Data Visualization (DSC 530/CIS 602-01)

Data

Dr. David Koop
HTML and CSS

• HTML: Tags define the boundaries of the structures of the content
  <em>This is <strong>cool</strong>. What about <u><strong>this?</strong></u></em>

• HTML id and class attributes identify specific elements

• CSS: Specifies the style of the content according to selectors
  em { color: green; }
  #main-header { color: red; }
  .important { color: blue; }
Scalable Vector Graphics (SVG)

- Vector graphics vs. Raster graphics

  - Drawing primitives:
    - Lines, Circles, Rects, Ellipses, Text, Polylines, Paths
    - Work by specifying information about how to draw the shape
    - Lots more: see MDN Documentation

- Ordering/Stacking:
  - SVG Elements are drawn in the order they are specified
SVG Example

- [http://codepen.io/dakoop/pen/yexVXb](http://codepen.io/dakoop/pen/yexVXb)
- `<svg id="mysvg" width="300" height="600">
  <circle cx="50" cy="50" r="50"/>
  <rect class="lego" x="150" y="150" width="50" height="20"/>
  <path id="triangle" d="M 20 200 L 120 200 L 120 250 Z"/>
</svg>

- `circle` { fill: green; stroke: black; stroke-width: 4px; } 
  .lego { fill: red; stroke: blue; stroke-width: 2px; } 
  #triangle { fill: none; stroke: orange; stroke-width:3px; }
JavaScript in one slide

• Interpreted and Dynamically-typed Programming Language
• Statements end with semi-colons, normal blocking with brackets
• Variables: var a = 0;
• Operators: +, -, *, /, [ ]
• Control Statements: if (<expr>) {...} else {...}, switch
• Loops: for, while, do-while
• Arrays: var a = [1,2,3]; a[99] = 100; console.log(a.length);
• Functions: function myFunction(a,b) { return a + b; }
• Objects: var obj; obj.x = 3; obj.y = 5;
  - Prototypes for instance functions
• Comments are /* Comment */ or // Single-line Comment
Important JavaScript Concepts

• Functional Programming: you can pass functions to functions
  - Array `map/filter/reduce/forEach`
    - `cTemps=fTemps.map(function(d){return (d-32)*5.0/9.0;});`

• Closures: functions keep track of their environments
  - `function makeAdder(x) {
      return function(y) { return x + y; }; }
  `

• Objects and Properties:
  - `var student = {name: "John Smith", id: "000012345", class: "Senior", hometown: "Fall River, MA, USA"};`
    - Properties can be accessed via dot or bracket notation
    - Objects can also function as associative arrays

• Function chaining: succinct, avoids intermediate variables in code
Manipulating the DOM with JavaScript

- Key global variables:
  - `window`: Global namespace
  - `document`: Current document
  - `document.getElementById(...):` Get an element via its id
- HTML is parsed into an in-memory document (DOM)
- Can access and **modify** information stored in the DOM
- Can add information to the DOM with JavaScript
  - `document.body.appendChild(document.createTextNode("I added text to your webpage."))`
Example: JavaScript and the DOM

- [http://codepen.io/dakoop/pen/MKqbjm](http://codepen.io/dakoop/pen/MKqbjm)

- Start with no real content, just divs:

```html
<div id="firstSection"></div>
<div id="secondSection"></div>
<div id="finalSection"></div>
```

- Programmatically add content:
  - `document.createElement`
  - `document.getElementById`
  - `document.createTextNode`
  - `Element.appendChild`
Creating SVG figures via JavaScript

• SVG elements can be accessed and modified just like HTML elements

• Create a new SVG programmatically and add it into a page:
  
  ```javascript
  var divElt = document.getElementById("chart");
  var svg = document.createElementNS("http://www.w3.org/2000/svg", "svg");
  divElt.appendChild(svg);
  
  svg.setAttribute("height", 400);
  svg.setAttribute("width", 600);
  ```

• You can assign attributes:
  
  ```javascript
  svg.setAttribute("height", 400);
  svg.setAttribute("width", 600);
  svgCircle.setAttribute("r", 50);
  ```
Example: UK Driving Fatalities

• Start: http://codepen.io/dakoop/pen/wMEoxW

• makeElt function creates an SVG element and can additionally add it to the DOM

• Possible Solution: http://codepen.io/dakoop/pen/RrYoYw

• Improvements?
Interactive Data Visualization by S. Murray

- Free version available on the Web
- http://chimera.labs.oreilly.com/books/1230000000345
- Representing and drawing with data
- Chapter 3 has a nice overview of Web technologies with examples
- Great resource for D3 as well
Assignment 1

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

“Computer-based visualization systems provide visual representations of **datasets** designed to help people carry out tasks more effectively.”

