Data Visualization (DSC 530/CIS 602-01)

Multiple Views

Dr. David Koop
Interaction Overview

- **Change over Time**

- **Select**

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

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

[http://bl.ocks.org/mbostock/3943967]
Animated Transitions

[http://bl.ocks.org/mbostock/3943967]
Selection

• Selection is often used to initiate other changes
• User needs to select something to drive the next change
• What can be a selection target?
  - Items, links, attributes, (views)
• How?
  - mouse click, mouse hover, touch
  - keyboard modifiers, right/left mouse click, force
• Selection modes:
  - Single, multiple
  - Contiguous? (all together in one region)
Highlighting

- Selection is the user action
- Feedback is important!
- How? Change selected item's visual encoding
  - Change color: want to achieve visual popout
  - Add outline mark: allows original color to be preserved
  - Change size (line width)
  - Add motion: marching ants
Highlighting

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  - Cut
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[Munzner (ill. Maguire), 2014]
Geometric vs. Semantic Zooming

- Geometric zoom: like a camera
- Semantic zoom: visual appearance of objects can change at different scales
Project Designs

• Use interaction
• Be creative!
• Next step: Designs
  - 3 Designs (Either iterations or three separate ideas)
  - At least one must be prototyped (if others are not prototyped, turn in detailed sketches)
  - Due Thursday, April 5
• Inspiration: mbtaviz.github.io
Test 2

- Next Wednesday, April 11
- Similar Format
- Covers material since the beginning of class but with an emphasis on the material covered since Test 1
Multiple Views

[Image of a software interface with multiple windows showing data visualizations, such as maps and scatter plots, with text references suggesting the use of data visualization tools for exploratory data analysis.]

[Improvise, Weaver, 2004]
Multiple Views

• Why have just one visualization?
• Sometimes data is best examined in more than one view
  - Clutter/visual overload
  - Different attributes (cannot show all attributes in one view)
  - Different scales (task requires overview or detail)
  - Different encodings (no single encoding is optimal for all tasks)
• Eyes Beat Memory (Ch. 6)
  - Aiding working memory:
    side-by-side/layers > animated > jump cuts
  - Showing all visual elements at once → don't need to remember
Multiple Views

• Big questions:
  - How to partition display or layer views?
  - How to coordinate views (e.g. navigation, selection)?
  - What data is shared?
Design Space of Composite Visualization

- Composite visualization views (CVVs)
  - Includes Coordinated multiple views (CMV)
  - + More!
- Design Patterns:
  - Juxtaposition: side-by-side
  - Superimposition: layers
  - Overloading: vis meshed with another
  - Nesting: vis inside a vis (recursive vis)
  - Integration: "merge" views + links

[W. Javed and N. Elmqvist, 2012]
Juxtaposition

![Image of juxtaposed views in visualization tools](image)

[ComVis, K. Matkovic et al., 2008]
Juxtaposition
Juxtaposition Guidelines

• Benefits:
  - The component visualizations are independent and can be composed without interference
  - Easy to implement

• Drawbacks:
  - Implicit visual linking is not always easy to see, particularly when multiple objects are selected
  - Space is divided between the views, yielding less space for each view

• Applications: Use for heterogeneous datasets consisting of many different types of data, or for where different independent visualizations need to be combined.

[W. Javed and N. Elmqvist, 2012]
Integration

Figure 4: Visual exploration of meteorology data using semantic substrates (NYSS).

Figure 5: Visual exploration of a simulated ion trajectory using semantic substrates.

[Semantic Substrates, Schneiderin and Aris, 2006]
Integration

Figure 5 shows VisLink being used for exploring a dataset of En-... [VisLink, Collins and Carpendale, 2007]
"best statistical graphic ever"

Carte Figurative des pétées successives en hiver de l'Armée Française, dans la campagne de... Russia, 1812-1813

Best statistical graphic ever (later known as a Sankey Diagram)

[Napoleon's March to Moscow, C. J. Minard, 1869]
Integration Guidelines

• Benefits:
  - Easy to perceive one-to-one and one-to-many relations between items in components
  - Visualizations are less independent compared to juxtaposed views, but still separate

• Drawbacks:
  - Extra visual clutter added to the overall view
  - Display space is split between the views
  - Some dependencies exist between views to allow for the visual linking

• Applications: Use for heterogeneous datasets where correlation and comparisons between views is particularly important.

