Data Visualization (CSCI 490/680)

Multiple Views & Filtering

Dr. David Koop
Interaction Overview

Change over Time

Navigate

Select

Item Reduction

Attribute Reduction

Geometric or Semantic

Zoom

Slice

Pan/Translate

Cut

Constrained

Project

Munzner (ill. Maguire), 2014
Sorting & Slope Graphs: LineUp

[Gratzl et al., 2013]
Animation: Jump Cut vs. Animated Transitions

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D. Koop, CS 490/680, Fall 2019

Northern Illinois University
Animation: Jump Cut vs. Animated Transitions

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Animated Transitions

- Stacked
- Grouped

[M. Bostock]
Animated Transitions

- Stacked
- Grouped

[M. Bostock]
Heer and Robertson Study

- User Preferences: Staged animation > animation > static transitions

- Animation improves graphical perception
- Staging is better (do axis rescaling before value changes)
- Avoid axis rescaling when possible

[Heer and Robertson, 2007]
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?
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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Interaction Latency

- The Effects of Interactive Latency on Exploratory Visual Analysis, Z. Liu and J. Heer, 2014
- Brush & link, select, pan, zoom
- 500ms added latency causes significant cost
  - decreases user activity and dataset coverage
  - reduces rate of observations, generalizations, and hypotheses
Navigation

- **Item Reduction**
  - **Zoom**
    - Geometric or Semantic
  - **Pan/Translate**
  - **Constrained**

- **Attribute Reduction**
  - **Slice**
  - **Cut**
  - **Project**

[Reference: 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 Design

• Work on turning your visualization ideas into designs
• Turn in:
  - Three Designs Sketches
  - Progress on Implementation
• Options:
  - Try vastly different options
  - Refine an initial idea
• Due Monday, Nov. 11
Assignment 5

- Farming data with multiple views & interaction
- Add Crop Sales Information
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

[Exploring the Design Space of Composite Visualization - D. Koop, CS 490/680, Fall 2019]
Juxtaposition

![Juxtaposition Diagram](image-url)

[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

Semantic Substrates

[Semantic Substrates, Schneiderin and Aris, 2006]
Integration

[VisLink, Collins and Carpendale, 2007]
Integration

[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.

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.

[Mapgets, A. Voisard, 1995]
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Superimposition

[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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Overloading

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

Figure 10: [ZAME, N. Elmqvist et al., 2008]
6.2 Graph Links on Treemaps

The technique is based on converting the space between pairs of scatterplots on a parallel coordinates visualization [18] (Figure 8). Yuan et al. [45] presented a system that allows overloading of 2D components. We will see examples of this below.

In other words, it is no longer possible to merely use visualization system designed to explore large-scale adjacency matrix protein-protein interaction dataset in ZAME.

The tool allows the user to zoom in data space, which amounts to drilling-down and rolling-up in the aggregation hierarchy. The tool also supports coloring edges based on their attributes. The tool also supports recognizing the direction of the link. The tool also supports controlling the visibility of various edges to reduce visual clutter, and through overlaid edges. The overlaid edges are not straight lines, but are curved to highlight source and target locations. The edges are curved more near the source, hence making it easy to visually recognize the direction of the link. The tool also supports containing edge labels. The tool also supports the ability to control edge length, weight, and other visual properties.

This design pattern characterizes compositions where one visualization, called the host, is rendered inside another visualization, called the client. In other words, it is no longer possible to merely use visualization marks of the host with the visual structure of the host visualization. Again the users need not divide their attention between multiple views, and the host visualization is allowed to zoom and pan. However, unlike Superimposed Views, there exists no imposition, the client visualization in this design pattern is overlaid on the host. However, unlike Superimposed Views, there exists no imposition, the client visualization in this design pattern is overlaid on the host. However, unlike Superimposed Views, there exists no imposition, the client visualization in this design pattern is overlaid on the host.

This design pattern characterizes compositions where one visualization, called the client, whereas overloading requires a much more integrated pose the actual visual structures of the components, which typically see details. Furthermore, just like overloading, nested views combine the components. We will see examples of this below.

Nested Views are becoming increasingly prominent for visualizing visual structures themselves must be modified to combine the components. We will see examples of this below. This fact that it is possible to decompose a graph into a tree structure and a set of remaining graph edges that are not included in the tree. This provides a way to visualize the structure of a graph in a hierarchical manner.

Fekete et al. [14] proposed a technique for rendering graphs using a visual representation. However, they make it hard to correlate trends in any dimension of a dataset [10]. Combining both techniques allows for sharing their advantages.

