Information Visualization

Visualization Research

Dr. David Koop
Visualization Tools & Tradeoffs

• Fast, turnkey approaches
• Control over all visual elements

• You can use **multiple** tools! Think about purpose
  - Exploration
  - Explanation (custom design, handle interaction)
Scatterplot Matrices and Parallel Coordinates

[Munzner (ill. Maguire), 2014]
Scatterplot Matrices and Parallel Coordinates

Scatterplot Matrix

Math

Physics

Dance

Drama

Parallel Coordinates

Math

Physics

Dance

Drama

[100]

[90]

[80]

[70]

[60]

[50]

[40]

[30]

[20]

[10]

[0]

[Munzner (ill. Maguire), 2014]
Map with Two Variables

This map removes mostly uninhabited areas, revealing Mr. Bush’s suburban and rural support in the East and South.

Treemaps

- Containment marks instead of connection marks
- Encodes some attribute of the items as the size of the rectangles
- Not as easy to see the intermediate rectangles
- Scalability: millions of leaf nodes and links possible
- Need a layout algorithm!
  - Slice-and-Dice vs. Squarify
  - Viewing Hierarchy: Cushion Treemap
Avoid Rainbow Colormaps!

[Borland & Taylor, 2007]
Colormaps

- Binary
  - y
  - n
- Diverging
  - y
  - n
  - -1 0 +1

Categorical
- Binary
  - y
  - n
  - T F A

Sequential
- 3 2 1
- 25 50 75

D. Koop, CSCI 628, Fall 2021

[Munzner (ill. Maguire), 2014]
Interaction Overview

- **Change over Time**
  - [Diagram showing data change over time]

- **Navigate**
  - **Item Reduction**
    - **Zoom**
      - Geometric or Semantic
    - **Pan/Translate**
    - **Constrained**
  - **Attribute Reduction**
    - **Slice**
    - **Cut**
    - **Project**

[Munzner (ill. Maguire), 2014]
Animated Transitions

- Stacked
- Grouped

[M. Bostock]
Multiple Views

- Juxtapose and Coordinate Multiple Side-by-Side Views
  - Share Encoding: Same/Different
  - Linked Highlighting
  - Share Data: All/Subset/None
  - Share Navigation

- Partition into Side-by-Side Views

- Superimpose Layers

<table>
<thead>
<tr>
<th>Data</th>
<th>All</th>
<th>Subset</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encoding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same</td>
<td>Redundant</td>
<td>Overview/Detail</td>
<td>Small Multiples</td>
</tr>
<tr>
<td>Different</td>
<td>Multiform</td>
<td>Multiform, Overview/Detail</td>
<td>No Linkage</td>
</tr>
</tbody>
</table>

[Munzner (ill. Maguire), 2014]
Composite Visualization Techniques

(a) Juxtaposed views.  
(b) Integrated views.  
(c) Superimposed views.  
(d) Overloaded views.  
(e) Nested views.

[W. Javed and N. Elmqvist, 2012]
Carte figurative des pertes successives de l’Armée Française dans la Campagne de Russie 1812-1813. (Dessiné par M. Minard, Ingénieur Général des Ponts et Chaussées en Retraite. Paris, le 20 Novembre 1869.)

Les nombres d’hommes représentés sont ceux de la ligne des zones ombreuses à raison d’une millimètre pour 1000 hommes, le sommet le plus élevé en termes des zones. Le tracé des zones qui entourent les noms des villes, à saber Moscou, Saint-Pétersbourg, Léningrad, etc., montre l’avancement des troupes de l’armée depuis le 23 Octobre. Enfin, une ligne de points dans la dimension de l’Armée, qui représente la marche du Corps Déserteur de J. J. Mortier, qui se composait de soldats attachés aux forces de Minard, à Malorev et au régiment d’Italie. — Début du mois de Mars avec l’Armée.

TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

[Napoleon’s March to Moscow, C. J. Minard, 1869]
Nesting

[NodeTrix, N. Henry et al., 2007]
Brushing

M. Bostock
Filtering and Aggregation

Reducing Items and Attributes

- Filter
  - Items
  - Attributes

- Aggregate
  - Items
  - Attributes

Reduce

- Filter
- Aggregate
- Embed

[Munzner (ill. Maguire), 2014]
Filtering using Widgets

![Map of New York City with restaurant locations highlighted.](image)

Restaurant locations are derived from the New York City Department of Health and Mental Hygiene database. Due to the limitations of the Health Department's database, some restaurants could not be placed. By JEREMY WHITE.

The New York City Department of Health and Mental Hygiene performs unannounced sanitary inspections of every restaurant at least once per year. Violation points result in a letter grade, which can be explored in the map below, along with violation descriptions. The information on this map will be updated every two weeks. For menus and reviews by New York Times critics, visit our restaurants guide.

