

## 5. Interaction with Visualizations

Dynamic linking, brushing and filtering in  
Information Visualization displays

Vorlesung „Informationsvisualisierung“

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Konzept und Basis für Folien: Thorsten Büring

# Outline

- InfoVis & Interaction
- Direct Manipulation (DM)
- Common Interaction Techniques
  - Brushing
  - Zooming & Panning
  - Dynamic Queries
- Attribute Explorer
- Brushing Histograms vs. DQ
- Dynamic Queries and Movable Filters

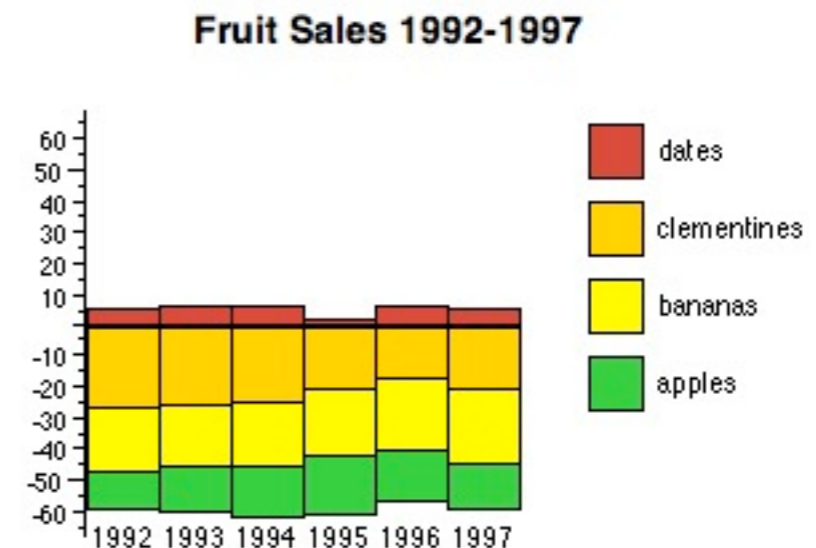
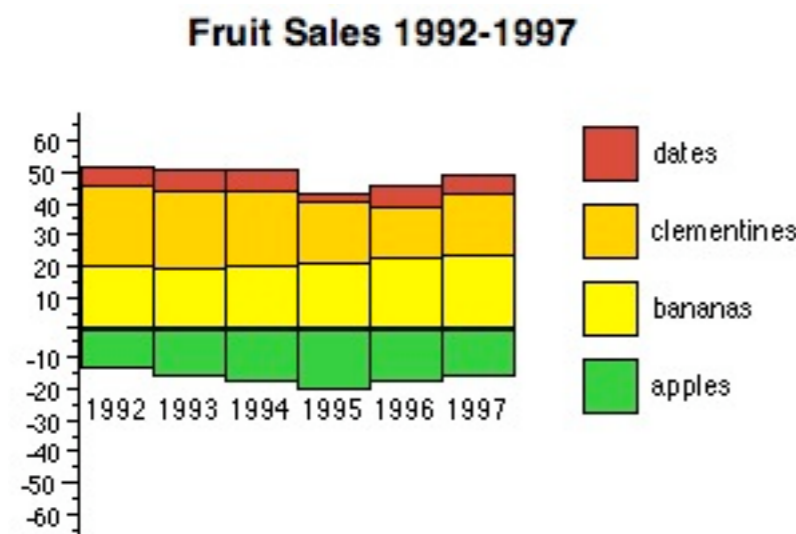
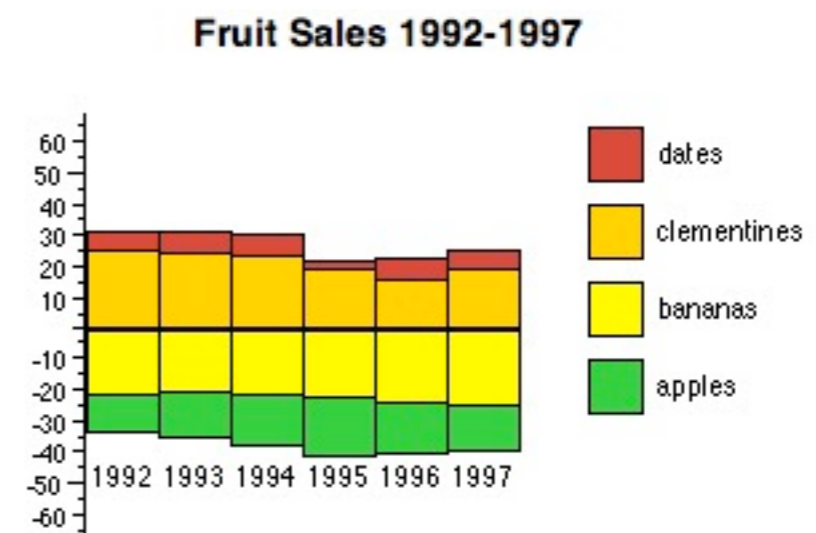
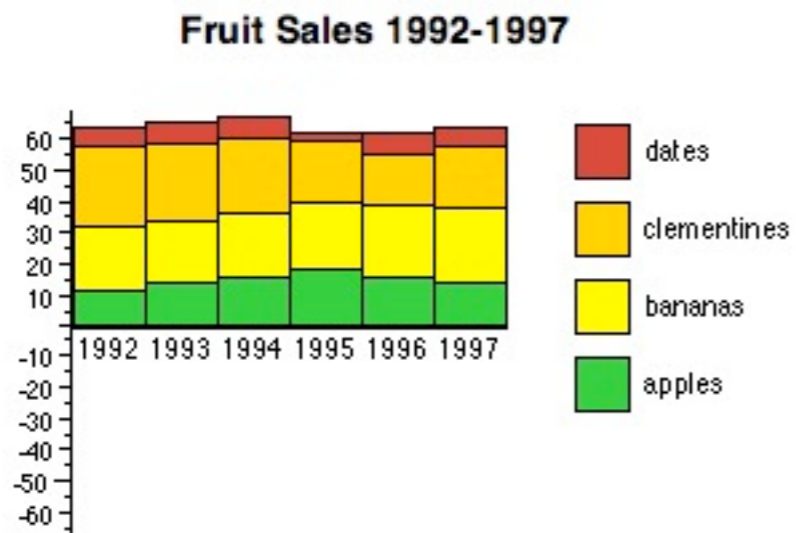
# InfoVis & Interaction

