Data Visualization (DSC 530/CIS 602-01)

Tasks & Design

Dr. David Koop
Recap (Data)

• Basic Data Types:
  - Items, Attributes, Links, Positions, Grids

• Dataset Types:
  - Tabular, Networks, Fields, Geometry, Sets

• Attribute Types:
  - Categorical and Ordered (Ordinal and Quantitative)
  - Ordered: Sequential, Diverging, and Cyclic

• Tables: Keys and Values

• Fields: Scalar, Vector, and Tensor

• Time-Varying Data
## Items & Attributes

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<tr>
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</table>
Items (Nodes) & Links

[Image of a network diagram with nodes and links, indicating connections between items.]

[Bostock, 2011]
Positions and Grids
Dataset Types

- **Tables**
- **Networks**
- **Fields** (Continuous)
- **Geometry** (Spatial)

**Multidimensional Table**

[Munzner (ill. Maguire), 2014]
# Tables

<table>
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Table Visualizations

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<th>cylinders</th>
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<th>power (hp)</th>
<th>weight (lb)</th>
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[M. Bostock, 2011]
Networks

• Why networks instead of graphs?
• Tables can represent networks
  - Many-many relationships
  - Also can be stored as specific graph databases or files
Figure 7: US airlines graph (235 nodes, 2101 edges) (a) not bundled and bundled using (b) FDEB with inverse-linear model, (c) GBEB, and (d) FDEB with inverse-quadratic model.

Figure 8: US migration graph (1715 nodes, 9780 edges) (a) not bundled and bundled using (b) FDEB with inverse-linear model, (c) GBEB, and (d) FDEB with inverse-quadratic model. The same migration flow is highlighted in each graph.

Figure 9: A low amount of straightening provides an indication of the number of edges comprising a bundle by widening the bundle. (a) $s=0$, (b) $s=10$, and (c) $s=40$. If $s$ is 0, color more clearly indicates the number of edges comprising a bundle.

we generated use the rendering technique described in Section 4.1. To facilitate the comparison of migration flow in Figure 8, we use a similar rendering technique as the one that Cui et al. [CZQ ⇤08] used to generate Figure 8c.

The airlines graph is comprised of 235 nodes and 2101 edges. It took 19 seconds to calculate the bundled airlines graphs (Figures 7b and 7d) using the calculation scheme presented in Section 3.3. The migration graph is comprised of 1715 nodes and 9780 edges. It took 80 seconds to calculate the bundled migration graphs (Figures 8b and 8d) using the same calculation scheme. All measurements were performed on an Intel Core 2 Duo 2.66GHz PC running Windows XP with 2GB of RAM and a GeForce 8800GT graphics card.

Our prototype was implemented in Borland Delphi 7.

[Holten & van Wijk, 2009]
Fields

- Difference between continuous and discrete values
- Examples: temperature, pressure, density
- **Grids** necessary to sample continuous data:

  ![Grids Diagram]

  - uniform
  - rectilinear
  - structured
  - unstructured

- **Interpolation**: “how to show values between the sampled points in ways that do not mislead”

[Weiskopf, Machiraju, Möller]
Spatial Data Example: MRI

[slide via Levine, 2014]
Sets & Lists

# OF UNIQUE WORDS USED WITHIN ARTIST'S FIRST 35,000 LYRICS

Notes/sources:
(1)(2) I used the first 5,000 words for 7 of Shakespeare's works: Hamlet, Romeo and Juliet, Othello, Macbeth, As You Like It, Winter's Tale, and Troilus and Cressida. For Melville, I used the first 35,000 words of Moby Dick.

All lyrics are provided by Rap Genius, but are only current to 2012. My lack of recent data prevented me from using quite a few current artists.

This data viz uses code by Amelia Bellamy-Royds's in this jsfiddle.