Related Article »

**Find a Restaurant**

- **FIND A RESTAURANT**
  - Name of restaurant

**Find a Location**

**Filter**

- All grades
- All violations
- All cuisines

**Gracie's Cafe**
Grade: Grade pending
Violation points: 27
Click for details

**J. White, New York Times**
Aggregation: Histograms

- Very similar to bar charts
- Often shown without space between (continuity)
- Choice of number of bins
  - Important!
  - Viewers may infer different trends based on the layout

[Munzner (ill. Maguire), 2014]
Spatial Aggregation

In cartography, changing the boundaries of the regions used to analyze data can yield dramatically different results.
Aggregation: Boxplot
Aggregation: Boxplot

[C. Choonpradub and D. McNeil, 2005]
Dimensionality Reduction: PCA

For more explanations, visit the Explained Visually project homepage.

Focus+Context

- Embed
  - Elide Data
  - Superimpose Layer
  - Distort Geometry

Reduce
- Filter
- Aggregate
- Embed

[Munzner (ill. Maguire), 2014]
It can be difficult to observe micro and macro features simultaneously with complex graphs. If you zoom in for detail, the graph is too big to view in its entirety. If you zoom out to see the overall structure, small details are lost.

Focus + context techniques allow interactive exploration of an area.
Cartesian Distortion
Cartesian Distortion
The purpose of visualization is about **insight**, not pictures

– B. Shneiderman
Visualization Research
Visualization Research

- General Goals: "New visual displays, control panels, features, and workflows that improve the capabilities of users."
- Perceptual and Cognitive Theories: help accomplish goals, guide design, aid in development of new tools.
- Evaluation Methods:
  - Quantitative and Qualitative
  - Validate hypotheses, refine theories.

[B. Shneiderman, 2019]
Areas of Visualization Research

- Tools that make it easier to create visualizations
- New encodings
- Knowledge from controlled studies of visualization effectiveness
- Visualization-based communication
- Studies of visualization use in the world
- Formal theories of visualization
- Applications (Schneiderman)

[J. Hullman, 2018]
Tools that make it easier to create visualizations

- Tableau, Spotfire, D3 were all proposed and developed by visualization researchers
- Not just create visualizations, but **effective** visualizations
- Current Trends:
  - Web-based frameworks
  - Declarative, more concise specification (Vega-Lite)

[J. Hullman, 2018]
New Encodings

- Determine what cannot currently be done
- Think about how new designs can show new, interesting patterns

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Fig 9. Word tree of the King James Bible showing all occurrences of "love the."
Knowledge from studies of visualization effectiveness

Figure 4. Graphs from position–length experiment.

Figure 3. Graphs from position–angle experiment.

[Cleveland & McGill, 1984]
Knowledge from studies of visualization effectiveness

[Padilla et al., 2017]
Knowledge from studies of visualization effectiveness

- Controlled experiments often focus on visual building blocks
- Need not only very controlled, focused experiments. Can be impacted by
  - Different encodings
  - Framings
  - User predispositions or prior beliefs
- Holistic studies of new visualization techniques
Supporting Visual Analytics

- Exploratory Data Analysis
- Sensemaking & Meaning-making
- Interpretability of Machine Learning Models
Visualization-based Communication

[J. Hullman, 2018]
Design Studies

- Studies of visualization in the world
- Often involve collaboration with domain specialists
- Specific problems in that domain that can provide lessons for other domains as well
Formal Theories of Visualization

• Grammar of Graphics
• Discrete/Continuous Taxonomy
• Algebraic Visualization
What should Visualization Research be about?

• "[V]isualization is a method for contextualizing data, enabling people to apply their prior experiences and perceptual and cognitive abilities to draw conclusions about phenomena in the real world" — J. Hullman

• Perception and cognition

• Not only that Vis A is better than Vis B, but why

[J. Hullman, 2018]
Visualization Research Boundaries?

- Interactive illustration
- Satellite imagery
- Sketching and analogical reasoning
- Understanding aesthetics independent of analytical utility
- Tables
- Uncertainty Vis: Worse than Nothing?
Grand Challenges

• Amplifying human cognition in the exploration of data.
  - Data science
  - Explainable artificial intelligence
  - Information visualization is vital to successful outcomes for both topics.
• Improve storytelling capacity for the general public
• Engage users to explore on their own
• Support researchers in understanding causality
• Shift from rationalism, which assumes that algorithms are the answer, to empiricism, which assumes that continuous exploration, persistent questioning, and vigorous dialog will promote a deeper understanding of our world.

[B. Shneiderman, 2019]
Shneiderman's Advice to a Ph.D. Student

• "Start by working on a real problem—one that you have or that you get from someone else. Working on real problems leads to better theories and better tools."

[B. Shneiderman, 2019]