- Information Visualization research: focus on finding novel visual representations
- Recently one can observe an increasing interest in interaction design, HCI models and evaluation as well as aesthetics
- HCI Interaction models help us to better understand the complex concepts of human-machine communication
- Norman's execution-evaluation cycle (Norman 1988)
  - 1. Establishing the goal
  - 2. Forming the intention
  - 3. Specifying the action sequence
  - 4. Executing the interaction
  - 5. Perceiving the system state
  - 6. Interpreting the system state
  - 7. Evaluating the system state with respect to the goals and intentions



# Simple Interaction Example

- Stacked histogram
  - how are the banana sales progressing???
  - <http://www.hiraeth.com/alan/topics/vis/hist.html>



# Direct Manipulation (DM)

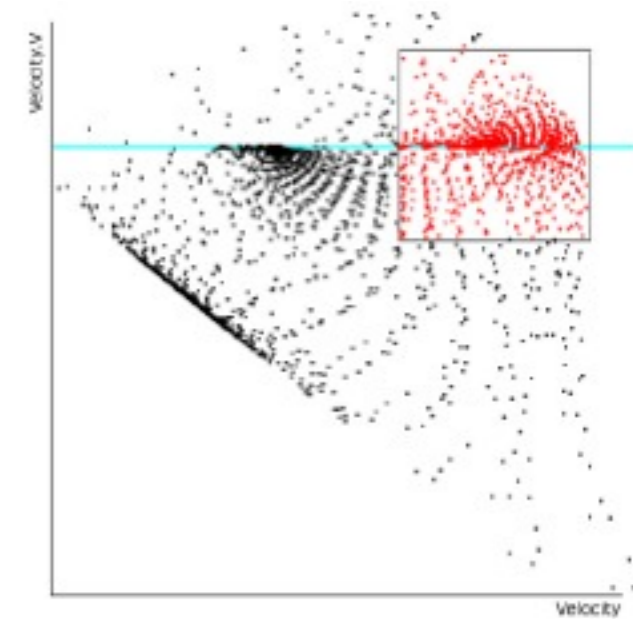
- Shneiderman 1982
- DM features
  - Visibility of the objects of interest
  - Incremental action at the interface with rapid feedback on all actions
  - Reversibility of all actions, so that users are encouraged to explore without penalties
  - Syntactic correctness of all actions, so that every user action is a legal operation
  - Replacement of complex command languages with actions to manipulate directly the visible objects
- DM does not only make interaction easier for novice users but fundamentally extends visualization capabilities

