09

Interaction Concepts and Techniques

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Notice

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Bibliography….
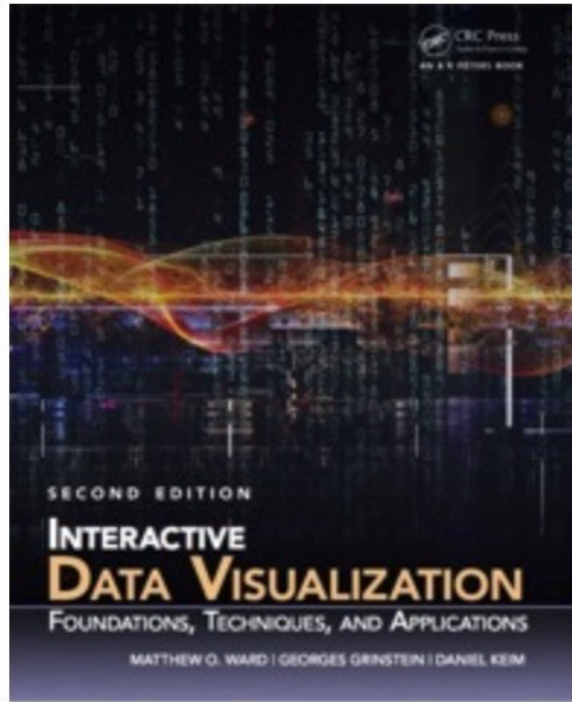
Interactive Data Visualization: Foundations, Techniques, and Applications
Matthew O. Ward, Georges Grinstein, Daniel Keim
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- **reconfiguring**: changing the way data is mapped to graphical entities or attributes, such as reordering the data or layouts. => a different way of viewing a data subset.

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- **hybrid**: combining several of the above in one technique, for example, increasing the screen space assigned to one or more focus areas to enable users to see details, while showing the other areas of data in a smaller space, in a way that preserves context.

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Operators, Spaces, and parameters

- **The classes of interactive operations can be described in terms of operators and the operand (the space upon which the operator is applied).**

Navigation Operators

Selection Operators

Filtering Operators

Reconfiguring Operators

Encoding Operators

Connection Operators

Abstraction/Elaboration Operators

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Screen Space (Pixels)

Data Value Space (Multivariate Data Values)

Data Structure Space (Components of Data Organization)

Attribute Space (Components of Graphical Entities)

Object Space (3D Surfaces)

Visualization Structure Space

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- **Data can be structured** in a number of ways, such as lists, tables, grids, hierarchies, and graphs. For each structure, one can develop interaction mechanisms to indicate what portions of the structure will be manipulated, and how this manipulation will be manifested

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- **Object Space. In these displays, the data is mapped to a geometric object, and this object (or its projection) can undergo interactions and transformations**

- **Visualization Structure Space. A visualization consists of a structure that is relatively independent of the values, attributes, and structure of data. For example, the grid within which a scatterplot matrix is drawn and the axes displayed in many types of visualizations are each components of the visualization structure.**

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Interaction Operators and Spaces

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    - ◆ Check "projection pursuit" for automatic navigation.

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- **Navigating in data value space involves using the data values as a mechanism for view specification. The analogous operations for panning and zooming would be to change the data values being displayed;**

  - **panning would shift the start of the value range to be shown**

  - **while zooming would decrease the size of this range.**

Navigation Operators

■ **Navigation in data structure space involves moving the view specification**

along the structure:

♦ **showing sequential groups of records;**

♦ **moving down or up a hierarchical structure (as in drill-down and roll-up).**

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Navigation Operators

- **Navigation in data structure space involves moving the view specification along the structure:**

    - showing sequential groups of records;

    - moving down or up a hierarchical structure (as in drill-down and roll-up).

- **Navigation in attribute space is similar to that in data value space;**

    - Panning involves shifting the range of the values of interest,

    - Zooming can be accomplished by either scaling the attributes or enlarging the range of values of interest.

Navigation Operators

- **Navigation in visualization structure space might include moving through pages in a spreadsheet-style visualization tool or zooming in on an individual plot in a scatterplot matrix.**

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Selection Operators

■ **Selection is used to isolate a subset of the display components, which will then be subjected to some other operation, such as highlighting, deleting, masking, or moving to the center of focus.**

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- **Selection can be articulated in many different ways:**

  - ♦ **The user may click on entities**

  - ♦ **Paint over a selection of entities (e.g., holding the mouse button down while moving over the entities of interest)**

  - ♦ **Isolate the entities via techniques such as bounding boxes and lassoes.**

  - ♦ **In an indirect manner, where the system selects elements that match a user's input set of constraints**

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    - ◆ **Clicking on an entity in the display might result in selection of the smallest addressable component (e.g., a vertex or edge) or might target a broader region around the specified location (e.g., a surface, region of the screen, or object).**

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Selection Operators

- **Pixel-based selection** means that at the end of the operation, each pixel will be classified as either selected or unselected.

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- **Data value space selection** is similar to a database query in that the user specifies a range of data values for one or more data dimensions.

  - ♦ This can be performed via **direct manipulation**, as in the **data-driven brushing** or via **sliders** or other **query specification mechanisms**

  - ♦ Selection may involve a **single value**, or one or more **ranges of values**

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Selection Operators

- **Selection in data structure space generally involves displaying the structure and allowing the user to identify regions of interest within it. This in turn can drive the display of the data corresponding to the selected substructure.**

  - ◆ **For example, structure-based brushing involves controlling the selection of data stored in a cluster hierarchy, with interactions such as highlighting data that fall within a particular branch of the tree**

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- **Attribute-space selection requires the user to indicate the subrange of a given attribute of interest.**

  - **For example, given a visual depiction of a color map, a user can select one or more entries to highlight.**

