Comp/Phys/Mtsc 715

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 (private) by next Thursday!
  - Comment on posts by others by following Monday

Foundation for a Science of Data Visualization

- What are the advantages of visualization?

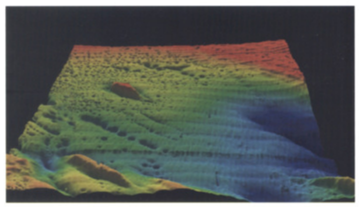


Figure 1.1 Passamaquoddy Bay visualization. *Data courtesy of the Canadian Hydrographic Service.*

Visualization Stages

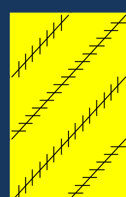
- Collect the data (lab work or simulation)
- Transform the data
  - into a format readable by the visualization software
  - into the form most likely to reveal information (Rspace)
- Visualization algorithms run on graphics hardware or software renderer
- Human views and interacts with the visualization (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”
    - “perro”, “hund”, “chien”, “cane”, “cão”, “犬”, “개”, “狗”

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

Two-Stage Model of Perceptual Processing

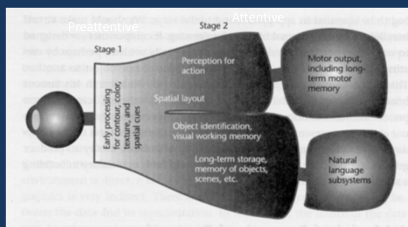


Figure 1.11 This schematic diagram presents an overview of a two-stage model of human visual information processing.

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)

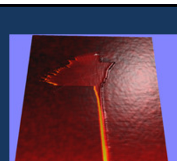
Print this lecture for reference (homeworks)!

Data Characteristics

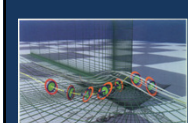
- Dimensionality
- Category of each value/field
- Structure of the sampling
- Other data characteristics

Dimensionality

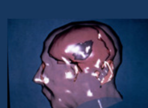
- Of each data field (0=point, 1=line, 2=surface, 3=volume, …)
- Of the space the fields are embedded in (2D or 3D) + time (some call 4D)
- Of the data type in each field
  - (scalar, vector, tensor)
- Of the space used to visualize the data



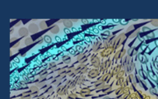
Two 2D scalar fields in 2D (drawn in 3D)



3D vector field in 3D



2D isosurfaces of 3D scalar field in 3D



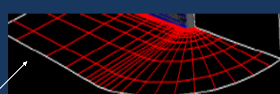
2D vec/tensor fields Embedded in 3D Drawn in 2D

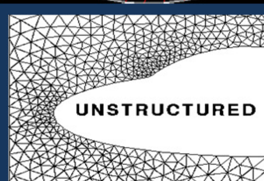
Category of each Scalar Field

- 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

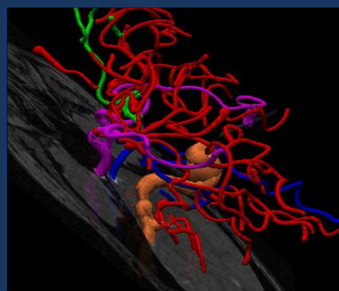




Other Data Characteristics

- 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)

Data Characteristics: Example



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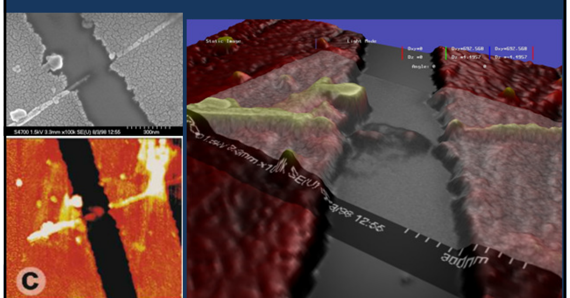
Data Characteristics: Example



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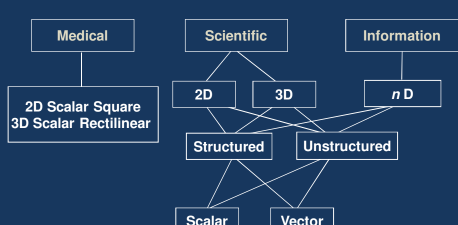
Visualization Problems vs. Data Types



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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 → 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?"

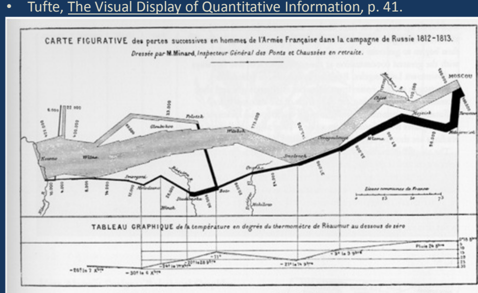
Specialized ↕ General

Presentation Tasks

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

Example: to Convince

- Tufte, The Visual Display of Quantitative Information, p. 41.