[W. Javed and N. Elmqvist, 2012]
Superimposition

Superimposed views overlay two or more visual spaces on top of each other (Figures 6 and 7). The resulting visualization becomes the visual combination of the component visualizations, often using transparency to enable seeing all views. Superimposed views are generally used to highlight spatial relations in the component visualizations. In other words, the spatial linking present in these views is one-to-one, i.e., all the overlay visualizations share the same underlying visual space. Line graph visualizations with several data series, where more than one graph is superimposed in a single chart (e.g., [19]), is a very commonly used example of this design pattern.

The spatial linking in the superimposed views allows for easy comparison across different datasets because the user does not have to split their attention between different parts of the visual space. Furthermore, the fact that visualizations are stacked means that they can each use the full available space in the view. However, because the composition simply adds the component visualizations together, the visual clutter may become significant, and it is also likely to cause conflicts arising from one visualization occluding another.

5.1 Mapgets

Mapgets [38] is a geographic visualization system that allows users to interactively perform map editing and querying of geographical datasets. The maps generated using Mapgets are built on an underlying presentation stack that superimposes multiple dataset layers on top of each other. The users can dynamically select the dataset to use for each layer and the total number of layers to compose. Different layers in the presentation stack allow users to independently interact with each of the associated visualization and control the layer attributes. The technique also allows the users to reorder layers in the presentation stack to achieve the desirable map result.

Figure 6 shows an example of a European map generated in Mapgets. The presentation stack associated with this map consists of three layers: the bottom layer visualizes rivers, the center layer is used to depict the country borders, and the topmost layer is used to display the country labels.

5.2 GeoSpace

GeoSpace [22] allows users to interactively explore complex visual spaces using superimposed views. It permits progressively overlaying different datasets, based on the user queries, in a single view. Beyond allowing users to explore datasets through dynamic queries, GeoSpace also supports pan and zoom operations for navigation.

Figure 7 shows GeoSpace system being used for exploring crime around the Cambridge, MA area. The figure shows a 2D view of the visualization, where red dots that are spatially coupled to the underlying layer show the reported crime cases in the region.

[Mapgets, A. Voisard, 1995]
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[GeoSpace, I. Lokuge and S. Ishizaki, 1995]
Superimposition Guidelines

• Benefits:
  - Allows direct comparison in the same visual space.

• Drawbacks:
  - May cause occlusion and high visual clutter.
  - The client visualization must share the same spatial mapping as the host visualization.

• Applications: In settings where comparison is common, or where the component visualization views need to be as large as possible (potentially the entire available space).

[W. Javed and N. Elmqvist, 2012]
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Figure 8: SPPC [45] (Overloaded Views). This tool overloads points into the region bounded by two axes in the parallel coordinate plot.

Figure 9: Links on treemaps [14] (Overloaded Views). The tool identifies a tree structure in a graph and visualizes it using a treemap.

[SPCC, X. Yuan et al., 2009]
Overloading

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[Links on Treemaps, J.-D. Fekete et al., 2003]
Overloading Guidelines

• Benefits:
  - The client visualization does not have to share the same coordinate space as the host visualization
  - This also yield more flexibility and control over visual clutter

• Drawbacks:
  - Visual clutter is increased
  - Visual design dependencies between components are significant

• Applications: Situations where one visualization can be folded into another to yield a compact (and complex) result.

[W. Javed and N. Elmqvist, 2012]
Nesting

Even though Fekete et al. structure, and then overload links corresponding to the remaining graph decomposition allows for using a treemap to visualize the tree a set of remaining graph edges that are not included in the tree. This fact that it is possible to decompose a graph into a tree structure and treemap [20] with overloaded graph links. The idea is based on the techniques allows for sharing their advantages.

6.2 Graph Links on Treemaps

terplots, on the other hand, provide an effective way of correlating across multiple dimensions due to their inherent visual clutter. Scat- efficient for visualizing multiple dimensions in a compact 2D vi- pensate for their individual shortcomings. Parallel coordinates are means that this space is open for being overloaded.