# Common Interaction Techniques

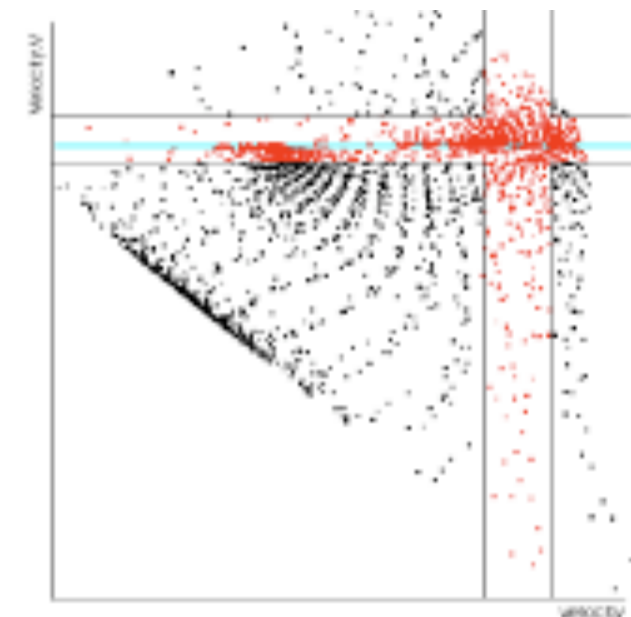
- **Details-on-demand**
  - Provides improved scalability by displaying information about data case(s) on demand to the user
  - View may move from aggregation of objects to the elements contained
- **Direct Walk**
  - Linkage between cases
  - Exploring one case may lead to another (e.g. hyperlinks on news page)
- **Manipulate View**
  - Rearrange view (e.g. move view position, sorting items in a table)
  - Change representation (e.g. from histogram to scatterplot)
- **Linking**
  - Connection between multiple views of the same data space
  - Updating one view means updating all

# Brushing

- Becker & Cleveland 1987
- A collection of dynamic methods for viewing multidimensional data
- Brush is an interactive interface tool to select / mark subsets of data in a single view, e.g. by sweeping a virtual brush across items of interest
- Given linked views (e.g. scatterplot matrix) the brushing can support the identification of correlations across multiple dimensions (brushing & linking)
- Usually used to visually filter data (via highlighting)
- Additional manipulation / operations may be performed on the subsets (masking, magnification, labeling etc.)
- Different types of brushes (Hauser et al. 2002)
  - Simple brush via sweeping
  - Composite brush: composed multiple single-axis brushes by the use of logical operators
  - Angular brush
  - Smooth brush