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"

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Props for Visualization Context

Hand-Held: CT Scan Slicer

- Ken Hinckley, UVA

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Hand-Held: Molecular Models

- Mike Pique and Art Olson, Scripps Research

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CG and Force Overlay

- Mike Pique and Art Olson, Scripps Research

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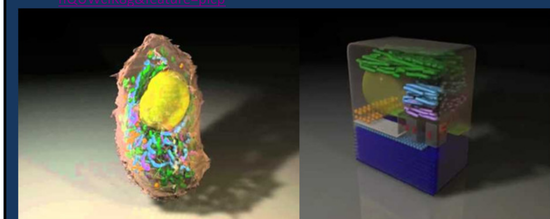
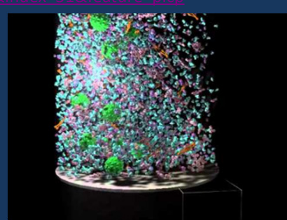
Visual Inventory

- Graham Johnson and Art Olson, Scripps
- http://www.youtube.com/watch?v=Dl1ufW3cj4g&list=UUz7CvhTKmz6wklnQUWcIK8g&feature=plcp



Auto-Fill Blood Vessel

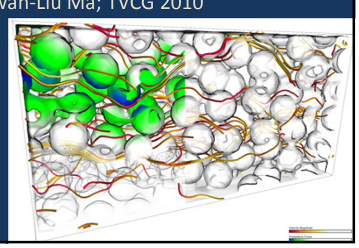
- Graham Johnson and Art Olson, Scripps
- http://www.youtube.com/watch?v=DKJPL79Uy_w&list=UUz7CvhTKmz6wklnQUWcIK8g&index=31&feature=plcp
- Molecules in blood
- Correct ratios
- Stir with Cinema 4D



Proximity-based Rendering

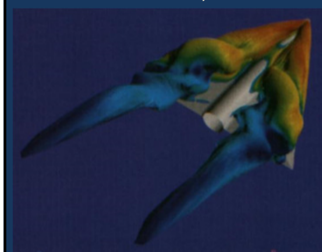
- Visualizing Flow Trajectories Using Locality-based Rendering and Warped Curve Plots
  - Chad Jones, Kwan-Liu Ma; TVCG 2010

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



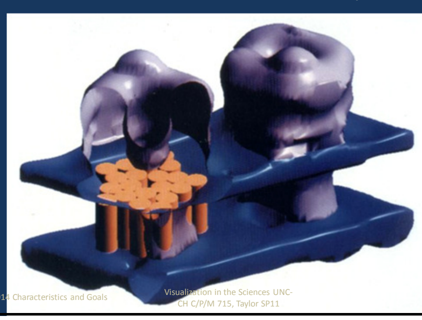
Geometric: Winged Aircraft

- Han-Wei Shen, 1998



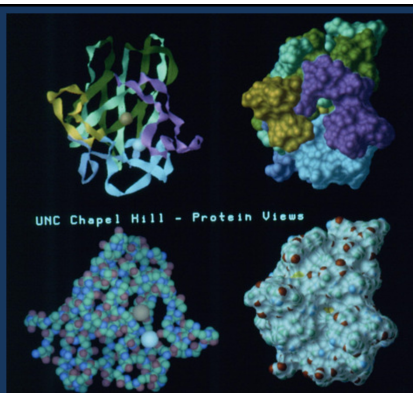
Geometric: Theory plus Data

- Julie Newdoll, UCSD (Keller&Keller p126)



Video

- What does a Protein Look Like?
- (Online copy)
- Subset of the visualizations shown here



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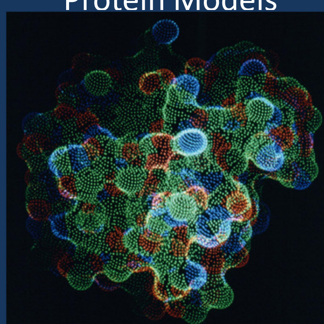
Protein Models



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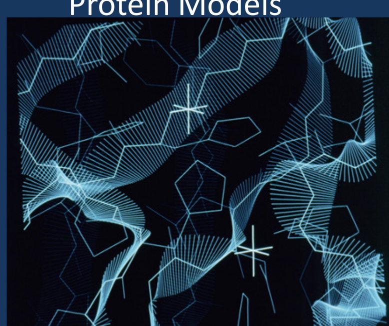
Protein Models



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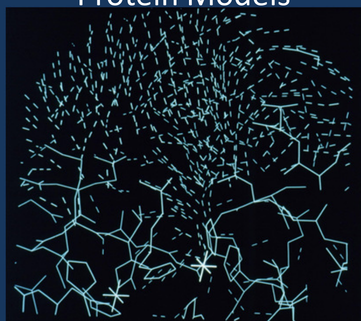
Protein Models



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