Introduction to Scientific Data Visualization and Analytics

Han-Wei Shen
The Ohio State University
What is Visualization?

• A process of transforming numerical data to images
• The goal is to extraction information from the data, or data analytics
• Interdisciplinary
Visual Analysis Pipeline

- Data Acquisition/Generation
- Data Preparation
- Feature Extraction and Visual Mapping
- Rendering
- Analysis
- Image and Animation
Visual Analysis Pipeline

- Data Acquisition/Generation
- Data Preparation
- Feature Extraction and Visual Mapping
- Rendering
- Analysis
- Image and Animation
Visual Analysis Pipeline

- Data Acquisition/Generation
- Data Preparation
- Feature Extraction and Visual Mapping
  - Rendering
  - Analysis
    - Image and Animation
Visual Analysis Pipeline

- Data Acquisition/Generation
- Data Preparation
- Feature Extraction and Visual Mapping
  - Rendering
  - Analysis
- Image and Animation
Visual Analysis Pipeline

Data Acquisition/Generation

Data Preparation

Feature Extraction and Visual Mapping

Rendering

Analysis

Image and Animation
Visual Analysis Pipeline

Data Acquisition/Generation

Data Preparation

Feature Extraction and Visual Mapping

Rendering

Analysis

Image and Animation
Data Acquisition and Generation

- Spatial Data
  - Medical imaging
  - Numerical simulations
  - Sensor data (Radar, LiDAR, etc.)
Data Acquisition and Generation

- Non-Spatial Data
  - Network Data (Graphs and Trees)
  - Text Data (Documents)
  - Matrix Data (Spreadsheets)
Data Preparation

• Reconstruction
• Smoothing/De-noising
• Re-sampling
• Transformation (wavelet, Fourier, etc. transforms)
• Projections (to lower dimensions)
• Compression/down-sampling
• Partitioning/Bricking
• Multi-resolution
• Data distribution and file layout
• ...
Feature Extraction

• Generic features: isosurfaces, streamlines, critical points etc.

• Specific features: vortices, material boundaries, flow separation, etc.
Visual Mapping and Rendering

• The process of converting features to visual forms

\[ I(D) = I_0 \exp \left( - \int_0^D \tau(s) \, dt \right) + \int_0^D c(t) \tau(t) \, dt \exp \left( - \int_0^D \tau(s) \, dt \right) \]

• Volume rendering
  – Optical models
  – Transfer functions

• Polygon rendering
  – Raster graphics
  – Ray tracing

• Advanced illumination and stylized rendering
Illumination and Sylized Rendering
Visual Analysis Pipeline

- Data Acquisition/Generation
- Data Preparation
- Feature Extraction and Visual Mapping
  - Rendering
  - Analysis
    - Image and Animation
Analysis

The goal of analysis is to extract/prioritize features and raw data

• Topological
  – Surface topology: contour trees, reeb graphs
  – Vector field topology (sink, source, saddle)

• Geometry
  – Surfaces and curves: first and second fundamental forms, various types of curvatures

• Statistical
  – First, second, or higher order moments
  – Distribution, histograms
  – Entropy, information theory
Image and Animation

- Often the final output of the visualization pipeline
- The quality of the output is affected by the visualization algorithm parameters
- Many metrics are available to evaluate the images and in turn to optimize the visualization algorithm parameters
- Visualization algorithms can also be optimized if the property of the images are considered (visibility, object size etc)
Visual Analysis Pipeline

Data Acquisition/Generation

Data Preparation

Feature Extraction and Visual Mapping

Rendering

Analysis

Image and Animation