— T. Munzner
Data

• What is this data?

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</table>

• **Semantics**: real-world meaning of the data
• **Type**: structural or mathematical interpretation
• Both often require **metadata**
  - Sometimes we can infer some of this information
  - Line between data and metadata isn’t always clear
# Data

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Data Types

• Items
  - An item is an individual discrete entity
  - e.g. row in a table, node in a network

• Attributes
  - An attribute is some specific property that can be measured, observed, or logged
  - a.k.a. variable, (data) dimension
# Items & Attributes

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<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>S</th>
<th>T</th>
<th>U</th>
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</thead>
<tbody>
<tr>
<td>Order ID</td>
<td>Order Date</td>
<td>Order Priority</td>
<td>Product Container</td>
<td>Product Base Margin</td>
<td>Ship Date</td>
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</table>
Data Types

- **Nodes**
  - Synonym for item but in the context of networks (graphs)

- **Links**
  - A **link** is a relation between two items
  - e.g. social network friends, computer network links
Items & Links

[Bostock, 2011]
Data Types

• Positions:
  - A **position** is a location in space (usually 2D or 3D)
  - May be subject to projections
  - e.g. cities on a map, a sampled region in an CT scan

• Grids:
  - A **grid** specifies how data is sampled both geometrically and topologically
  - e.g. how CT scan data is stored
Positions and Grids
Dataset Types

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

**Multidimensional Table**

- **Trees**

---

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

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Table Visualizations

[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
Networks

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 \( s = 0 \), 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\textsuperscript{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]
Networks

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Our prototype was implemented in Borland Delphi 7.

[Holten & van Wijk, 2009]
Fields

Scalar Fields

Vector Fields

Tensor Fields

Each point in space has an associated...
Fields

Scalar Fields
(Order-0 Tensor Fields)

Vector Fields
(Order-1 Tensor Fields)

Tensor Fields
(Order-2+)

Each point in space has an associated...

Scalar

$ s_0 $

Vector

$ \begin{bmatrix} v_0 \\ v_1 \\ v_2 \end{bmatrix} $

Tensor

$ \begin{bmatrix} \sigma_{00} & \sigma_{01} & \sigma_{02} \\ \sigma_{10} & \sigma_{11} & \sigma_{12} \\ \sigma_{20} & \sigma_{21} & \sigma_{22} \end{bmatrix} $
Fields

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

![Uniform Grid](image1)
![Rectilinear Grid](image2)
![Structured Grid](image3)
![Unstructured Grid](image4)

- **uniform**
- **rectilinear**
- **structured**
- **unstructured**

[Weiskopf, Machiraju, Möller]

• **Interpolation**: “how to show values between the sampled points in ways that do not mislead”
Spatial Data Example: MRI

[slide via Levine, 2014]
Scivis and Infovis

- Two subfields of visualization
- **Scivis** deals with data where the spatial position is given with data
  - Usually continuous data
  - Often displaying physical phenomena
  - Techniques like isosurfacing, volume rendering, vector field vis
- In **Infovis**, the data has no set spatial representation, designer chooses how to visually represent data
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]
### Categorial, Ordinal, and Quantitative

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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]
3. Mathematical description and types of spirals

A spiral is easy to describe and understand in polar coordinates, i.e. in the form \( r = f(\phi) \). The distinctive feature of a spiral is that \( f \) is a monotone function. In this work we assume a spiral is described by

\[
rf(\phi) = \frac{R}{\phi + \omega},
\]

\[
ra(\phi) = \frac{a}{\phi},
\]

\[
a(\phi) = \frac{k}{r(\phi)} = e^{-k(\phi)},
\]

\[
u(\phi) = \max(\phi, -\phi) \frac{1}{\phi} - \frac{1}{\phi} + 1.
\]

3.2. Mapping data to the spiral

In general, markers, bars, and line elements can be used to visualize time-series data similar to standard point, bar, and line graphs on Spiral Graphs. For instance, quantitative, discrete data can be presented as bars on the spiral or by marks with a corresponding distance to the spiral. However, since the \( x \) and \( y \) coordinate are needed to achieve the general form of the spiral their use is limited for the display of data values. One might consider to map data values to small absolute changes in the radius, i.e. \( \Delta r \).

