Lecture 3: Visualization Stages, Sensory vs. Arbitrary symbols, Data Characteristics, Visualization Goals, Props

Example Videos

• Dam breaking simulation
• Multi-data set isosurface similarity
• Tumor access safety rays

Administrative

• Office Hours: Sitterson 258
  – Mondays 10-11
  – Thursdays 9-10

• Homework
  – Wordpress site up and running
  – Some users registered
  – Upload your posts by Thursday!
  – Comment on posts by others
Foundation for a Science of Data Visualization

• What are the advantages of visualization?

Visualization Stages

Collect the data (lab work or simulation)
Transform the data
- into a format readable by the visualization software
- into the form most likely to reveal information (Rspace)
Visualization algorithms run on graphics hardware or software renderer
Human views and interacts with the visualization (changing parameters, techniques, view direction)
• Preferably: User studies to evaluate effectiveness
Sensory vs. Arbitrary Symbols

- Sensory: You can see and understand without training.
  - Match the way our brains are wired
  - Object shape, color, texture

- Arbitrary: Must be learned
  - Having no perceptual basis
  - The word “dog”

Properties of Sensory Reps.

- Can be understood without training
- Resistant to instructional bias
- Is processed very quickly, and in parallel
- Is valid across cultures

- Danger: Poor mappings can be misunderstood, even in the presence of instruction, quickly and without effort.

Properties of Arbitrary Reps.

- Formally powerful
- Capable of rapid change
- May already be learned (summation notation)

- Dangers:
  - Can be hard to learn (alphabet)
  - Can be easy to forget
  - Can vary with culture and application (different disciplines use different symbols for the same concept and the same symbol for different concepts):
    - \( i = \sqrt{-1} \), \( i = \) current
What is a Good Visualization?

- Understanding means making a model that captures the essence of a system.
- A model is an abstraction with the important things in and the unimportant out.
- Different visualizations provide different levels of detail, show and hide different things; so support different abstractions.
- Good visualizations are those that are useful to aid understanding, not just realistic representations (what color is a carbon atom?)
- Good visualizations map the important parts of the task onto techniques that show the relevant characteristics best.
Data Characteristics and Visualization Goals

- Why classify data and visualization goals?
  - No known “silver bullet” technique
  - Helps select which technique(s) to try
  - Helps predict other uses for good techniques
  - Some tools only work with some formats

(This section draws heavily on sources outside the Ware book)
Print this lecture for reference (homeworks)!

Data Characteristics

- Dimensionality
- Category of each value/field
- Structure of the sampling
- Other data characteristics

Dimensionality

- Of each data field (0=point, 1=line, 2=surface, 3=volume, ...)
- Of the space the fields are embedded in (2D or 3D) + time (some call 4D)
- Of the data type in each field
  - (scalar, vector, tensor)
- Of the space used to visualize the data
Category of each Scalar Field

- Nominal: names without ordering
  - Continents: Africa, America, Asia, Australia, Europe.
- Ordinal: “Less than” relationship holds
  - Rental cars: Economy, Compact, Mid-sized, Full-sized.
- Interval: Relative measurements, no absolute zero
  - Height of AFM scan or location
- Ratio: Absolute zero (can say “twice as much as”)
  - Account balance, Height above sea level, not “height”

Structure of the Sampling Grid

- Structured
  - Square/Cube
  - Rectilinear
  - Curvilinear
- Unstructured
  - Tetrahedral
  - Cloud of points

Other Data Characteristics

- Continuous vs. Discrete
  - Sampling of the field
  - Values within each sample
- Rapid spatial/temporal changes in the data
- Missing values?
  - Interpolate?
  - Show explicitly?
- Special values?
  - Of particular interest to visualize
  - Zero for some ratio scales (height above sea level)
Visualization Problems vs. Data Types

- Medical
- Scientific
- Information

2D
3D
nD

- Scalar
- Vector

Structured
Unstructured
Goal-Based Visualization Design

- High-level goals / middle-level tasks / atomic actions
- Determine task(s) before determining representations!!!
  - tasks often determined informally or implicitly
- Each representation may serve one high-level goal

Visualization Goals

- Debugging
  - Quality control of simulations, measurements
- Exploration
  - Gaining new insights \( \rightarrow \) hypotheses
  - Increasing scientific productivity
  - Making invisible visible
- Presentation
  - Enhancing understanding of concepts and processes
  - Visual medium of communication
Exploration Tasks

- Identify and distinguish objects
  - Categorize objects
- Compare values
  - Discover extrema (qualitative)
  - Look up metric information (quantitative)
- Recognize pattern/structure
  - Identify clusters
  - Correlations between data sets
  - “What’s going on here?”