[Daniels, http://experiments.undercurrent.com]
Attribute Types

- Attribute Types
  - Categorical
  - Ordered
  - Ordinal
  - Quantitative

Ordering Direction

- Sequential
- Diverging
- Cyclic

[Munzner (ill. Maguire), 2014]
Data Model vs. Conceptual Model

• Data Model: raw data that has a specific data type (e.g. floats):
  - Temperature Example: [32.5, 54.0, -17.3] (floats)

• Conceptual Model: how we think about the data
  - Includes semantics, reasoning
  - Temperature Example:
    • Quantitative: [32.50, 54.00, -17.30]

[via A. Lex, 2015]
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  - Temperature Example:
    - Quantitative: [32.50, 54.00, -17.30]
    - Ordered: [warm, hot, cold]

[via A. Lex, 2015]
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• Conceptual Model: how we think about the data
  - Includes semantics, reasoning
  - Temperature Example:
    • Quantitative: [32.50, 54.00, -17.30]
    • Ordered: [warm, hot, cold]
    • Categorical: [not burned, burned, not burned]

[via A. Lex, 2015]
Sequential and Diverging Data

• Sequential: homogenous range from a minimum to a maximum
  - Examples: Land elevations, ocean depths

• Diverging: can be deconstructed into two sequences pointing in opposite directions
  - Has a zero point (not necessary 0)
  - Example: Map of both land elevation and ocean depth

[Rogowitz & Treinish, 1998]
Cyclic Data

[Sunlight intensity, Weber et al., 2001]
Semantics

• The type of data does not tell us what the data means or how it should be interpreted

• Tables have keys/values, fields have independent/dependent vars

[Muñzner (ill. Maguire), 2014]
Assignment 1

- HTML, CSS, SVG, and JavaScript
- Part 3 will likely take significantly more time than the other parts!
- Turn in a1.html (and a1.css, a1.js) via myCourses
- Due Friday, February 12 @ 11:59pm
- Late Policy

Assignment 1 Notes

- Grading will be done via Chrome v48
- For Part 3a, you do not need to use all of the functions I list, just avoid loops
- Other Questions?
“Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.”

— T. Munzner
Tasks

- Why? Understand data, but what do I want to do with it?
- Levels: High (Produce/Consume), Mid (Search), Low (Queries)
- Another key concern: Who?
  - Designer <-> User (A spectrum)
  - Complex <-> Easy to Use
  - General <-> Context-Specific
  - Flexible <-> Constrained
  - Varied Data <-> Specific Data
Tasks

- **What?**
  - Analyze
    - Consume
      - Discover
      - Present
      - Enjoy
  - Produce
    - Annotate
    - Record
    - Derive

- **Why?**
  - All Data
    - Trends
    - Outliers
    - Features
  - Attributes
    - One
      - Distribution
    - Many
      - Dependency
      - Correlation
      - Similarity
  - One
    - Extremes

- **How?**
  - Search
    - Target known
      - Location known
      - Lookup
      - Browse
    - Location unknown
      - Locate
      - Explore
  - Query
    - Identify
    - Compare
    - Summarize

[Munzner (ill. Maguire), 2014]
Actions: Analyze

➡️ **Analyze**

➡️ **Consume**
  ➡️ **Discover**

➡️ **Present**

➡️ **Enjoy**

➡️ **Produce**
  ➡️ **Annotate**

➡️ **Record**

➡️ **Derive**

[Munzner (ill. Maguire), 2014]
Visualization for Consumption

• Discover new knowledge
  - Generate new hypothesis or verify existing one
  - Designer doesn’t know what users need to see

• Present known information
  - Presenter already knows what the data says
  - Wants to communicate this to an audience

• Enjoy
  - Similar to discover, but without concrete goals
Name Voyager

NameVoyager: Explore baby names and name trends letter by letter
Looking for the perfect baby name? Sign up for free to receive access to our expert tools!