Yet, we have found this way of visualizing to be ineffective. We conclude that the general shape of the spiral should be untouched and other attributes should be used, such as

- colour,
- texture, including line styles and patterns.

Figure 1: Two visualizations of sunshine intensity using about the same screen real estate and the same color coding scheme. In the spiral visualization it is much easier to compare days, to spot cloudy time periods, or to see events like sunrise and sunset.

[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

[Semantics diagram showing the difference between Flat and Multidimensional Tables and Fields]

[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]
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]
    - Ordered: [warm, hot, cold]

[viA. Lex, 2015]
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]
    • Ordered: [warm, hot, cold]
    • Categorical: [not burned, burned, not burned]

[via A. Lex, 2015]
Assignment 1

- [http://www.cis.umassd.edu/~dkoop/dsc530/assignment1.html](http://www.cis.umassd.edu/~dkoop/dsc530/assignment1.html)
- HTML, CSS, SVG, and JavaScript
- Part 3 will likely take significantly more time than the other parts!
- Start now
- Turn in `a1.html` (and possibly `a1.css`, `a1.js`) via myCourses
- Due Friday, February 12 @ 11:59pm
- Late Policy

Tasks

What? Why? How?

Actions

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

Why?

- **All Data**
  - Trends
  - Outliers
  - Features
- **Attributes**
  - One
    - Distribution
  - Many
    - Dependency
    - Correlation
    - Similarity
- **Network Data**
  - Topology
    - Paths
- **Spatial Data**
  - Shape

Search

<table>
<thead>
<tr>
<th>Location known</th>
<th>Target known</th>
<th>Target unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location known</td>
<td>Lookup</td>
<td>Browse</td>
</tr>
<tr>
<td>Location unknown</td>
<td>Locate</td>
<td>Explore</td>
</tr>
</tbody>
</table>

Query

- Identify
- Compare
- Summarize

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

• Consume
  – Exploration
  – Explanation
  – Enjoyment

• Produce
  – Annotation
  – Record
  – Derivation
    • Leads to new directions/ideas

[Munzner (ill. Maguire), 2014]
Actions: Search and Query

• Search based on what a user knows
  - Target
  - Location

• Query depends on what data matters
  - One
  - Some (Often Two)
  - All

[Monzner (ill. Maguire), 2014]
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]
How do we do visualization?

<table>
<thead>
<tr>
<th>Encode</th>
<th>Manipulate</th>
<th>Facet</th>
<th>Reduce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrange</td>
<td>Change</td>
<td>Juxtapose</td>
<td>Filter</td>
</tr>
<tr>
<td>Express</td>
<td>Hue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separate</td>
<td>Saturation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order</td>
<td>Luminance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Align</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Map from **categorical** and **ordered** attributes

- **Color**
  - Hue
  - Saturation
  - Luminance
- **Size, Angle, Curvature, ...**
- **Shape**
  - +
  - ●
  - ■
- **Motion**
  - Direction, Rate, Frequency, ...
Analysis Example

SpaceTree

TreeJuxtaposer

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

SpaceTree

TreeJuxtaposer


What?

Why?

How?

Tree

Actions

- Present
- Locate
- Identify

Targets

- Path between two nodes

SpaceTree

- Encode
- Navigate
- Select
- Filter
- Aggregate

TreeJuxtaposer

- Encode
- Navigate
- Select
- Arrange

[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


---

**Task 1**

- **In Tree**
- Out Quantitative attribute on nodes

**Task 2**

- **In Tree** + **In Quantitative attribute on nodes**
- **Out Filtered Tree** (Removed unimportant parts)

**What?**
- **In Tree**
- **Out Quantitative attribute on nodes**

**Why?**
- Derive

**How?**
- Summarize
- Reduce
- Filter

[Munzner (ill. Maguire), 2014]