Announcements

Final Project: multiple due dates

• Project proposal due Wed Nov 17, 11pm
• Progress report 1 due Mon Nov 22, 11pm
• Progress report 2 due Wed Dec 1, 11pm
• Final report due Wed Dec 8, 11pm

Final Exam - Mon Dec 13  8-11am
Why Do We Create Visualizations?

What is Visualization?

Definition [www.oed.com]

1. The action or fact of visualizing; the power or process of forming a mental picture or vision of something not actually present to the sight; a picture thus formed.

2. The action or process of rendering visible.
Why Do We Create Visualizations?

Three Primary Functions

Record information
- Photographs, blueprints, …

Support reasoning about information (analyze)
- Process and calculate
- Reason about data
- Feedback and interaction

Convey information to others (present)
- Share and persuade
- Collaborate and revise
- Emphasize important aspects of data
Record Information

Drawing: Phases of the Moon

Galileo’s drawings of the phases of the moon from 1616
http://galileo.rice.edu/sci/observations/moon.html

Answer Question

Gallop, Bay Horse "Daisy" [Muybridge 1884–86]
Support Reasoning

Data in Context: Cholera Outbreak

In 1864 John Snow plotted the position of each cholera case on a map. [from Tufte 83]
**Data in Context: Cholera Outbreak**

Used map to hypothesize that pump on Broad St. was the cause. [from Tufte 83]

**Make a Decision: Challenger**

2 of 13 pages of material faxed to NASA by Morton Thiokol [from Tufte 1997]

**Make a Decision: Challenger**

Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]
Make a Decision: Challenger

Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]

Convey Information to Others

Present Argument: Exports & Imports

[Playfair 1786]
Tell Story: Most Powerful Brain?

The Dragons of Eden [Carl Sagan]

Tell Story: Most Powerful Brain?

The Elements of Graphing Data [Cleveland]
Attention

“What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it.”

~Herb Simon
as quoted by Hal Varian
Scientific American
September 1995

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Data

Data Types

Physical type (model)
- Characterized by storage format
- Characterized by machine operations

Example:
- bool, short, int32, float, double, string, …

Abstract type
- Provide (conceptual) descriptions of the data
- May be characterized by methods/attributes
- May be organized into a hierarchy

Example:
- nominal, ordinal, quantitative, …,
  plants, animals, metazoans, …
Nominal, Ordinal & Quantitative

N - Nominal (labels)
- Fruits: Apples, oranges, …

O - Ordered
- Quality of meat: Grade A, AA, AAA

Q - Quantitative
- Real numbers
- Ordered, with measurable distances, or amounts
- Dates: Jan, 19, 2006; Location: (LAT 33.98, LONG -118.45)
- Physical measurement: Length, Mass, Temp, …

S. S. Stevens, On the theory of scales of measurements. 1946

From Data Model to Data Type

Data model
- 32.5, 54.0, -17.3, …
- floats

Conceptual model
- Temperature

Data type
- Burned vs. Not burned (N)
- Hot, warm, cold (O)
- Continuous range of values (Q)

Image

Jacques Bertin
Visual Variables

• Position
• Size
• Value
• Texture
• Color
• Orientation
• Shape

Note: Bertin does not consider 3D or time
Note: Card and Mackinlay extend the number of vars.

Information in Position

1. A, B, C are distinguishable
2. B is between A and C.
3. BC is twice as long as AB.
4. ∴ Encode quantitative variables (Q)

Information in Color and Value

Value is perceived as ordered
∴ Encode ordinal variables (Q)

∴ Encode continuous variables (Q) [not as well]

Hue is normally perceived as unordered
∴ Encode nominal variables (N) using color
Bertins’ “Levels of Organization”

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>O</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Position</strong></td>
<td>N</td>
<td>O</td>
<td>Q</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>N</td>
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<tr>
<td><strong>Value</strong></td>
<td>N</td>
<td>O</td>
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<td><strong>Texture</strong></td>
<td>N</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Orientation</strong></td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Shape</strong></td>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Q < O < N

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**Estimating Magnitude**

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**Detecting Brightness**

Which is brighter?
Detecting Brightness

Which is brighter?

(128, 128, 128)  (144, 144, 144)

Just Noticeable Differences

JND (Weber's Law)

\[ \Delta S = k \frac{\Delta I}{I} \]

Ratios more important than magnitude

Most continuous variations perceived in discrete steps

Steven's Power Law

\[ S = I^p \]

\[ p < 1 : \text{underestimate} \]
\[ p > 1 : \text{overestimate} \]

(graph from Wilkinson 99, based on Stevens 61)
Exponents of Power Law

<table>
<thead>
<tr>
<th>Sensation</th>
<th>Exponent</th>
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</thead>
<tbody>
<tr>
<td>Loudness</td>
<td>0.6</td>
</tr>
<tr>
<td>Brightness</td>
<td>0.33</td>
</tr>
<tr>
<td>Smell</td>
<td>0.55 (Coffee) - 0.6 (Heptane)</td>
</tr>
<tr>
<td>Taste</td>
<td>0.6 (Saccharine) - 1.3 (Salt)</td>
</tr>
<tr>
<td>Temperature</td>
<td>1.0 (Cold) – 1.6 (Warm)</td>
</tr>
<tr>
<td>Vibration</td>
<td>0.6 (250 Hz) – 0.95 (60 Hz)</td>
</tr>
<tr>
<td>Duration</td>
<td>1.1</td>
</tr>
<tr>
<td>Pressure</td>
<td>1.1</td>
</tr>
<tr>
<td>Heaviness</td>
<td>1.45</td>
</tr>
<tr>
<td>Electric Shock</td>
<td>3.5</td>
</tr>
</tbody>
</table>

[Psychophysics of Sensory Function, Stevens 61]

Compare area of circles

Proportional Symbol Map

Newspaper Circulation

[Cartography: Thematic Map Design, Figure 8.8, p. 172, Dent, 96]
Apparent Magnitude Scaling

\[ S = 0.98A^{0.87} \]  
(from Flannery 71)

[Cartography: Thematic Map Design, Figure 8.6, p. 170, Dent, 96]

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Figure 4. Graphs from position–length experiment.

[Cleveland and McGill 84]

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Figure 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]
Relative Magnitude Estimation

Most accurate
- Position (common) scale
- Position (non-aligned) scale
- Length
- Slope
- Angle
- Area

Least accurate
- Color hue-saturation-density

Deconstructions
Stock Chart

- x-axis: time (Q)
- y-axis: price (Q)

Exports and Imports [Playfair 1786]
Exports and Imports [Playfair 1786]

x-axis: year (Q)
y-axis: currency (Q)
color: imports/exports (N)
color: positive/negative (O)

Summary

We create visualizations to
- Record information
- Support reasoning about the information
- Convey information to others

Choose the right mark for your data
- Position good for N, O, Q, but Hue best only for N

With careful design it is possible to display many dimensions at once