Names starting with 'AN' per million babies

[Graph showing name trends from 1880s to 2013]

Visualization for Production

- **Generate new material**
- **Annotate:**
  - Add more to a visualization
  - Usually associated with text, but can be graphical
- **Record:**
  - Persist visualizations for historical record
  - Provenance (graphical histories): how did I get here?
- **Derive (Transform):**
  - Create new data
  - Create derived attributes (e.g. mathematical operations, aggregation)
### Actions: Search

- What does a user know?
  - Lookup: check bearings
  - Locate: find on a map
  - Browse: what’s nearby
  - Explore: where to go (patterns)

---

**Search**

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<th>Target known</th>
<th>Location unknown</th>
<th>Target unknown</th>
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<td>Lookup</td>
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<td>Browse</td>
</tr>
<tr>
<td>Location unknown</td>
<td>Locate</td>
<td>Location unknown</td>
<td>Explore</td>
</tr>
</tbody>
</table>
• Number of targets: One, Some (Often 2), or All
• Identify: characteristics or references
• Compare: similarities and differences
• Summarize: overview of everything
Targets

- **ALL DATA**
  - Trends
  - Outliers
  - Features

- **ATTRIBUTES**
  - One
    - Distribution
    - Extremes
  - Many
    - Dependency
    - Correlation
    - Similarity

- **NETWORK DATA**
  - Topology
    - Paths

- **SPATIAL DATA**
  - Shape

[Munzner (ill. Maguire), 2014]
Analysis Example: Different “Idioms”

[SpaceTree, Grosjean et al.]  [TreeJuxtaposer, Munzner et al.]
“Idiom” Comparison

SpaceTree

TreeJuxtaposer

What?
Action
Targets

Why?
Present  Locate  Identify
Path between two nodes

How?
Encode  Navigate  Select  Filter  Aggregate


[Munzner (ill. Maguire), 2014]
“Idiom” Comparison

**SpaceTree**

**TreeJuxtaposer**

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<th>Why?</th>
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<td><strong>What?</strong></td>
<td><strong>Why?</strong></td>
<td><strong>How?</strong></td>
</tr>
<tr>
<td>Tree</td>
<td>Actions</td>
<td>SpaceTree</td>
</tr>
<tr>
<td>➤ Present</td>
<td>➤ Encode</td>
<td>➤ Encode</td>
</tr>
<tr>
<td>➤ Locate</td>
<td>➤ Navigate</td>
<td>➤ Navigate</td>
</tr>
<tr>
<td>➤ Identify</td>
<td>➤ Select</td>
<td>➤ Select</td>
</tr>
<tr>
<td></td>
<td>➤ Filter</td>
<td>➤ Filter</td>
</tr>
<tr>
<td></td>
<td>➤ Aggregate</td>
<td>➤ Aggregate</td>
</tr>
<tr>
<td>➤ Targets</td>
<td>➤ TreeJuxtaposer</td>
<td>➤ Arrange</td>
</tr>
<tr>
<td>➤ Path between two nodes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


[Munzner (ill. Maguire), 2014]
Analysis Example: Derivation

- **Strahler number**
  - centrality metric for trees/networks
  - derived quantitative attribute
  - draw top 5K of 500K for good skeleton


[Munzner (ill. Maguire), 2014]
“Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.”

— T. Munzner
Design Iteration

http://chartsnthings.tumblr.com/post/62679766588/19-sketches-of-quarterback-timelines
## Design Iteration