Scatterplots, on the other hand, provide an effective way of correlating trends, but are curved more near the source, hence making it easy to visually recognize the direction of the link. The tool also supports containing edge labels. The tool also supports the ability to control edge length, weight, and other visual properties.

VERLOADING

SPPC is also an example of combining two techniques to compose nested inside the visual marks of the host. The base matrix represents the actual visual structures of the components, which typically see details. Furthermore, just like overloading, nested views combine the components. We will see examples of this below.

DM. Koop, CS 490/680, Fall 2019
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 \textit{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>
</tr>
<tr>
<td>Improvise [39] (Figure 3)</td>
<td>any</td>
<td>any</td>
<td>juxtapose</td>
<td>none</td>
</tr>
<tr>
<td>Jigsaw [36]</td>
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<td>any</td>
<td>juxtapose</td>
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<td>Snap-Together [30]</td>
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<td>none</td>
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<td>node-link</td>
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<td>VisLink [11] (Figure 5)</td>
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<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>
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<td>text</td>
<td>superimpose</td>
<td>item-item</td>
</tr>
<tr>
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<td>bar graph</td>
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<td>map</td>
<td>glyphs</td>
<td>superimpose</td>
<td>item-item</td>
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<td>Scatter Plots in Parallel Coordinates [45] (Figure 8)</td>
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<td>overload</td>
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<td>item-item</td>
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<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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<td>NodeTrix [17] (Figure 11)</td>
<td>node-link</td>
<td>matrix</td>
<td>nested</td>
<td>item-group</td>
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<td>TimeMatrix [44]</td>
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<td>glyphs</td>
<td>nested</td>
<td>item-group</td>
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<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.

Application: Limited space for the client visualizations, clutter.

Drawbacks: Again, situations that call for augmenting a particular visual representation with additional mapping.

Benefits: Very compact representation, easy correlation.

Figure 12(e) shows an example composition of scatterplot and bar graph visualizations based on this design pattern. In the figure, the scatterplot visualization is acting as a host and bar graph visualization. This is achieved by nesting clients inside the visual marks in the host.

There are several direct benefits to structuring the design space of techniques into patterns not only helps in understanding these techniques but also in evaluating their strengths and weaknesses. It is also not always straightforward to separate representations that may significantly advance the state of the art.

Conclusion

We have proposed a novel framework for specifying, designing, and evaluating compositions of multiple visualizations in the same visual space that we call composite visualization views. The benefit is inherent in the visual structures—which is the case for overloaded and nested components—visualization, particularly when the compositions on evidence from the literature of how existing visualization tools present in various ways, but also to suggest new combinations of visual representations that may significantly advance the state of the art.

There is probably not a clear winner among different design patterns while designing an information visualization tool. The correct choice of design pattern to use for a particular implementation depends on different conditions, such as the available view space, user knowledge, and the complexity of the underlying dataset. Ideally, designers should be able to combine any existing visualizations to generate a composite visualization view.

We have classified the common composite visualization techniques using our design space, as shown in Table 1. The classification of visualizations is based on the spatial layout of component visualizations. However, it is possible to envision other ways to combine two or more visualizations, for example using interaction or animation. However, the design patterns presented in this paper are all based on the spatial layout of component visualizations. This is achieved by nesting clients inside the visual marks in the host.

References

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

D. Koop, CS 490/680, Fall 2019

Northern Illinois University
One such example is the use of interactive hyperlinking [6, 43] (or more visualizations, for example using interaction or animation. However, it is possible to envision other ways to combine two or more visualizations, for example using interaction or animation.

8.2 Delimitations

The choice of design pattern to use for a particular implementation depends on the nature of the data, the type of analysis being performed, and the user's needs. Ideally, the choice should be based on a combination of these factors, taking into account the complexity of the underlying dataset.

The nested visualizations are nested inside its visual marks. The scatterplot visualization is acting as a host and bar graph visualization is nested item-group.

The dataset, visualized through client visualizations. This is achieved by nesting clients inside the visual marks in the host. This is achieved by nesting clients inside the visual marks in the host. This is achieved by nesting clients inside the visual marks in the host.

Algorithms to generate a composite visualization view.

While our above CVV design patterns are general in nature, they are based solely on the spatial layout of component visualizations. This is achieved by nesting clients inside the visual marks in the host. This is achieved by nesting clients inside the visual marks in the host. This is achieved by nesting clients inside the visual marks in the host.

