A Review of *Angular Brushing of Extended Parallel Coordinates* by Hauser et al.

Chad A. Steed

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Label is **HauserIV2002**.
Category is **Information Visualization**.

My Thoughts

- Apply these techniques to the NOAA "best-track" dataset.
- What about application of NPR techniques (artistic brushes, painterly rendering) to parallel coordinates visualization.
- Would be interesting to analyze the use of parallel coordinates in exploring relationships in geospatial data and spatio-temporal data.

Introduction

- When used interactively, parallel coordinates are very effective in visualizing correlations between neighboring axes and outliers, etc.
- IDEA: PARALLEL COORDINATES MIGHT BE GOOD FOR ANALYZING SATELLITE DATA.
- **Brushing** - User actively marks sub-sets of the data as interesting using a brush-like interface. When used with multiple views, brushing helps understand correlations across multiple dimensions.
- Brushing also good for controlling a drill-down into the data; specify focus and details are shown for selected data-points; relates to **focus+context** visualization.
- F+C idea is to jointly visualize some of data in detail and rest of data in a reduced style; maintains user's orientation; ease navigation into large datasets.
- Assign 1 or 0 to each data-point, depending on whether or not data point is of interest or not currently.

Extended Brushing for Parallel Coordinates

- Need to extend standard brushing techniques.
- Specify focus with respect to at least two data attributes (dimensions).
- **Angular Brushing of Parallel Coordinates**

  - Ability to move axes interactively enables effective exploration of relationships in the data attributes.
  - Slope of line segments also tells user whether there are positive or negative correlation in-between values.
  - Outliers can be found easily with respect to two data dimensions (when all but a few line-segments have a positive slope the others clearly stand-out).
  - Extend these features for implementing angular brushings
  - User can do standard brushing on parallel axes.
  - User can do extended brushing on space in-between axes (interactively specify sub-set of slopes which yields data-points to be marked as part of current focus which exhibit matching correlation in between the brushed axes).
  - E.g., negative slopes marked in-between second and third axes.
  - Useful extension - corresponds well to effective visual cues provided by parallel coordinates.

- **Smooth Brushing**
  - Specify brush by user-defined percentage to create smooth gradient of DOI-values at its borders.

- **Composite Brushes**
  - Logical combination of brushes.
  - For supporting more concrete understanding of data (gives flexible and multidimension description of features).
  - Supporting user centered specifications (e.g., all those cars which are fast but do not cost a lot).
  - Multiple brushes - a new brush is instantiated when new brushing interaction triggered.; new brushes are named and added to a brush list; user can swith between previously defined brushes or combine them to form composites.
  - Composite brushes - single brushes combined to form composites through application of logical operators; composites can also be constructed by added new constraints interactively.
  - Support of linking - parallel coordinates can be used as one of several linked views (e.g., parallel coordinate view combined with 3D scivis view).

Further Extensions for Parallel Coordinates

- Histograms over Parallel Coordinates - For the axes; found to be especially useful; give intuitive clue where data-points accumulate along coordinate axes; plotted semi-transparent representation of bins;
- Flexible Layout with Parallel Coordinates
  - Axes re-ordering - re-order layout of axes in use; dragging axes around.
  - Flipping of axes - useful for data investigation; flip certain axes (top-down ordering instead of bottom-up style); helps in investigating correlations between axes; important in conjunction with angular brushings.

  - Changing the mapping - default mode is min-max mapping of values; two other modes available; a) user enforces zero is mapped to same height along all coordinate axes; b) min-max mapping correlated long all axes resulting in consistent mapping for them all.
  - Axis scaling and panning - interactively scale and pan mapping for single axes; important means when working in-between dimensions.
  - Deletion and addition of axes - interactively delete single axes from view; also allow addition of axes to view (even if already in use)

Detail on Demand

- Feature implemented as mouse-over effect.
- When mouse moved over a poly-line, all details shown for respective data-point.
- Also use this feature to display textual data attributes.

Implementation

- Improve brute force technique.
- In real-world datasets, drawing multiple line segments for each and every data point puts a big load on graphics hardware.
- Also needed semi-transparency, coloring, anti-aliased line-segments for features.
- Approaches to support real-time interactivity:
  - Exploiting coherence - during interaction, application trys to reuse as much of current visual output as possible; e.g., when axes flipped only inter-axis space on left and right hand side of flipped axis re-rendered.
  - Progressive rendering - for immediate feed-back; preview-style rendering (w/o anti-aliasing or semi-transparency); when more time for better rendering, application computes high quality image and replaces preview.
  - Bi-threaded implementation - to de-couple rendering and interaction; one thread for UI and other thread for rendering.

Application and Results

- Investigate multi-dimensional datasets from CFD simulations; dozens of data dimensions or more.
- Parallel coordinates with presented extensions proved to be very useful for data investigation.
- Linked views eased data exploration (to show where points are in 3D space).
- combinations with scatter plots useful mainly because it is easier to specify composite brushes.

References

[1] H. Hauser, F. Ledermann, and H. Doleisch, "Angular Brushing of Extended Parallel Coordinates," *Proceedings of IEEE Symposium on Information Visualization 2002*, Boston, Massachusetts, Oct. 2002, IEEE Computer Society, pp. 127–130.