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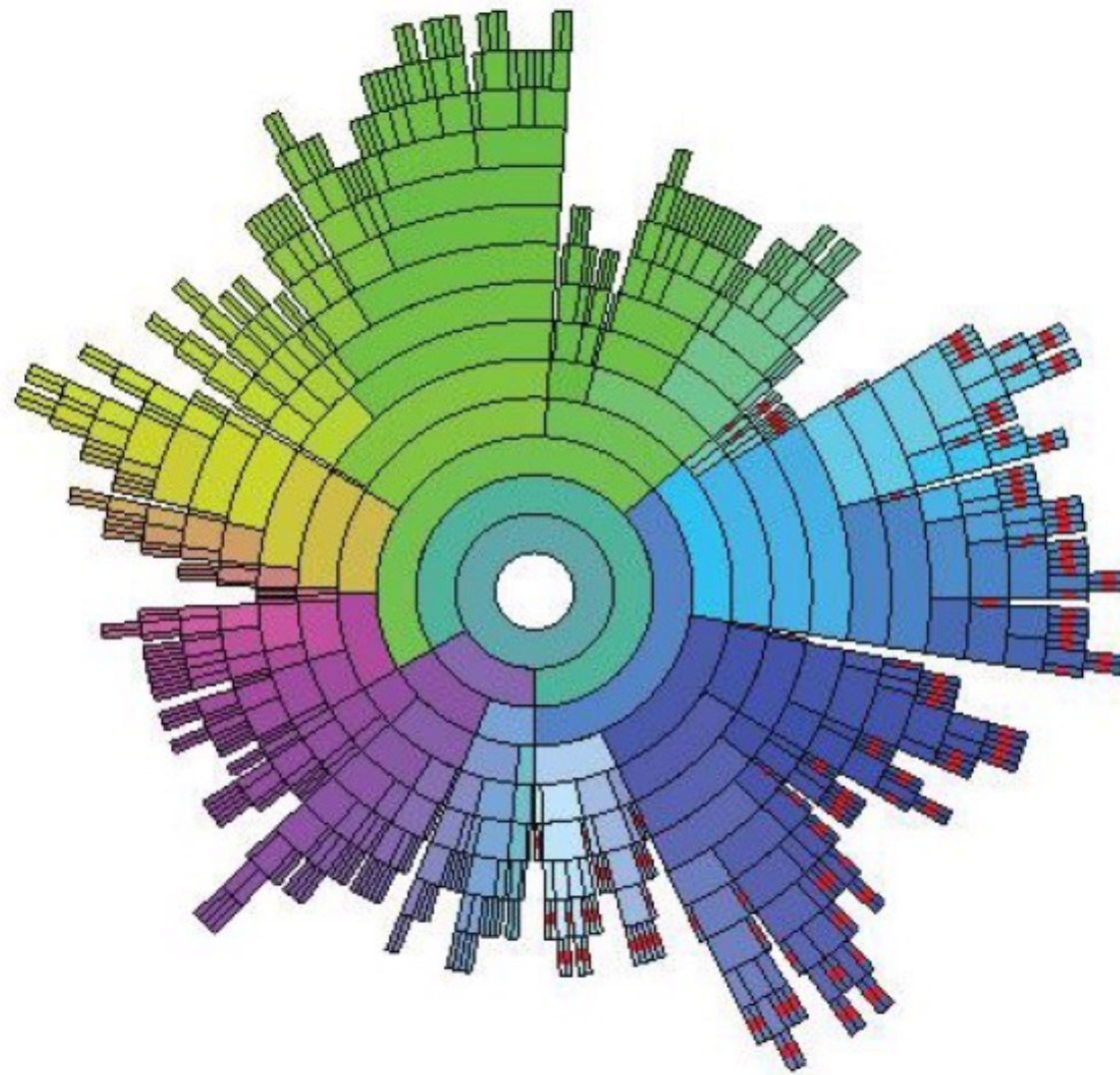
Selection of nodes in a hierarchy via InterRing. Nodes with a red stripe in them have been selected via a user-specified query, rather than one node at a time. The hierarchy consists of nearly 400 nodes (Image from [478], © 2003 IEEE.)

Selection Operators

■ **For selection in Visualization Structure Space, typical operations would include choosing components to hide, move, or rearrange.**

♦ **For example, one might select an axis in parallel coordinates and drag it to a new location to discover different relationships among the data dimension**
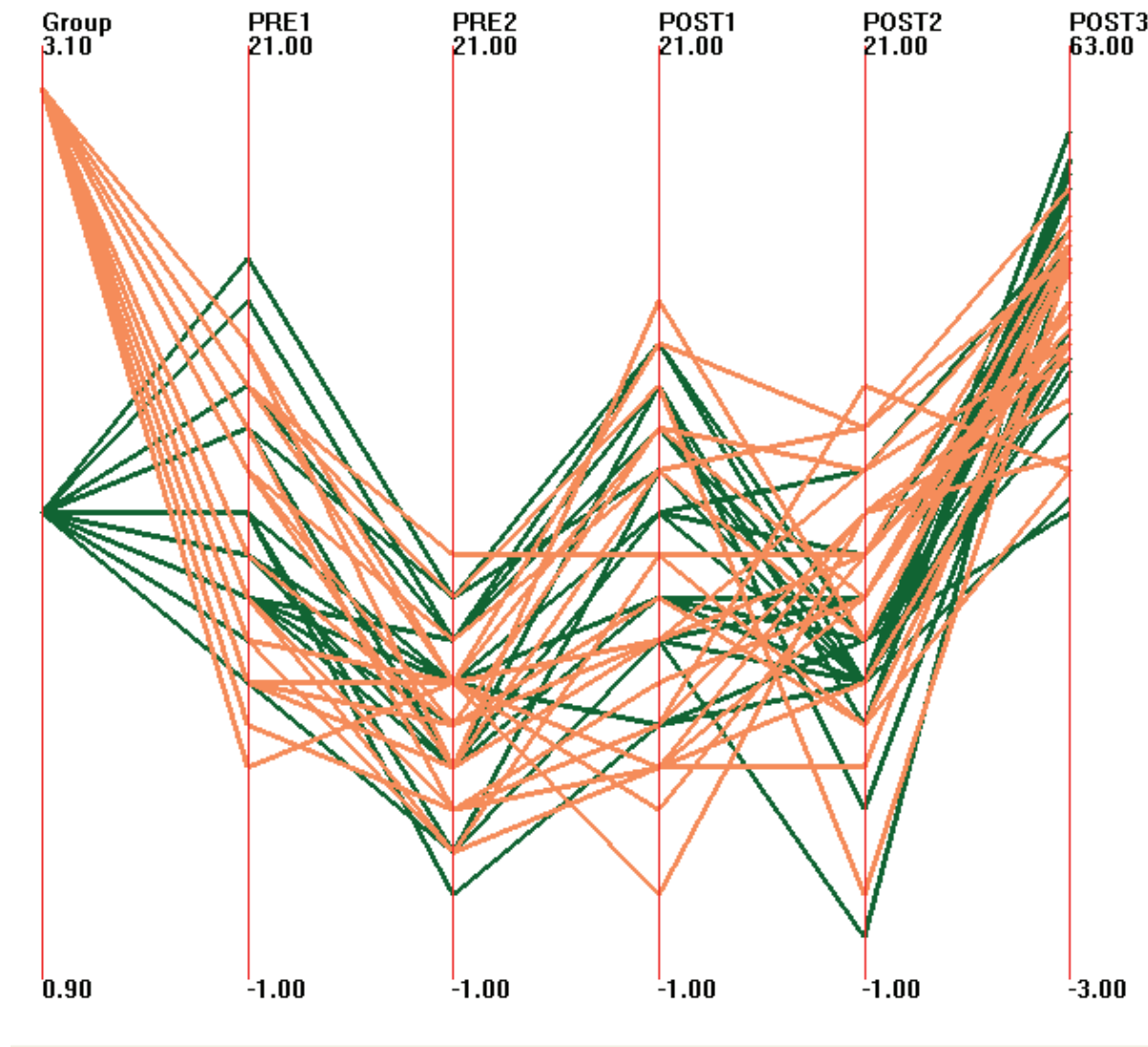
Filtering Operators