8

selected coordinate dimensions in a parallel coordinate plot into scatterplots on a parallel coordinates visualization [18] (Figure 8).

Yuan et al. [45] presented a system that allows overloading of 2D protein-protein interaction dataset in ZAME.

Figure 10: [ZAME, N. Elmqvist et al., 2008]
Nesting

Bederson et al.

Plaisant et al.

Shneiderman et al.

PARC

Eick et al.

CMU- Roth et al.

Berkeley

[NodeTrix, N. Henry et al., 2007]
Nesting Guidelines

• Benefits:
  - Very compact representation
  - Easy correlation

• Drawbacks:
  - Limited space for the client visualizations
  - Clutter is high
  - Visual design dependencies are high

• Applications: Situations that call for augmenting a particular visual representation with additional mapping

[W. Javed and N. Elmqvist, 2012]
Design Space

- Visualizations: the techniques or idioms used
- Spatial relation: relationship between visual structures in display space
- Data relation: visual relationship between items in different views
  - None: No relation
  - Item-item: One-to-one
  - Item-group: One-to-many
  - Item-dimension: Item in one view is a scale in another

[W. Javed and N. Elmqvist, 2012]
Summary

<table>
<thead>
<tr>
<th>Technique</th>
<th>Visualization A</th>
<th>Visualization B</th>
<th>Spatial Relation</th>
<th>Data Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ComVis [24] (Figure 2)</td>
<td>any</td>
<td>any</td>
<td>juxtapose</td>
<td>none</td>
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<tr>
<td>Improvise [39] (Figure 3)</td>
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<td>any</td>
<td>juxtapose</td>
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</tr>
<tr>
<td>Jigsaw [36]</td>
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<td>any</td>
<td>juxtapose</td>
<td>none</td>
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<tr>
<td>Snap-Together [30]</td>
<td>any</td>
<td>any</td>
<td>juxtapose</td>
<td>none</td>
</tr>
<tr>
<td>semantic substrates [34] (Figure 4)</td>
<td>node-link</td>
<td>node-link</td>
<td>juxtapose</td>
<td>item-item</td>
</tr>
<tr>
<td>VisLink [11] (Figure 5)</td>
<td>radial graph</td>
<td>node-link</td>
<td>juxtapose</td>
<td>item-item</td>
</tr>
<tr>
<td>Napoleon’s March on Moscow [37]</td>
<td>time line view</td>
<td>area visualization</td>
<td>juxtapose</td>
<td>item-item</td>
</tr>
<tr>
<td>Mapgets [38] (Figure 6)</td>
<td>map</td>
<td>text</td>
<td>superimpose</td>
<td>item-item</td>
</tr>
<tr>
<td>GeoSpace [22] (Figure 7)</td>
<td>map</td>
<td>bar graph</td>
<td>superimpose</td>
<td>item-item</td>
</tr>
<tr>
<td>3D GIS [8]</td>
<td>map</td>
<td>glyphs</td>
<td>superimpose</td>
<td>item-item</td>
</tr>
<tr>
<td>Scatter Plots in Parallel Coordinates [45] (Figure 8)</td>
<td>parallel coordinate</td>
<td>scatterplot</td>
<td>overload</td>
<td>item-dimension</td>
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<tr>
<td>Graph links on treemaps [14] (Figure 9)</td>
<td>treemap</td>
<td>node-link</td>
<td>overload</td>
<td>item-item</td>
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<td>SparkClouds [21]</td>
<td>tag cloud</td>
<td>line graph</td>
<td>overload</td>
<td>item-item</td>
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<tr>
<td>ZAME [13] (Figure 10)</td>
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<td>glyphs</td>
<td>nested</td>
<td>item-group</td>
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<tr>
<td>NodeTrix [17] (Figure 11)</td>
<td>node-link</td>
<td>matrix</td>
<td>nested</td>
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<tr>
<td>TimeMatrix [44]</td>
<td>matrix</td>
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<td>nested</td>
<td>item-group</td>
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<tr>
<td>GPUVis [25]</td>
<td>Scatterplot</td>
<td>glyphs</td>
<td>nested</td>
<td>item-group</td>
</tr>
</tbody>
</table>

Table 1: Classification of common composite visualization techniques using our design space.