AND-brush

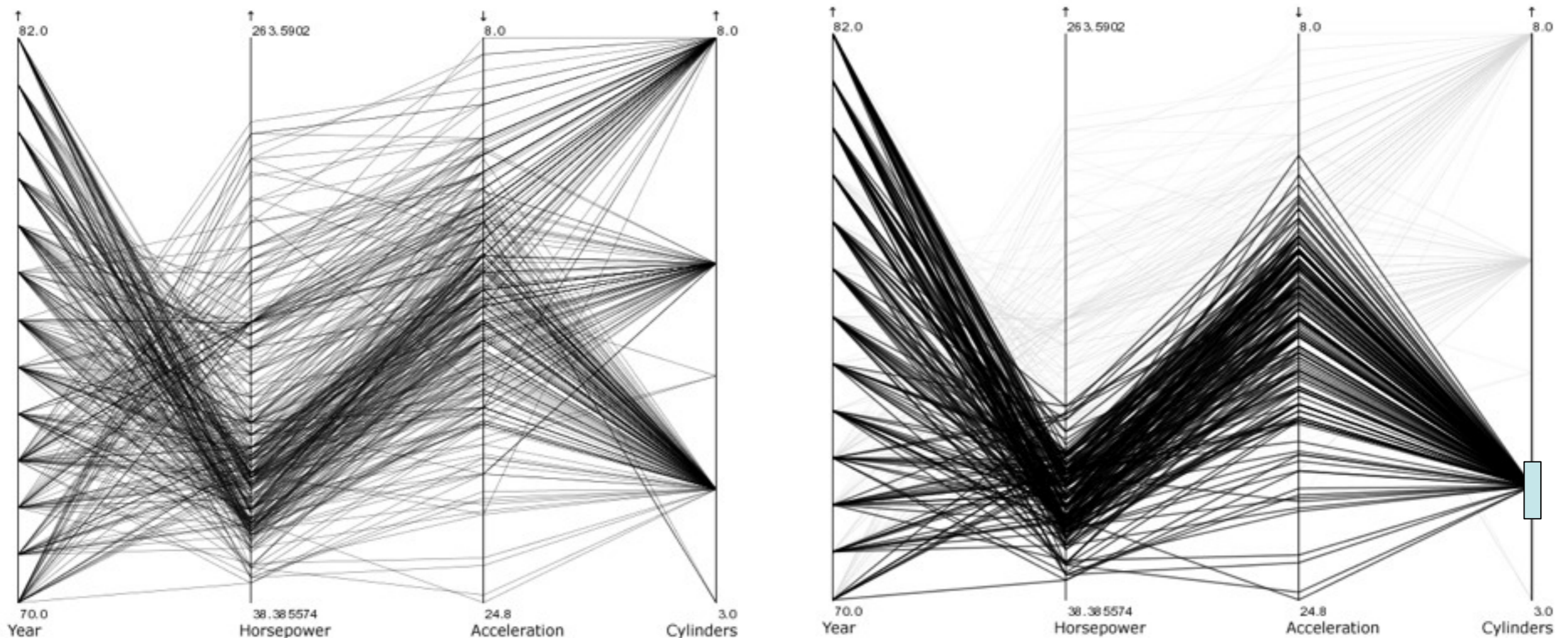


OR-brush

Composite scatterplot brushes - Hauser et al. 2002

# Brushing Example

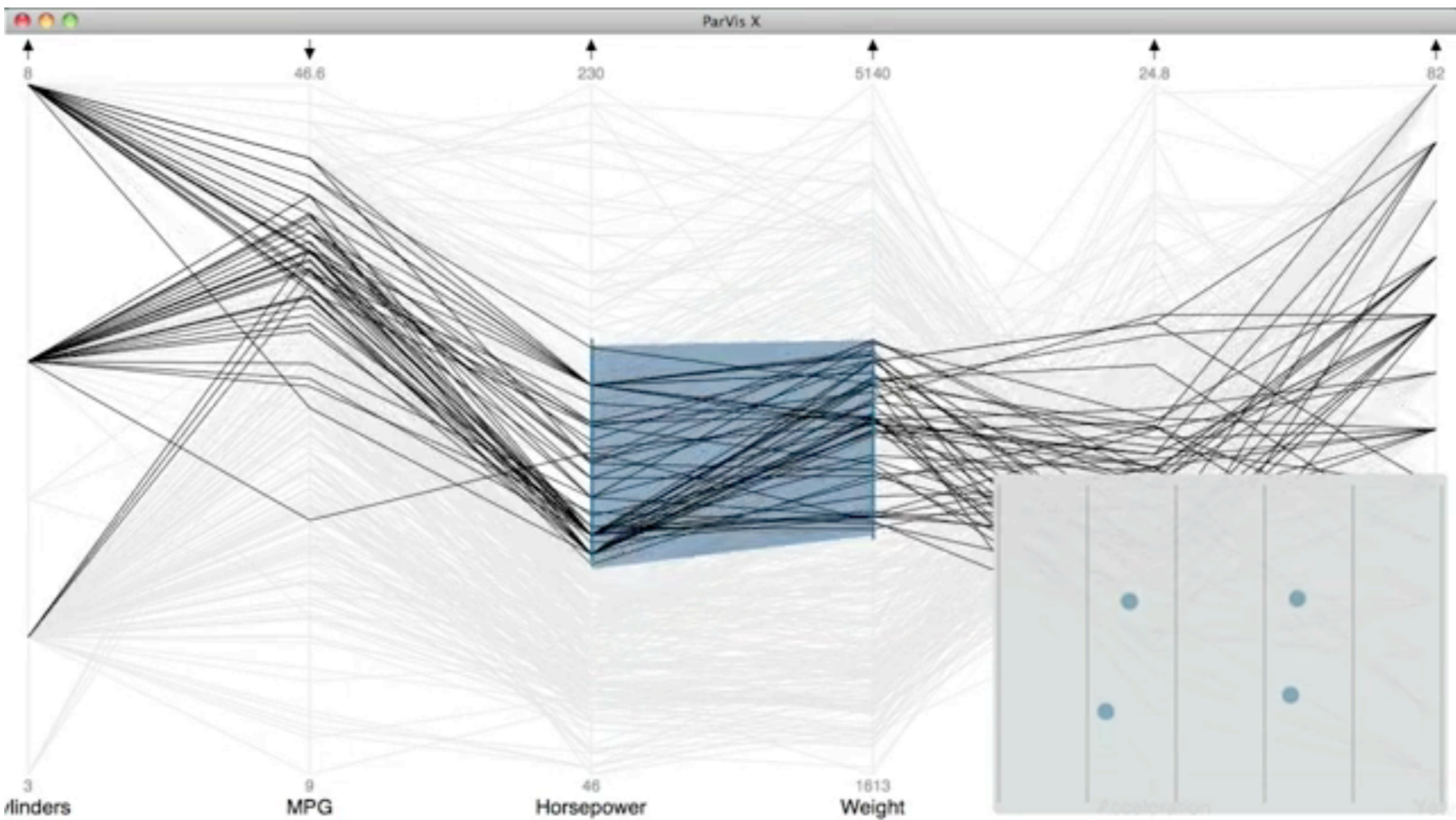
- Brushing one dimension in parallel coordinates to highlight car data objects with 4 cylinders



