sometimes difficult to build a complete mental model.
3D Visualizations

- Point plots
- Animation can bring out the surface or pattern (MacSpin)
- Depth Cueing aids in the depth perception.

3D Visualizations

- Spheres or cubes dispersed throughout the volume
  - color-coded
  - optional shape-controlled.

3D Visualization

- Iso-contour surfaces

3D Visualization

- Can add information about an additional variable
  - Here, two additional variables control the color.
3D Visualization

Volume Rendering

Material Classification

- Drebin, Carpenter and Hanrahan
  - Material Probabilities
- Levoy
  - Contour surfaces
- MRI data
  - Skin versus Brain
- Using Texture mapping

Transfer Functions

- Maps raw voxel value into presentable entities: color, intensity, opacity...
  - Raw-data ⇒ material (R, G, B, α, Ka, Kd, Ks,...).
  - Material ⇒ shaded material.
- High gradient in the data values detects a surface and is used as a measure of its orientation.
3D Visualization

- Volume Rendering can mimic contouring.
- Use a transfer function with an impulse at the contour level.