References

C. Ahlberg and B. Shneiderman. Visual information seeking: Tight coupling of dynamic query filters with starfield displays. In Proceed...

W. Javed and N. Elmqvist, 2012
Summary (Scatterplot + Bar Chart)

(a) Juxtaposed views.  (b) Integrated views.  (c) Superimposed views.

(d) Overloaded views.  (e) Nested views.

[W. Javed and N. Elmqvist, 2012]
Multiple Views

• Facet (noun and verb)
  - particular aspect or feature of something
  - to split

• Partition visualization into views/layers
  - Either juxtapose (side-by-side), superimpose (layer), nest, etc.
  - Depends on data and encoding
  - Generally, superimposing does not scale as well
  - Multiple views eats display space (either large screens or small visualizations)
Multiple Views

- Share Encoding: Same/Different
  - Linked Highlighting

- Share Data: All/Subset/None

- Share Navigation

[Munzner (ill. Maguire), 2014]
# Multiple Views

<table>
<thead>
<tr>
<th>Encoding</th>
<th>Data</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>Subset</td>
<td>None</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>

[Maguire, 2014]
Multiform

[Improvise, Weaver, 2004]
Multiform Views

- The same data visualized in different ways
- Does not need to be a totally different encoding (all choices need not be disjoint), e.g. horizontal positions could be the same
- One view becomes cluttered with too many attributes
- Consumes more screen space
- Allows greater separability between channels
Small Multiples

• Same encoding, but different data in each view (e.g. SPLOM)
Interaction with Multiform & Small Multiples

• Key interaction with multiform and small multiples: **brushing**
  - also called linked highlighting

• Want to understand correspondences between representation in the different views
Brushing
Schneiderman's Mantra

• Visual Information-Seeking Mantra [B. Schneiderman, 1996):
  - Overview first
  - Zoom and filter (Chapter 13)
  - Details on demand

• Goal of the overview is to **summarize** all of the data

• Want specific **details** about some aspect(s) of the data, need another view/layer
  - May be permanent: side-by-side
  - May be a popup layer: often opaque or separated

• (see textbook Ch. 6.7)
Overview-Detail View
Overview-Detail (Different Encoding)

EXPENDITURES BY FUNCTION
(BAR & DONUT)

- Academic Support
- Auxiliary Enterprises
- Depreciation and Amortization
- Impairment of Capital Assets
- Institutional Support
- Instruction
- Interest
- Medical Centers
- Operation and Maintenance of Plant
- Other
- Public Service
- Research
- Student Financial Aid
- Student Services

EXPENDITURES BY CAMPUS
FY 2012 reset

- Berkeley
- Davis
- Irvine
- Los Angeles
- Merced
- Riverside
- San Diego
- San Francisco
- Santa Barbara
- Santa Cruz

FIVE-YEAR TREND

S. Quigley

D. Koop, DSC 530, Spring 2018
Overview-Detail (with Zoom-Filter)

- Detail involves some subset of the full dataset
- Involves user selection or filtering of some type

- How question: includes facet
- Examples:
  - Maps: partition into two views with same encoding, overview-detail
  - UC Trends: partition into multiple views, coordinated with linked highlighting, overview+detail of expenditures
Fig. 2: The Cerebral display of the TLR4 graph (V=91, E=124) with associated LPS and LPS+LL-37 time series. The small multiples show an overview of all 8 experimental conditions. The most noticeable differences between the LPS and the LPS+LL-37 condition occur at hour 4. By selecting the hour 4 conditions, the main window shows the computed difference between the two conditions.