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  - **Filtering, in general, is most often done in an indirect manner, e.g., the filter specification is not performed on the data visualization itself, but via a separate interface or dialog box. In fact, filtering is often done prior to viewing the data, to avoid overloading the data display.**

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◆ **Selection is most often done in a direct manner, by indicating objects on the visualization via mouse motions, for example.**

Filtering Operators

■ **Data value space is perhaps the most obvious space in which to perform filtering. When visualizing extremely large data sets, it is common to first reduce the data to a particular region of data space.**

   ♦ **For spatial data, this is analogous to clipping the data falling outside of a viewing region;**

   ♦ **For nonspatial data, this involves eliminating some records, dimensions, or both.**
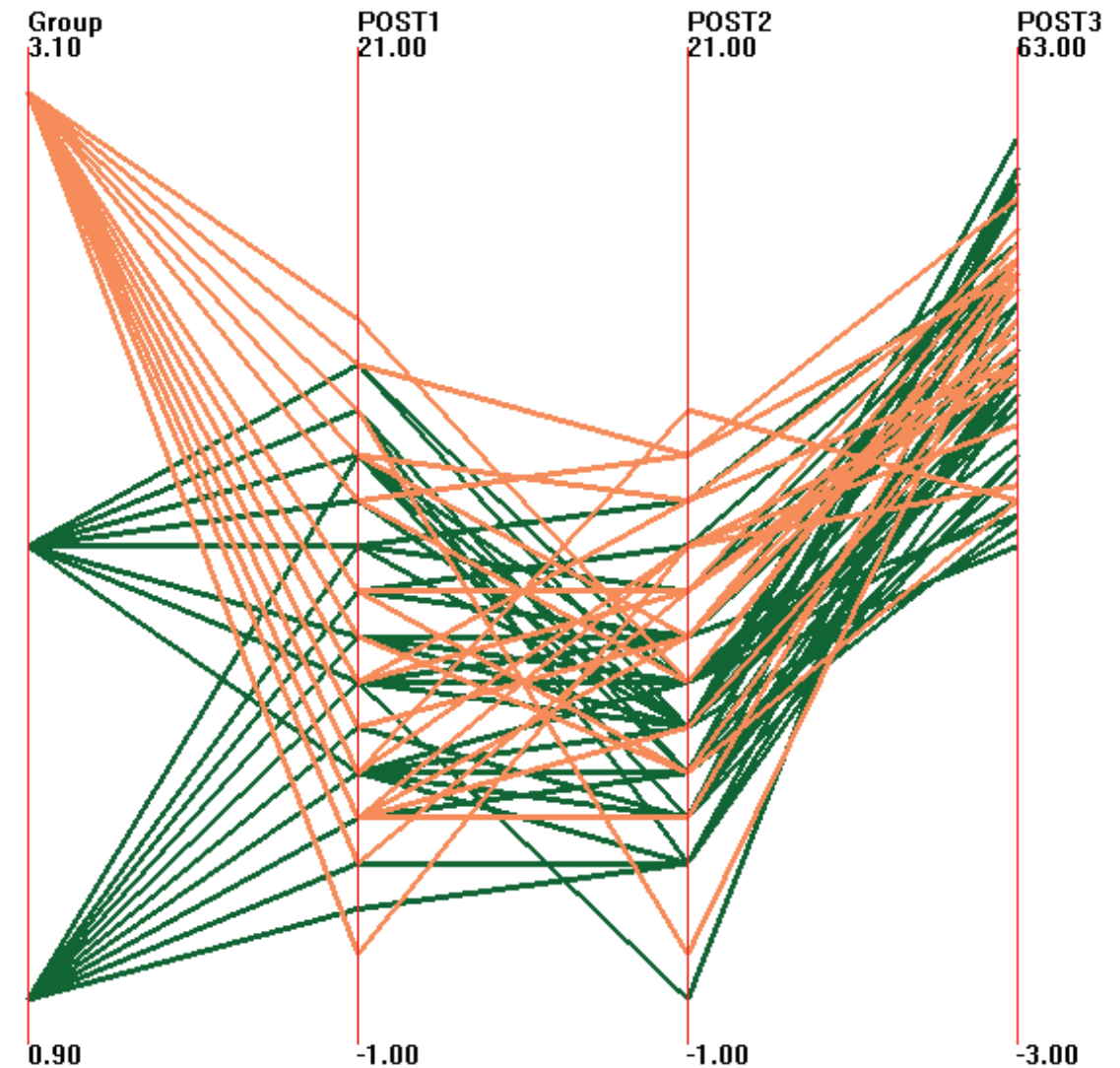
Filtering rows and columns of the grades data set using XmdvTool.

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  - ◆ **Examining neighborhoods in a graph visualization often consists of filtering out nodes and links that are greater than a particular number of links away from a focus point,**

  - ◆ **Many techniques for hierarchy visualization allow users to filter based on the level of the hierarchy**

Filtering Operators

- **Attribute-space filtering:**

    - if data records have attributes such as quality or uncertainty, a visual

        representation of these attributes, accompanied by suitable interaction

        techniques, can allow users to filter or emphasize data according to the attributes.

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Reconfiguring Operators

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  - To change the dimensions being used to control the x- and y-coordinates of a plotted marker.

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  - A powerful tool with table-based visualizations is to **sort** the rows or columns of the data to highlight trends and correlations.

  - To **change the dimensions** being used to control the x- and y-coordinates of a plotted marker.