There is probably not a clear winner among different design patterns for composite views. The problem is generative in nature. Furthermore, this list of patterns is not exhaustive.

Applications:

Drawbacks:

Benefits:

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

Technique Visualization A Visualization B Spatial Relation Data Relation

- GPUVis [25] Scatterplot glyphs nested item-group
- SparkClouds [21] tag cloud line graph overload item-item
- TimeMatrix [44] matrix glyphs nested item-group
- ZAME [13] (Figure 10) matrix glyphs nested item-group
- Mapgets [38] (Figure 6) map text superimpose item-item
- Improvise [39] (Figure 3) any any juxtapose none
- ComVis [24] (Figure 2) any any juxtapose none

References:

C. Ahlberg and B. Shneiderman. Visual information seeking: Tight coupling of the information space and the visual space.

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>
<th>All</th>
<th>Subset</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same</td>
<td>Redundant</td>
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<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
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<tr>
<td>Different</td>
<td>Multiform</td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
</tbody>
</table>

![Graph](image7)

[Munzner (ill. 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

[Wikipedia]
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

FIVE-YEAR TREND

[chart details]

[chart details]

[S. Quigley]
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] so that node position reveals biological function. We wrote a simple simulated annealing-based graph layout algorithm that uses node metadata to guide node placement.

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 view to explore the correlations between nodes.

[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

Population

65 Years and Over
45 to 64 Years
25 to 44 Years
18 to 24 Years
14 to 17 Years
5 to 13 Years
Under 5 Years

Example: Grouped Bar Chart

[Example Diagram]

M. Bostock
Example: Small Multiples Bar Chart

Group 1
- Q108
- Q208
- Q308
- Q408
- Q109
- Q209
- Q309
- Q409

Group 2
- Group
- Q108
- Q208
- Q308
- Q408
- Q109
- Q209
- Q309
- Q409

Group 3
- Group
- Q108
- Q208
- Q308
- Q408
- Q109
- Q209
- Q309
- Q409

Group 4
- Group
- Q108
- Q208
- Q308
- Q408
- Q109
- Q209
- Q309
- Q409

Example: Small Multiples Bar Chart

[M. Bostock]
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
Example: Trellis Matrix Alignment

[Becker et al., 1996]
Example: HiVE System

[Slingsby et al., 2009]
Example: HiVE System

[Slingsby et al., 2009]
Reducing Complexity
Reducing Complexity

- Too many items or attributes lead to visual clutter
- Interaction and Multiple Views can help, but often lose the ability to start understanding an entire dataset at first glance
- **Reduction** techniques show less data to reduce complexity
- Can reduce items or attributes (both are **elements**)
- **Filtering**: eliminate elements from the current view
  - "out of sight, out of mind"
- **Aggregation**: replace elements with a new element that represents the replaced elements
  - summarization is often challenging to design
- Another method is **focus+context**: show details in the context of an overview
Overview: Reducing Items & Attributes

Filter
- Items
- Attributes

Aggregate
- Items
- Attributes

[Munzner (ill. Maguire), 2014]
Filtering

- Just don't show certain elements
- Item filtering: most common, eliminate marks for filtered items
- Attribute filtering:
  - attributes often mapped to different channels
  - if mapped to same channel, allows many attributes (e.g. parallel coordinates, star plots), can filter
- How to specify which elements?
  - Pre-defined rules
  - User selection
Filter vs. Query

• Queries start with an empty set of items and add items
• Filters start with all items and remove items
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

Source: New York City Department of Health and Mental Hygiene

© 2013 The New York Times Company

New York Health Department Restaurant Ratings Map

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]
Dynamic Filters

• Interaction need not be with the visualization itself
• Users interact with **widgets** that control which items are shown
  - Sliders, Combo boxes, Text Fields
• Often tied to attribute values
• Examples:
  - All restaurants with an "A" Grade
  - All pizza places
  - All pizza places with an "A" Grade
Scented Widgets

