Visual Information Design

CS160: User Interfaces
Maneesh Agrawala

ModelCraft: Capturing Freehand Annotations and Edits on Physical 3D Models [Song 06]
Due Soon

Interactive Prototype (due Apr 6)
– Redesign interface based on lofi feedback
– Create first working implementation
  • Can include Wizard of Oz parts where justified
  • Can include pre-built (canned) functionality but only if heavily justified

In class Presentations (Apr 13, 15, 20)
– 10 min slide presentation (be careful about timing)
– Focus on showing prototype
– Feedback from class (you will need to provide feedback on each presentation on the wiki)
Upcoming Assignments

Team Assessment (Apr 20)
– Short individual assignment
– Tell us how your team functions

Pilot Usability Study (Apr 20)
– Refine your implementation
– Evaluate your implementation

Upcoming Lectures

Apr 6: Stephen Few
– Information display

Apr 8: Aaron Marcus
– UI design consultant
– Elected to CHI Academy this year
Talk You Should Attend

Bjoern Hartmann

- HCI faculty candidate
- Works on design, implementation and evaluation of authoring tools for UIs

Mon Apr 13: 1-2:30pm Wozniak Lounge

Topics

- Why do we create visualizations?
- Data and image
- Estimating magnitude
- Deconstructions
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.
Examples

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](http://galileo.rice.edu/sci/observations/moon.html)

---

**Answer Question**

Gallop, Bay Horse “Daisy” [Muybridge 1884-86]
Other Recording Instruments

Marey’s sphygmograph [from Braun 83]

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

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

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]

Convey Information to Others
Present Argument: Exports & Imports

Tell Story: Most Powerful Brain?
Tell Story: Most Powerful Brain?

The Dragons of Eden [Carl Sagan]

Tell Story: Most Powerful Brain?

The Elements of Graping 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

[slide from PARC UIR group]
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)

[based on slide from Munzner]

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 (O)
  ![Ordinal Colors](image)
  ∴ Encode continuous variables (Q) [not as well]

- Hue is normally perceived as unordered
  ∴ Encode nominal variables (N) using color
  ![Nominal Colors](image)

**Bertins’ “Levels of Organization”**

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

N Nominal
O Ordinal
Q Quantitative

Note: Q < O < N
Estimating Magnitude

Detecting Brightness

Which is brighter?
Detecting Brightness

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

Which is brighter?

Just Noticeable Difference

- JND (Weber's Law)
  \[ \Delta S = k \frac{\Delta I}{I} \]
- Ratios more important than magnitude
- Most continuous variations in stimuli are perceived in discrete steps
Steven’s Power law

\[ S = I^p \]

- \( p < 1 \): underestimate
- \( p > 1 \): overestimate

[graph from Wilkinson 99, based on Stevens 61]

[alternate graph: http://www.undergrad.ahs.uwaterloo.ca/~wchedder/stevenspowerlaw.htm]

Exponents of Power Law

<table>
<thead>
<tr>
<th>Sensation</th>
<th>Exponent</th>
</tr>
</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]

Figure 4. Graphs from position–length experiment.  
[Cleveland and McGill 84]
Figure 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]

Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

[Cleveland and McGill 84]
Relative Magnitude Estimation

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

Least accurate
- Color hue-saturation-density

Deconstructions
Exports and Imports [Playfair 1786]

• x-axis: year (Q)
• y-axis: currency (Q)
• color: imports/exports (N)
• color: positive/negative (O)
FilmFinder [Ahlberg 1994]

- x-axis: year of release (quantitative)
- y-axis: popularity (quantitative)
- color: genre (nominal)
- dynamic query filters
  - title (nominal)
  - actor (nominal)
  - actress (nominal)
  - director (nominal)
  - length (quantitative)
  - rating (ordinal)
**Interactivity**

- Turn visual analysis into a real-time iterative process
- Explore various hypotheses or interests
- Filter to hone in on data of interest
- Get details on demand

**Multi-Dimensional Data**

FilmFinder visualizes 3 dimensions
- 2 spatial dimensions
- 1 color dimension

Can we see more dimensions simultaneously?
Map of the Market [Wattenberg 1998]

- rectangle size: market cap (Q)
- rectangle position: market sector (N), market cap (Q)
- color hue: loss vs. gain (N, O)
- color value: magnitude of loss or gain (Q)

http://www.smartmoney.com/marketmap/
Napoleon’s March [Minard 1869]

Single Axis Composition

[Based on slide from Mackinlay]
Mark Composition

y-axis: temperature (Q)

+ x-axis: time (Q)

= temp over time (Q x Q)

[based on slide from Mackinlay]

Mark composition

y-axis: longitude (Q)

+ x-axis: latitude (Q)

+ width: army size (Q)

= army position (Q x Q) and army size (Q)

[based on slide from Mackinlay]
Depicts at least 5 quantitative variables
Any others?
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