  - The use of principal component analysis (PCA) or multidimensional scaling (MDS)

Encoding Operators

- **Recoding** can provide the user a library of possible different types of visualization; features of the data that are difficult or impossible to see with one such mapping might become quite apparent in another

  - For example, a scatterplot with one axis representing years may have many points that overlap, whereas a parallel coordinate display would represent these uniquely

- **Other forms of encoding operations include those that modify the color map used, the size of graphical entities, and their shape.**

Encoding Operators

Connection Operators

- **A frequent use for selection operations is to link the selected data in one view to the corresponding data in other views.**
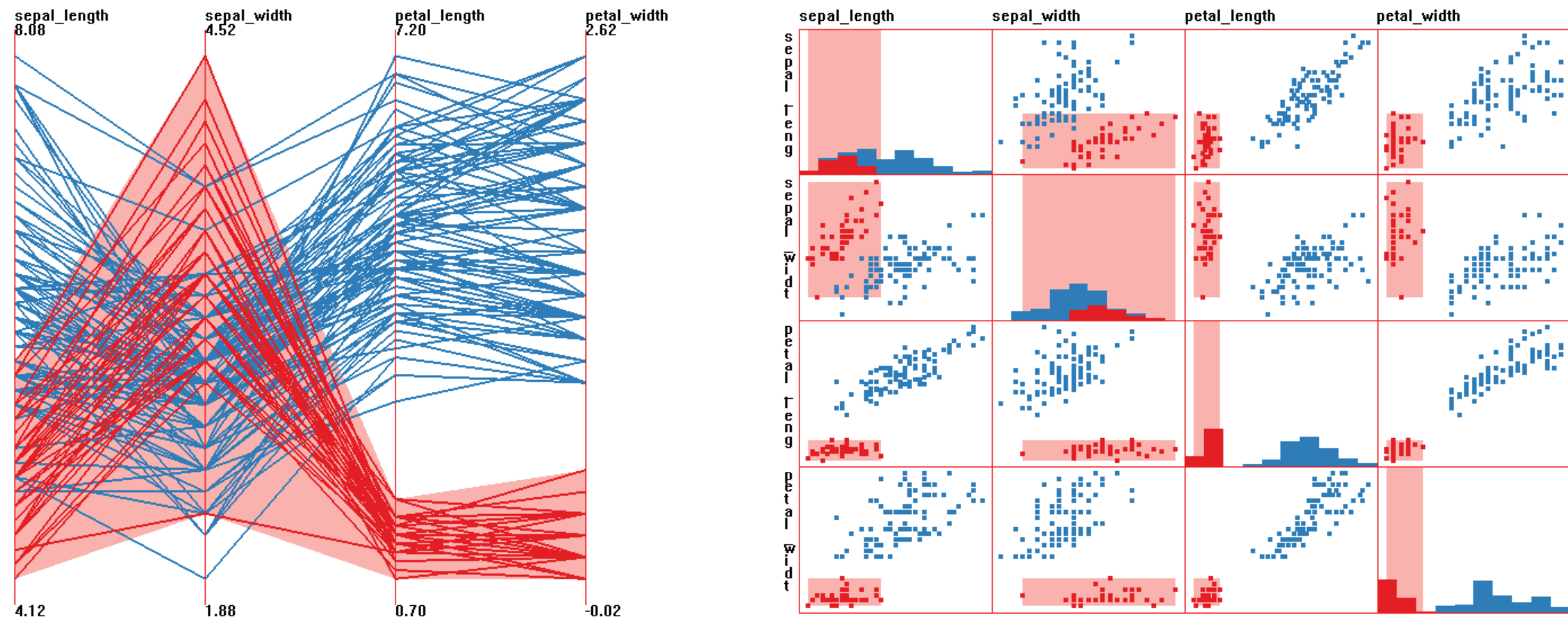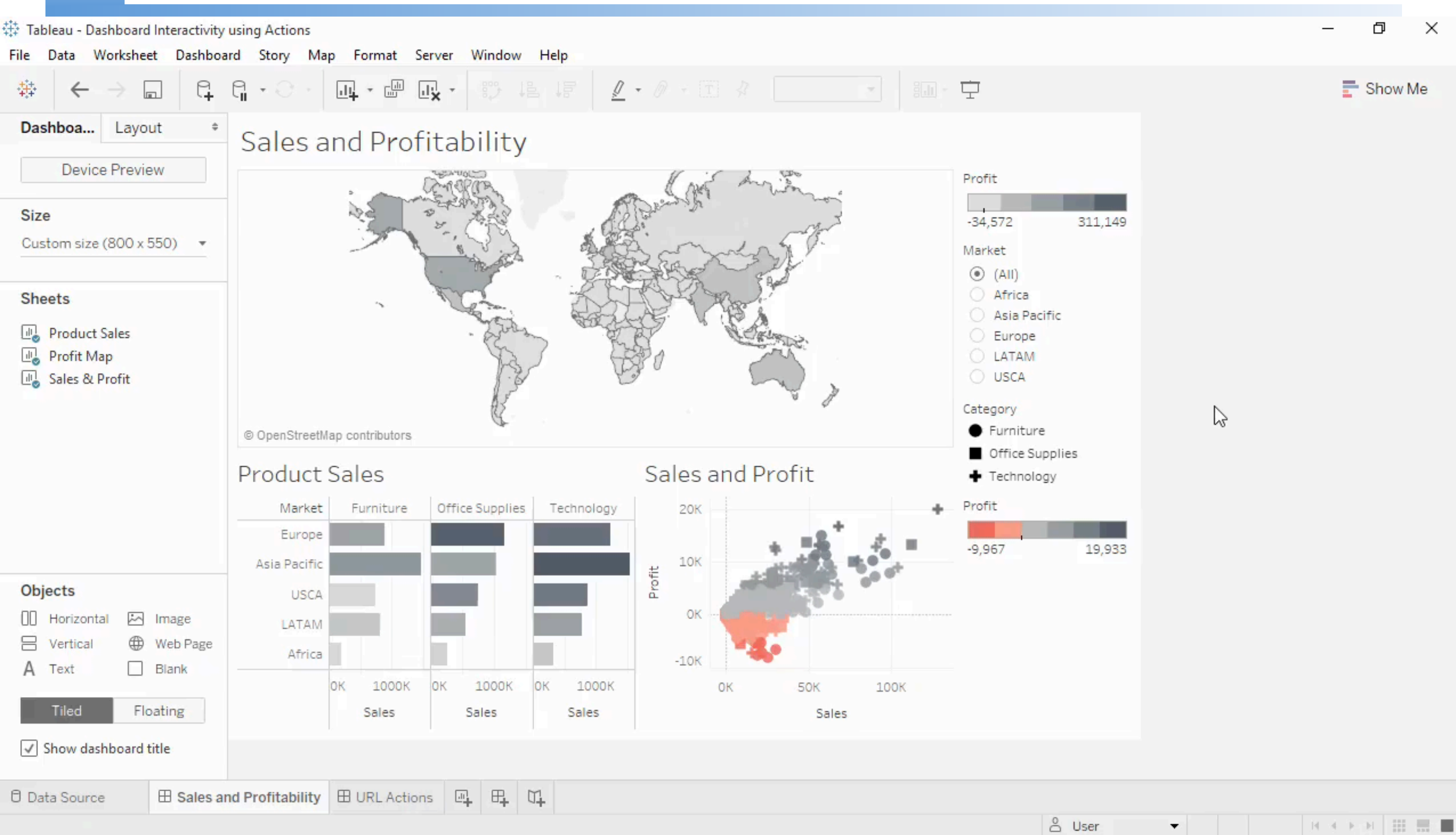