<table>
<thead>
<tr>
<th>Team</th>
<th>Quarterbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York Giants</td>
<td>Eli Manning</td>
</tr>
<tr>
<td>Indianapolis Colts</td>
<td>Peyton Manning</td>
</tr>
<tr>
<td>San Diego Chargers</td>
<td>Drew Brees, Drew Brees, Philip Rivers</td>
</tr>
<tr>
<td>Baltimore Ravens</td>
<td>Kyle Boomer, Steve McNair, Joe Flacco</td>
</tr>
<tr>
<td>New England Patriots</td>
<td>Tom Brady, Matt Cassel, Tom Brady</td>
</tr>
<tr>
<td>Green Bay Packers</td>
<td>Brett Favre, Aaron Rodgers, Aaron Rodgers</td>
</tr>
<tr>
<td>New Orleans Saints</td>
<td>Aaron Brooks, Drew Brees</td>
</tr>
<tr>
<td>Atlanta Falcons</td>
<td>Michael Vick, Michael Vick, Matt Ryan, Matt Ryan</td>
</tr>
<tr>
<td>New York Jets</td>
<td>Chad Pennington, Brett Favre, Mark Sanchez, Mark Sanchez</td>
</tr>
<tr>
<td>Cincinnati Bengals</td>
<td>Carson Palmer, Carson Palmer, Ryan Fitz, Carson Palmer, Andy Dalton</td>
</tr>
<tr>
<td>Houston Texans</td>
<td>David Carr, Matt Schaub</td>
</tr>
<tr>
<td>Carolina Panthers</td>
<td>Jake Delhomme, Jake Delhomme, Cam Newton</td>
</tr>
<tr>
<td>Denver Broncos</td>
<td>Jake Plummer, Jay Cutler, Kyle Orton, Tim Tebow, Peyton Manning</td>
</tr>
<tr>
<td>Arizona Cardinals</td>
<td>Matt Leinart, Kurt Warner</td>
</tr>
<tr>
<td>Jacksonville Jaguars</td>
<td>Byron Leftwich, David Garrard, David Garrard, Blaine Gabbert</td>
</tr>
<tr>
<td>Detroit Lions</td>
<td>Joey Harrington, Jon Kitna, Matthew Stafford</td>
</tr>
<tr>
<td>Tampa Bay Buccaneers</td>
<td>Chris Simms, Bruce Gradkowski, Jeff Garcia, Josh Freeman, Josh Freeman</td>
</tr>
<tr>
<td>Dallas Cowboys</td>
<td>Drew Bledsoe, Tony Romo, Tony Romo, Tony Romo</td>
</tr>
</tbody>
</table>

http://chartsnthings.tumblr.com/post/62679766588/19-sketches-of-quarterback-timelines
Design Iteration

Each streak shows consecutive starts by a quarterback for a single team. Streaks include playoffs.

Only two players have longer streaks: Brett Favre (275) and Eli's brother, Peyton (227).

Among active players, Philip Rivers (122) and Joe Flacco (96) are closest behind Eli.

Find a quarterback

Eli Manning (149)

http://chartsnthings.tumblr.com/post/62679766588/19-sketches-of-quarterback-timelines
Design

- Unlike a math problem, there are many different approaches for the visualization of some data
- Need to have some way to discuss how to determine whether a visualization is doing what we want
- Validation: Understand why a design is effective
  - What problems can be effective
  - Do this at different levels
Four Nested Levels of Design

- **Domain situation**
- **Data/task abstraction**
- **Visual encoding/interaction idiom**
- **Algorithm**
Potential problems at each level

- **Domain situation**
  - You misunderstood their needs

- **Data/task abstraction**
  - You’re showing them the wrong thing

- **Visual encoding/interaction idiom**
  - The way you show it doesn’t work

- **Algorithm**
  - Your code is too slow
Validation at each level

- **Threat**: Wrong problem
- **Validate**: Observe and interview target users

- **Threat**: Wrong task/data abstraction
- **Threat**: Ineffective encoding/interaction idiom
- **Validate**: Justify encoding/interaction design

- **Validate**: Analyze computational complexity
  - **Implement system**
- **Validate**: Measure system time/memory

- **Validate**: Qualitative/quantitative result image analysis
  - *Test on any users, informal usability study*
- **Validate**: Lab study, measure human time/errors for task

- **Validate**: Test on target users, collect anecdotal evidence of utility
- **Validate**: Field study, document human usage of deployed system

- **Validate**: Observe adoption rates
Visualization Design Principles

Slides from A. Lex
Examples of Bad Design