Visual Information Design

CS160: User Interfaces
Maneesh Agrawala

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

VIDEO
Upcoming Schedule

Pilot User Study (due today before class)

Final Presentation and Report (due Nov 27)
- Revise interface based on pilot study
- Last chance to finish implementation
- Presentations held in my office Nov 27 and 29
  - Sign up next week
  - We are planning a project fair for Dec 4

Review: 3 Principles of Design

- Form follows function
- Economy of form
- Integrity of materials
Review: Color

• Use a small palette (6 color Java look and feel)

• Don’t use all fully saturated colors

• Ensure good color contrast for text

Review: Gestalt Principles

• figure/ground
• proximity
• similarity
• symmetry
• connectedness
• continuity
• closure
• common fate
• transparency
Topics

- Grid-based design
- Why do we create visualizations?
- Data and image
- Estimating magnitude
- Deconstructions

Grid-Based Design
Grid Systems

Web Page Layout

Grids can shape layout without over constraining it

- Grid is not always obvious from page layout
- Produces good repetition of size and shape
Techniques

Reinforce structure through repetition
– Repeat design elements across the layout
– Stylesheets can help

Techniques

Canonical Grid
– Six-column grid with column separators and label templates
– Covers most common grid-based layouts
– Can be implemented with HTML tables
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
Answer Question

![Gallop, Bay Horse “Daisy” [Muybridge 1884-86]](image)

Other Recording Instruments

![Marey’s sphygmograph [from Braun 83]](image)
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]
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 Grapling 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

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. \[ \therefore \] Encode quantitative variables (Q)

**Information in Color and Value**

- Value is perceived as ordered
  \[ \therefore \] Encode ordinal variables (O)
  \[ \therefore \] Encode continuous variables (Q) [not as well]

- Hue is normally perceived as unordered
  \[ \therefore \] Encode nominal variables (N) using color
### 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></td>
</tr>
<tr>
<td>Color</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orientation</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N Nominal
O Ordinal
Q Quantitative

Note: Q < O < N

#### Estimating Magnitude
Detecting Brightness

Which is brighter?

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

Detecting Brightness

Which is brighter?

(128, 128, 128) (144, 144, 144)
**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 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]
### Relative Magnitude Estimation

<table>
<thead>
<tr>
<th>Most accurate</th>
<th>Least accurate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position (common) scale</td>
<td>Color hue-saturation-density</td>
</tr>
<tr>
<td>Position (non-aligned) scale</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td></td>
</tr>
<tr>
<td>Angle</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td></td>
</tr>
</tbody>
</table>

### Deconstructions
Stock Chart

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