Figure 11.3. Example of linked brushing. A cluster is isolated in parallel coordinates, with linked selection in the scatterplot matrix. Selected data is dark red, while brush extents are shown as light bands or rectangles.
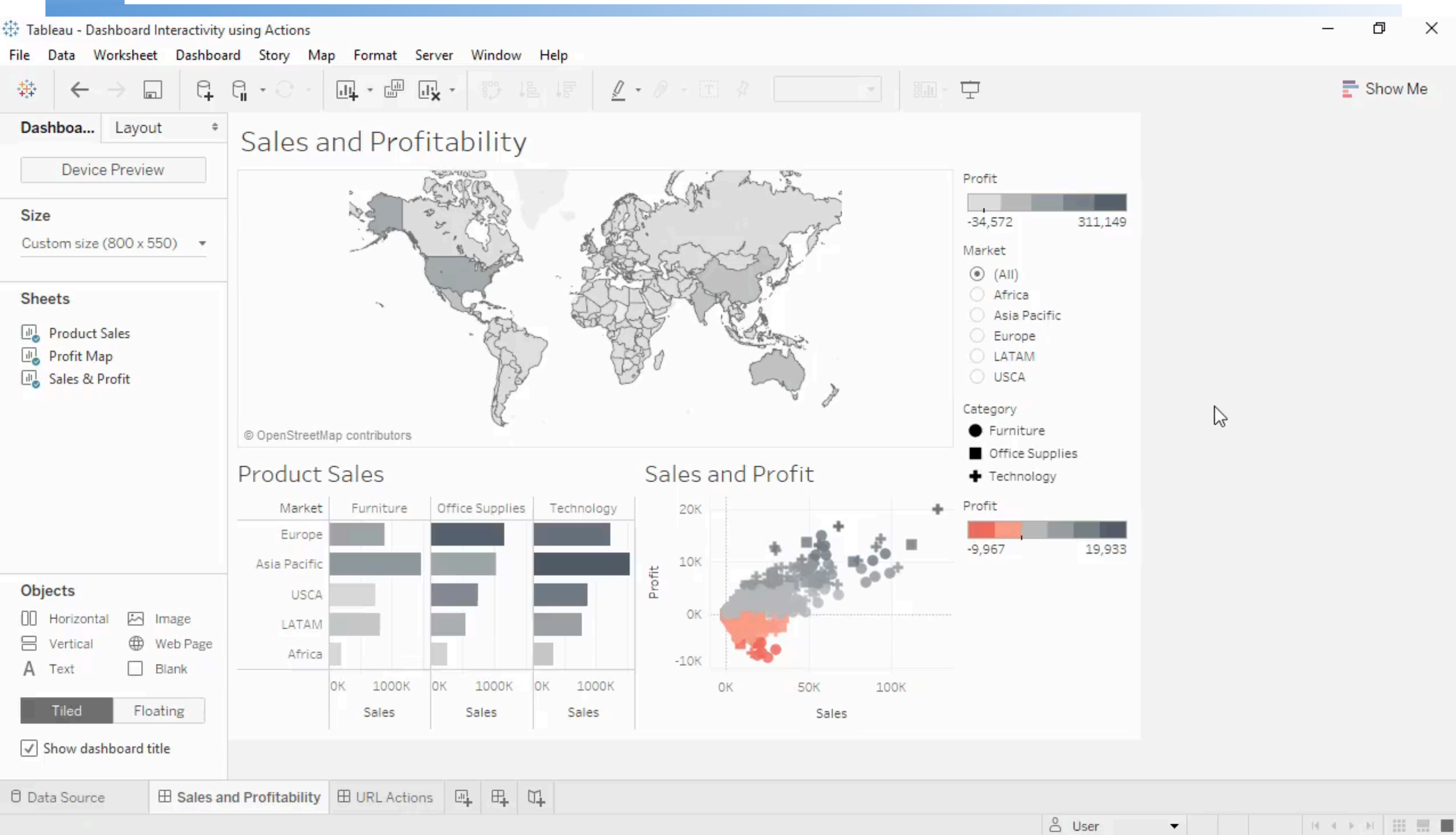
Connection Operators

- **In some situations, the user may want to unlink some visualizations in order to maintain a given view while exploring a different area of the data or different data set**

- **A user may also want to constrain the type of information being communicated, as well as its direction.**

- **Some types of interaction may be local to a particular window, e.g., zooming in and out, while others are meant to be shared, such as reordering dimensions.**

- **Check: http://www.tableau.com/learn/tutorials/on-demand/dashboard-interactivity-using-actions**

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Connection Operators

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Abstraction/Elaboration Operators

- **In dense data and information displays, it is often desirable to focus in on a subset of the data to acquire details (elaboration) while reducing the level of detail (abstraction) on other parts of the data set.**

- **One of the most popular techniques of this type is using distortion operators.**

  - **Some methods that distort the entire space being analyzed, and others that have more localized effects**