For each task, subjects with one of the three scenting conditions were instructed to make at least seven observations that provided evidence either for or against the current task hypothesis. At least two of the observations had to be unique findings on views not yet visited. To test this hypothesis, we created three vectors, each representing the number of visits to each view in each scenting condition. We then compared these visitation vectors to the visitation vector for the underlying activity measure used to seed the scented widgets. Using the moment statistic, we found that the correlations of $r(493) = 0.200$ for no scent, $r(493) = 0.217$ for food scent, and $r(493) = 0.217$ for female scent were not very strong. We believe that the semantics of the tasks also affect the likelihood that subjects would visit the same views that were visited in the seed data than users in the previous sense.us study used a small amount of manual seeding to balance the metrics from a study of the sense.us system [12] and supplemented them with a small amount of manual seeding to balance the metrics. However, we note that performance would improve over subsequent trials, regardless of conditions; conditions would have a higher occurrence of unique discoveries and make unique discoveries. Our hypotheses were that scented widgets across conditions. Subjects in the previous sense.us study used a small amount of manual seeding to balance the metrics. In the last half century, women have joined the workforce, but stereotypically male jobs remain almost entirely male. The food supply has diminished greatly since the 1800s. Technology is costing jobs by making occupations obsolete.}

We gave them an introductory tutorial to the system, and then exhibited a power law distribution, and so we scaled them logarithmically for display in the scented widgets. We presented subjects with one of the three scenting conditions. For each task, we presented social data as a histogram, a pie chart, and a stacked bar chart, representing the number of visits to each view in each scenting condition. We believe that the semantics of the tasks also affect the likelihood that subjects would visit the same views that were visited in the seed data than users in the previous sense.us study used a small amount of manual seeding to balance the metrics. In the last half century, women have joined the workforce, but stereotypically male jobs remain almost entirely male. The food supply has diminished greatly since the 1800s. Technology is costing jobs by making occupations obsolete. We believe that the semantics of the tasks also affect the likelihood that subjects would visit the same views that were visited in the seed data than users in the previous sense.us study used a small amount of manual seeding to balance the metrics. In the last half century, women have joined the workforce, but stereotypically male jobs remain almost entirely male. The food supply has diminished greatly since the 1800s. Technology is costing jobs by making occupations obsolete.

[Willett et al., 2007]
Scented Widgets

Scent Encoding Guidelines

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hue</td>
<td>Varies the hue of the widget (or of a visualization embedded in it)</td>
<td><img src="image" alt="Hue Example" /></td>
</tr>
<tr>
<td>Saturation</td>
<td>Varies the saturation of the widget (or of a visualization embedded in it)</td>
<td><img src="image" alt="Saturation Example" /></td>
</tr>
<tr>
<td>Opacity</td>
<td>Varies the saturation of the widget (or of a visualization embedded in it)</td>
<td><img src="image" alt="Opacity Example" /></td>
</tr>
<tr>
<td>Text</td>
<td>Inserts one or more small text figures into the widget</td>
<td><img src="image" alt="Text Example" /></td>
</tr>
<tr>
<td>Icon</td>
<td>Inserts one or more small icons into the widget</td>
<td><img src="image" alt="Icon Example" /></td>
</tr>
<tr>
<td>Bar Chart</td>
<td>Inserts one or more small bar chart visualizations into the widget</td>
<td><img src="image" alt="Bar Chart Example" /></td>
</tr>
<tr>
<td>Line Chart</td>
<td>Inserts one or more small line chart visualizations into the widget</td>
<td><img src="image" alt="Line Chart Example" /></td>
</tr>
</tbody>
</table>

Figure 2. Examples of several scent encodings.
Star Plots (aka Radar Charts)

Aberfeldy
- Malt
- Fruity
- Floral
- Body
- Sweetness

Aberlour

AnCnoc

Ardbeg

Ardmore
- Malt
- Fruity
- Floral
- Body
- Sweetness

ArranIsleOf

Auchentoshan

Auchroisk
Star Plot / Radar Chart

- Use:
  - Compare variables
  - Similarities/differences of items
  - Locate outliers

- Considerations:
  - Order of axes
  - Too many axes cause problems
Attribute Filtering on Star Plots

(a) [Yang et al., 2003]
Attribute Filtering

• How to choose which attributes should be filtered?
  - User selection?
  - Statistics: similarity measures, attributes with low variance are not as interesting when comparing items

• Can be combined with item filtering
Aggregation

- Usually involves **derived** attributes
- Examples: mean, median, mode, min, max, count, sum
- Remember expressiveness principle: still want to avoid implying trends or similarities based on aggregation

<table>
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<tr>
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<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
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</tr>
</tbody>
</table>
Aggregation

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• Examples: mean, median, mode, min, max, count, sum
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<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
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Mean of x: 9
Variance of x: 11
Mean of y: 7.50
Variance of y: 4.122
Correlation: 0.816
Anscombe's Quartet

![Anscombe's Quartet Diagrams]

[F. J. Anscombe]