Furthermore, the biologists’ assessment of what constitutes a good layout varies depending on the nature of the biomolecules involved. In the undirected portion of the graph, which comprises protein-protein interactions that propagate a signal from membrane to nucleus, they wish to see the network structure so that they can follow the signaling cascade. Thus for this section of the graph, it is important to minimize edge crossings, even if it places interacting nodes somewhat far apart. In contrast, for the directed portion of the graph, representing the genes whose expression was altered in response to the signaling cascade, the biologists want to see the nodes grouped tightly by function, even at the expense of not being able to clearly see the interactions between them. Translating these desires into automated graph layout requires an algorithm that uses metadata associated with the nodes, in addition to the direct graph structure, for node placement. Positioning nodes according to biological meta-data defines a semantic substrate [34].

3.2 Small multiple views for multiple conditions

Cerebral uses small multiples [38] to simultaneously display multiple experimental datasets. Each small multiple contains a complete copy of the interaction graph with the same spatial layout, but with different coloring according to the experimental data it is displaying. Our design target was to handle from two to a few dozen gene expression conditions, and from 50 to 3000 nodes in the interaction graph.

One obvious alternative to multiple small views would be a single changeable or animated view, where the color coding changes over time rather than being distributed over space [33, 32]. Comparing something visible with memories of what was seen before is more difficult than comparing things simultaneously visible side by side [31]. Thus, the limitations of human memory make comparing the few dozen conditions of our design goal through animation quite difficult [40]. Although small multiples would not scale to hundreds of conditions, they handle the current usage of 8-10 easily and will certainly accommodate the projected usage of few dozen conditions.

A second alternative is to embed a glyph, such as a line graph or heat map, near or within the node itself [24, 32, 41]. While embedded glyphs provide good detail when zoomed in for a local view, they become indistinguishable when zoomed out for a global view of graphs larger than a few dozen nodes. The biologists often need to see such a view, as it more readily allows for the identification of interacting genes/proteins whose expression behaves similarly across several conditions. Thus, glyphs would not be appropriate in this domain.

Saraiya et al. [32] evaluated four approaches to integrating graph and time series data, comparing one versus two views and slider-controlled animation versus embedded glyphs. While they used 10 time series data points, in a good match for our problem domain, their graph contained only 50 nodes. They found many tradeoffs between task type, speed, and accuracy. Our design can be considered an attempt to combine the strengths of the four different interfaces they studied into a single interface for a problem where the tasks are complex, accuracy outweighs raw speed, and the graph is large.

3.3 Parallel coordinates and clustering for data-driven exploration

Cerebral’s main views focus on the interaction graph model of the biological system or process of interest. We also provide a data-driven exploration feature [Barsky et al., 2008].
Navigation across multiple views

- Often navigation in one view updates navigation in another
- Example: Maps: overview shifts as you move around in detail view
- Selections in one view may trigger selections in another
Multiple Views

Partition into Side-by-Side Views

Superimpose Layers

[Munzner (ill. Maguire), 2014]
Partitioned Views

• Split dataset into groups and visualize each group
• Extremes: one item per group, one group for all items
• Can be a hierarchy
  - Order: which splits are more "related"?
  - Which attributes are used to split? usually categorical
Glyphs, Views, and Regions

• Glyphs are composed of multiple marks
• Views are a contiguous region of space
• A region is usually associated with a group of data
• Blurry lines of distinction between them
Example: Grouped Bar Chart
Example: Small Multiples Bar Chart

Group 4

Group 3

Group 2

Group 1

Q108 Q208 Q308 Q408 Q109 Q209 Q309 Q409
Matrix Alignment & Recursive Subdivision

- **Matrix Alignment:**
  - regions are placed in a matrix alignment
  - splits go to rows and columns
  - main-effects ordering: use summary statistic to determine order of categorical attribute

- **Recursive subdivision:**
  - Designed for exploration
  - Involves hierarchy
  - User drives the ways data is broken down in recursive manner
I page. In Figure 2 there are 6 panels, 1 column, 6 rows, and 1 page. Later, we will show a Trellis display with more than one page. We refer to the rectangular array as the trellis because it is reminiscent of a garden trelliswork.

Each panel of a trellis display shows a subset of the values of panel variables; these values are formed by conditioning on the values of conditioning variables. In Figure 1 the panel variables are variety and yield, and the conditioning variables are site and year. On each panel, values of yield and variety are displayed for one combination of year.
Example: HiVE System

[Slingsby et al., 2009]