 - **Distortion may take place within the original visualization, or may appear in a separate window**
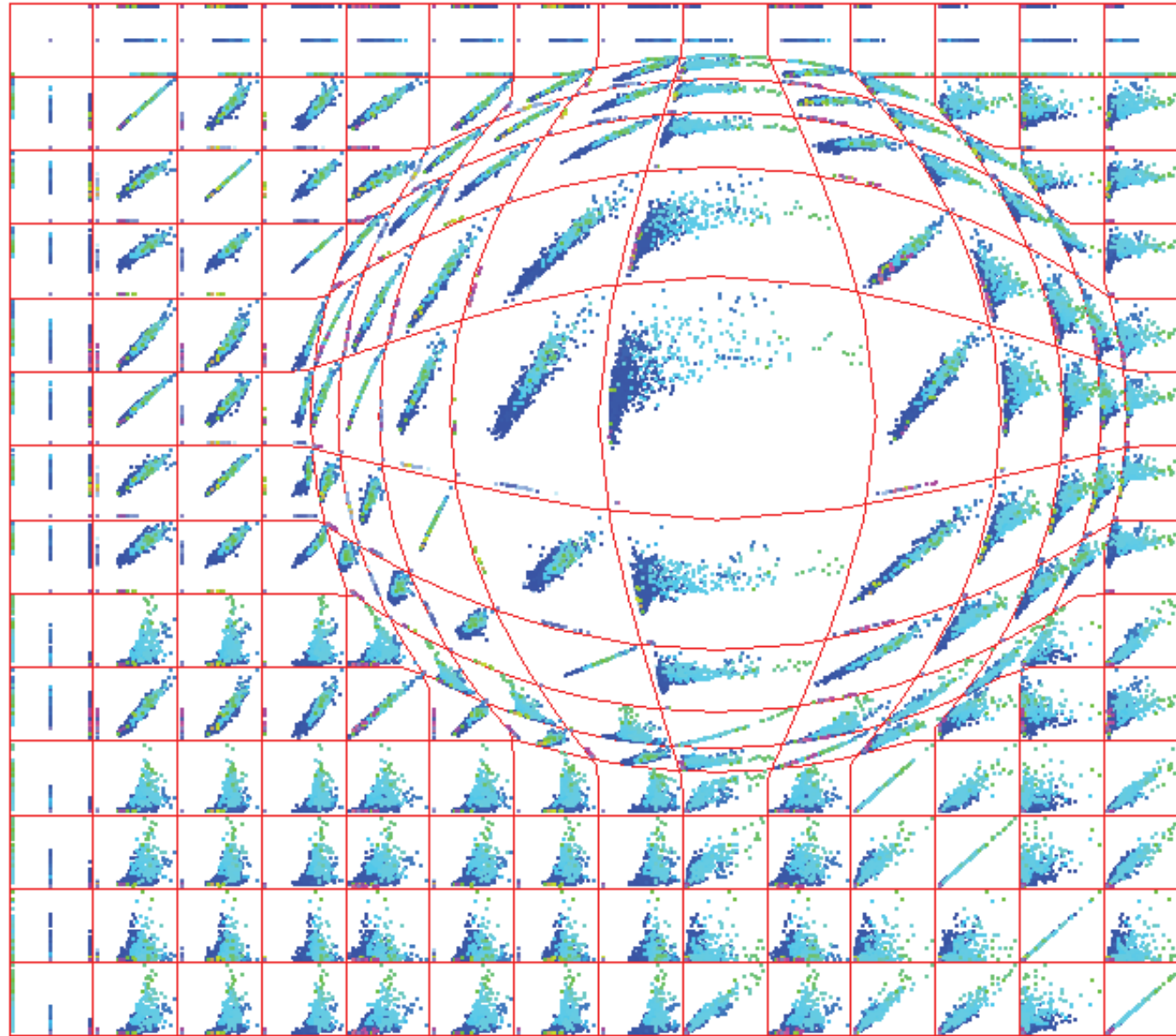
In screen space techniques, pixel regions are enlarged or reduced to provide selective detail. In this scatterplot matrix display, a center of focus has been selected and magnified using a confocal lens technique. (Image from [443], © 2004 Eurographics.)

Abstraction/Elaboration Operators

(a)   (b)
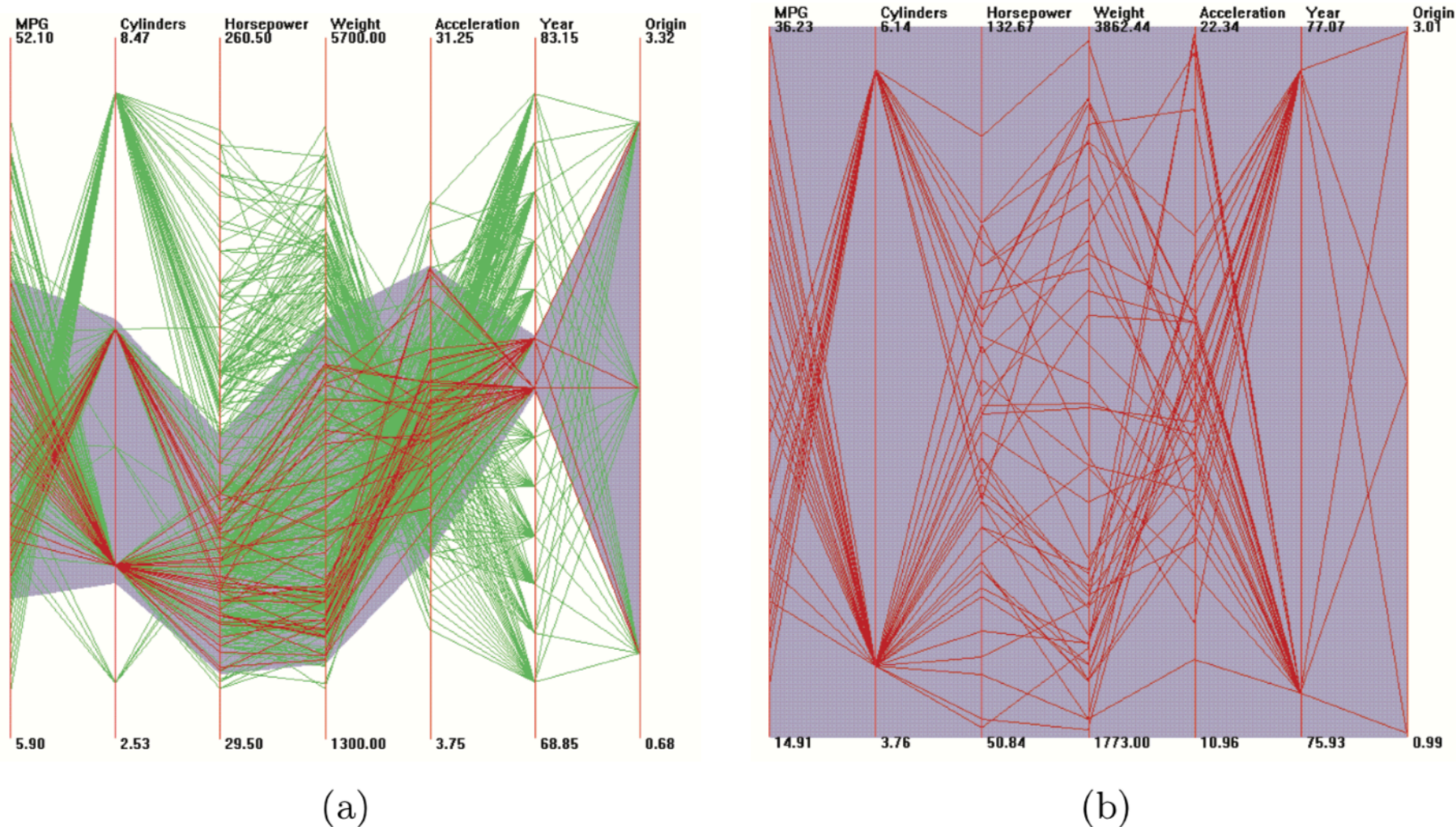
In data value space distortion, transformations are performed according to the dimensionality of the data. In this example, generated using XmdvTool [137], an N-dimensional hyperbox is selected via painting over a section of an axis and scaled in all dimensions (by different amounts) to fill a unit hypercube, which is then displayed. Animation is used to preserve context. Clusters and anomalies within the selected region are much easier to see in the zoomed version. (Image from [443], © 2004 Eurographics.)
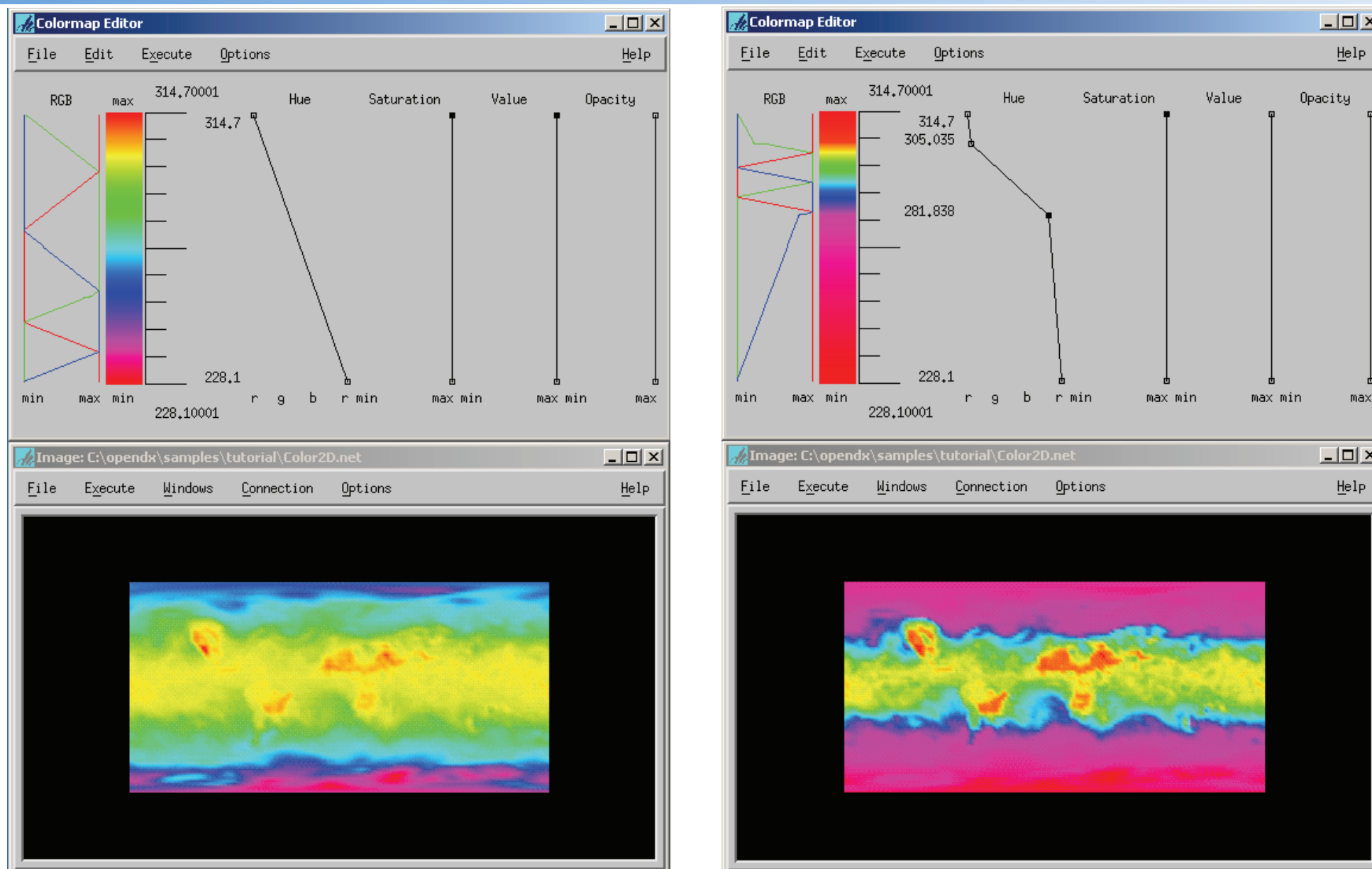
Abstraction/Elaboration Operators