Presentation Tasks

- Effective presentation of significant features
- Attempt to convince
- Attract interest

Example: to Convince

Consider Whole Visualization

• Interplay between techniques
  – 3D color-mapped objects?
    • Don’t vary lightness in color scale
  – Multiple variables displayed?
    • Map to different perceptual channels
• Integrated vs. separate
  – May separate in space (parallel presentation)
  – Maybe in time (animation, user switches)
  – Combine if you can effectively (shows correlation)

Summary

• Data Characteristics
  – For each technique, consider what dimensions and types of data it can support
  – For each visualization, consider the best space to display it in
    – Consider rapid changes and missing values
• Visualization Goals
  – Consider what tasks need to be done to achieve the visualization goals
  – Consider what tasks are to be achieved, and which techniques are well suited for each
• Final consideration: “Does this work?”
“But How Do We Know Which Techniques Are Suitable?”

• Learn a bit about how perception works...
• Learn what techniques:
  – Support different data types
  – Support different tasks

• That’s what we’ll hear about in this course!

The Dream System, part 1

• “Catalog of Visualizations:” Classification of simple and complex visualization techniques [WEH90]
• Categorize each visualization technique by:
  – what kind of data can be displayed (“attributes”): [scalar field, nominal, direction field, shape, position, spatially extend region or object, structure]
  – what operations act on these attributes (“operations/judgments”)
    • operations: [identify, locate, distinguish, categorize, cluster, distribution, rank, compare within and between relations, associate, correlate]
• Large 2-d matrix to identify meaningful visualization techniques for a pair of (attribute/operation).
The Dream System, part 2

• Assisted Visualization
  – Toolkit looks up the best visualization from the new version of the above table
  – Questions about the tasks drive selection from the table
  – AI gives you the best visualization
• Chris Healey (NCSU) and others are working on this
  – Working on a system that makes a reasonable first pass
• Several others are working on this as well (see notes from Domik lecture in ACM course)

The Current System

• “We’re not there yet” with the dream system
• This course will present what is known
• I try to organize like the ideal table
  – Lots of entries untested as we reach the frontier
• You are the “I” in place of “AI”
Comp/Phys/Mtsc 715

Props for Visualization Context

Hand-Held: CT Scan Slicer

• Ken Hinckley, UVA

Hand-Held: Molecular Models

• Mike Pique and Art Olson, Scripps Research
CG and Force Overlay

- Mike Pique and Art Olson, Scripps Research

Visual Inventory

- Graham Johnson and Art Olson, Scripps

- http://www.youtube.com/watch?v=Dl1ufW3cj4g&list=UUz7CvhTKmz6wknQUWcIK8g&feature=plcp

Auto-Fill Blood Vessel

- Graham Johnson and Art Olson, Scripps

- http://www.youtube.com/watch?v=DKJPL79Uy_w&list=UUz7CvhTKmz6wknQUWcIK8g&index=31&feature=plcp

- Molecules in blood
- Correct ratios
- Stir with Cinema 4D
Proximity-based Rendering

- Visualizing Flow Trajectories Using Locality-based Rendering and Warped Curve Plots
  - Chad Jones, Kwan-Liu Ma; TVCG 2010

Left side: Proximity to selected flow lines increases opacity; color map shows minimum. Streamline color shows speed.

Geometric: Winged Aircraft

- Han-Wei Shen, 1998

Geometric: Theory plus Data

- Julie Newdoll, UCSD (Keller&Keller p126)
Video
• What does a Protein Look Like?
• Subset of the visualizations shown here

Protein Models
References

• Foundation, Stages, Sensory vs. Arbitrary, 2-Stage Model: Ware.
• Goals, Data, Categorizations, Analysis: Gitta Domik.
• Problems vs. data types, data structure: David Ebert
• Exploration tasks, Consider Task, Consider Whole Visualization (and examples), Final Consideration: Penny Rheingans

Interview Example

• Interview on galaxy formation
  – Russ plays the visualization expert, naïve in galaxy studies
  – Ryan Tanner is the scientist
  – Comp Sci
     • Learn to interview
  – Everyone
     • Learn to abstract data
     • Learn to define goals
     • Push beyond first question