Figure 11.8.   Attribute-based distortion modifies one or more attributes of the graphical objects used to depict the data, as shown in this color map modification, generated using the color map editor in OpenDX. The color map is distorted to allot a greater portion to values in the middle of the data range.

Abstraction/Elaboration Operators
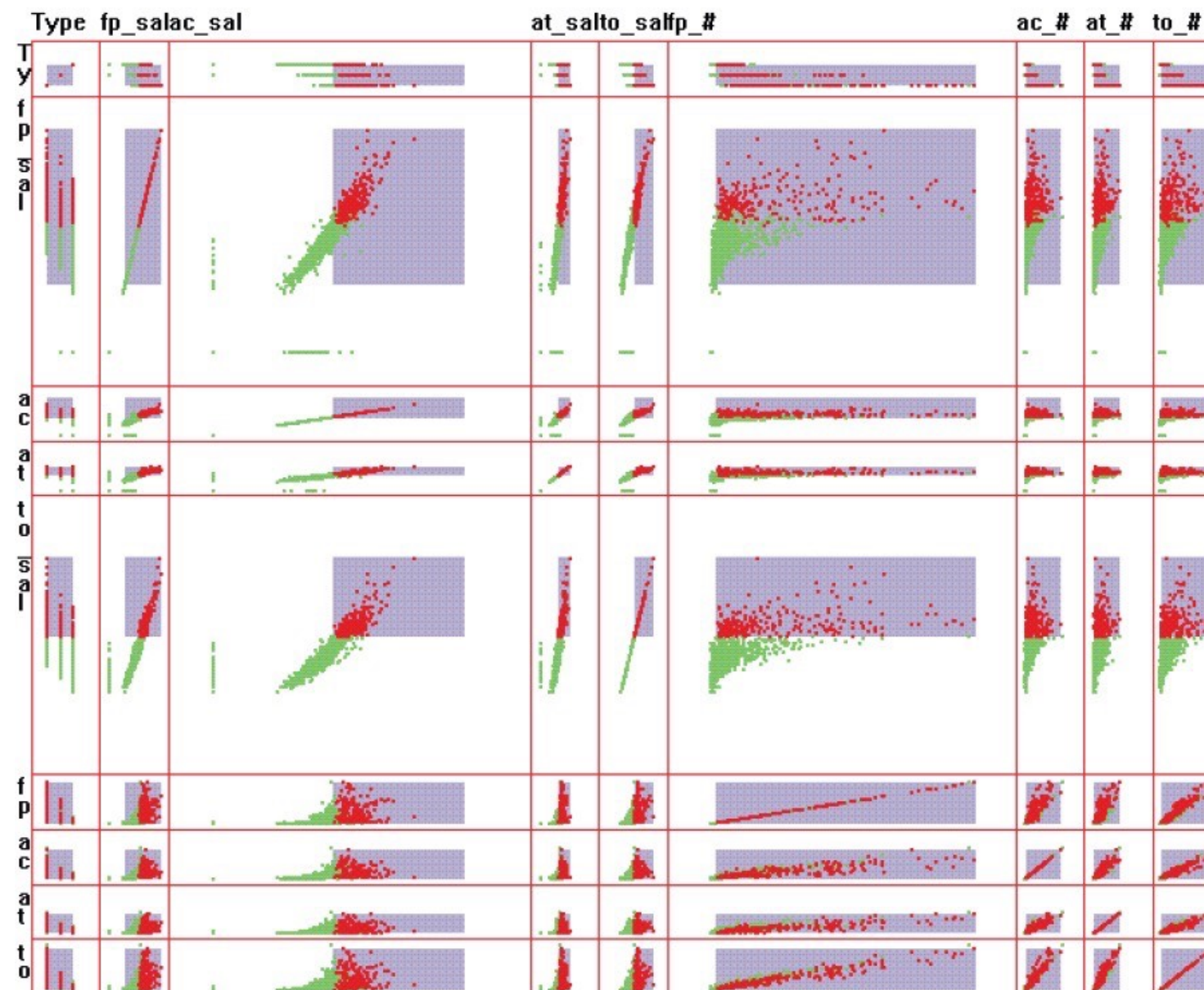
Structure-based distortion modifies the underlying structural elements of the visualization. This example, inspired by TableLens [328], shows a scatterplot matrix with two grid cells (and their corresponding rows and columns) magnified, with a corresponding shrinkage in other cells. (Image from [443], © 2004 Eurographics.)

Abstraction/Elaboration Operators

■ **Abstraction/elaboration operators take many forms in data structure space. With a hierarchical structure, abstraction simply means moving up the hierarchy to aggregations or summarizations of the data at the current level, while elaboration implies drilling down into the hierarchy.**

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A Unified Framework

A Unified Framework

- **For each interaction operator to be applied to a specified space/operand, several parameters are required:**

- **Focus. The location within the space at the center of the area of user interest. There may be multiple simultaneous foci, though for navigation this usually requires multiple display windows.**

- **Extents. The range within the space (can be multidimensional) defining the boundaries of the interaction. The metric used for specifying the range is specific to the space; in screen space this would be in pixels, while in structure-space this might be the number of rows in a table or links in a graph.**

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A Unified Framework

- **Transformation**. The function applied to the entities within the extents, generally a function of distance or offset from the focus. The shape of this transformation might also depend on the type of information being affected

- **Blender**. How to handle parts of space touched by more than one interaction. For selection, this operation may include performing logical operations on overlapping entities [287].

  - For distortion, Keahey and Robertson identify several approaches, including weighted average, maximal value, and composition.

A Unified Framework
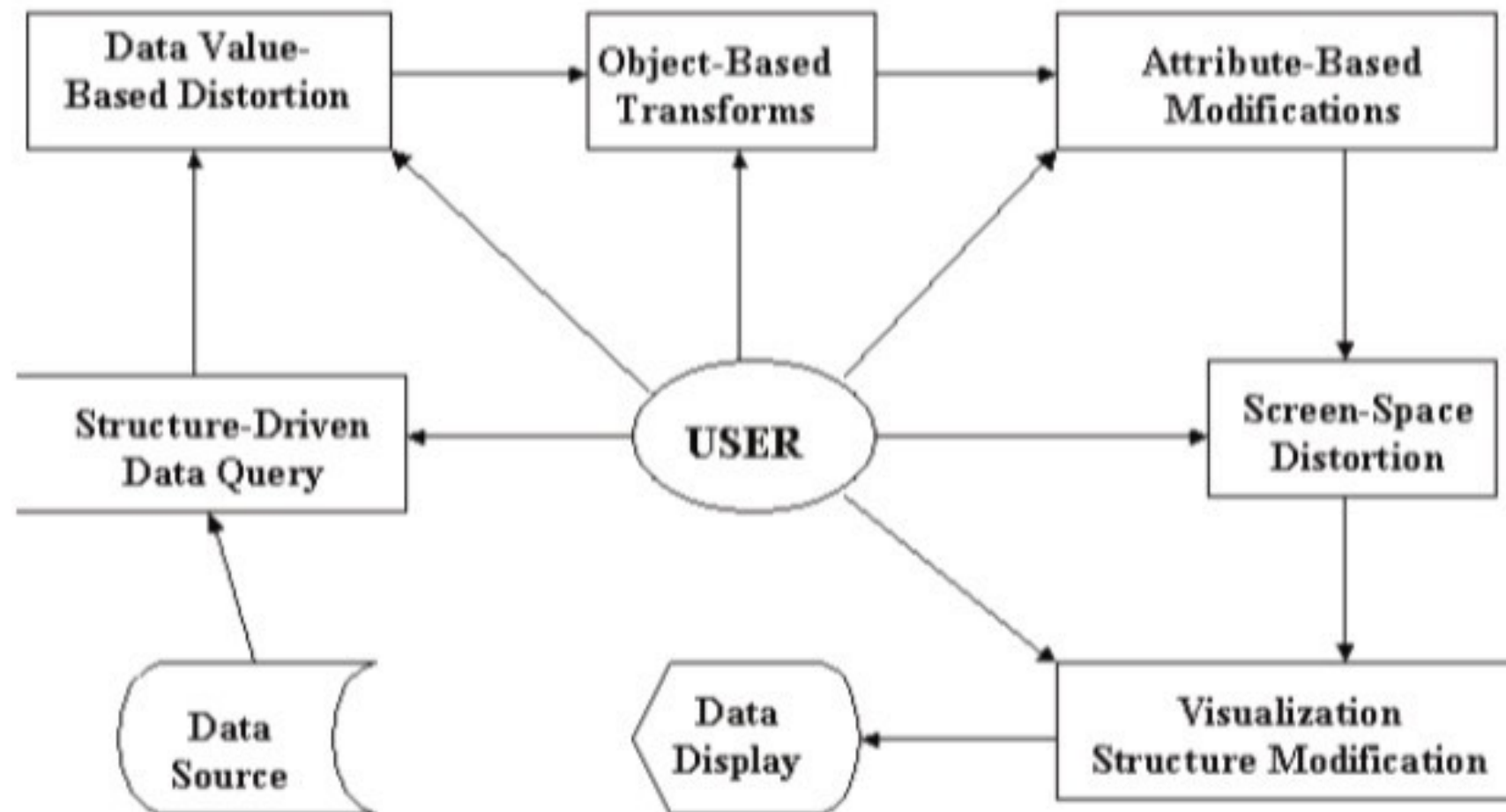
The distortion pipeline. The user interactively controls each stage of the pipeline. Each distortion operation is optional. (Image from [443], © 2004 Eurographics.)

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Further Reading and Summary

Further Reading

■ Pag 365 - 406 from Interactive Data Visualization: Foundations,

Techniques, and Applications, Matthew O. Ward, Georges Grinstein,

Daniel Keim, 2015