Hauser et al. 2002



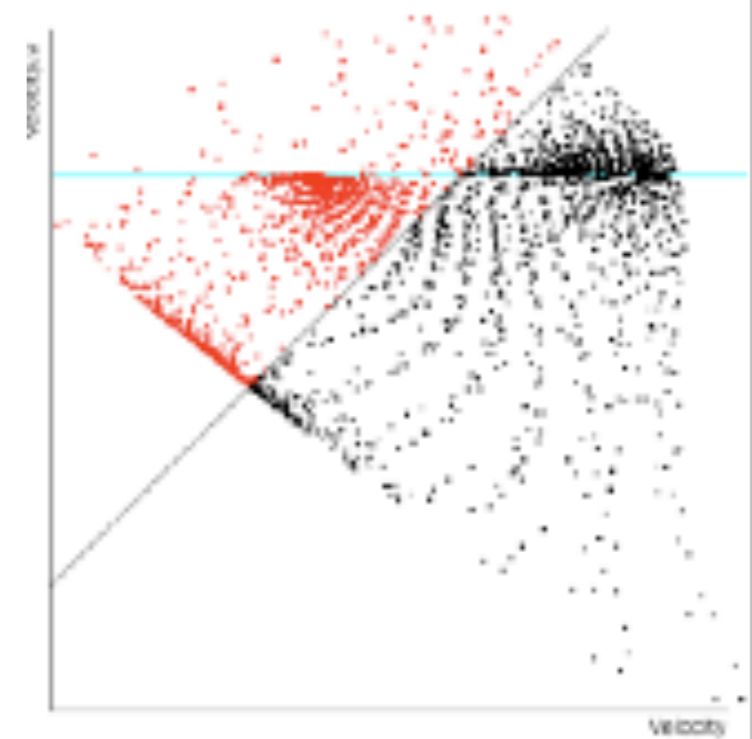
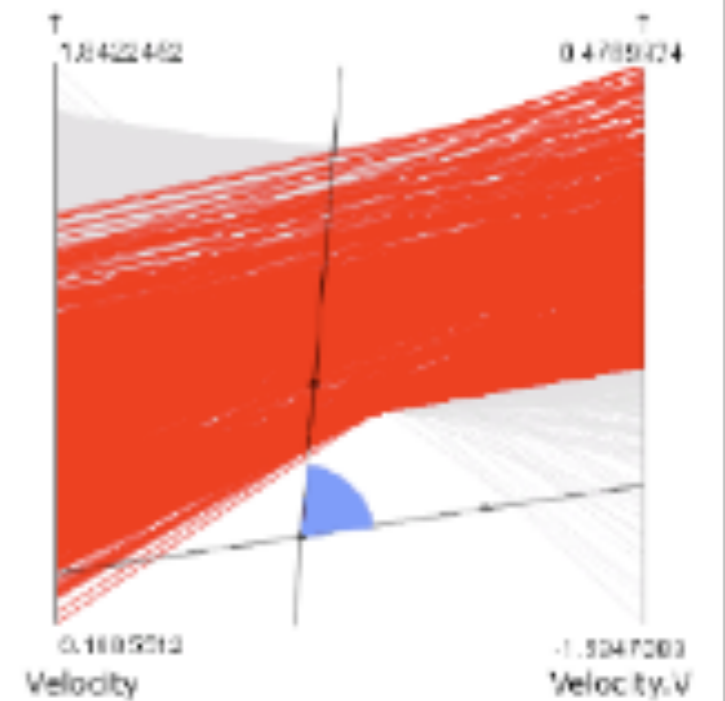
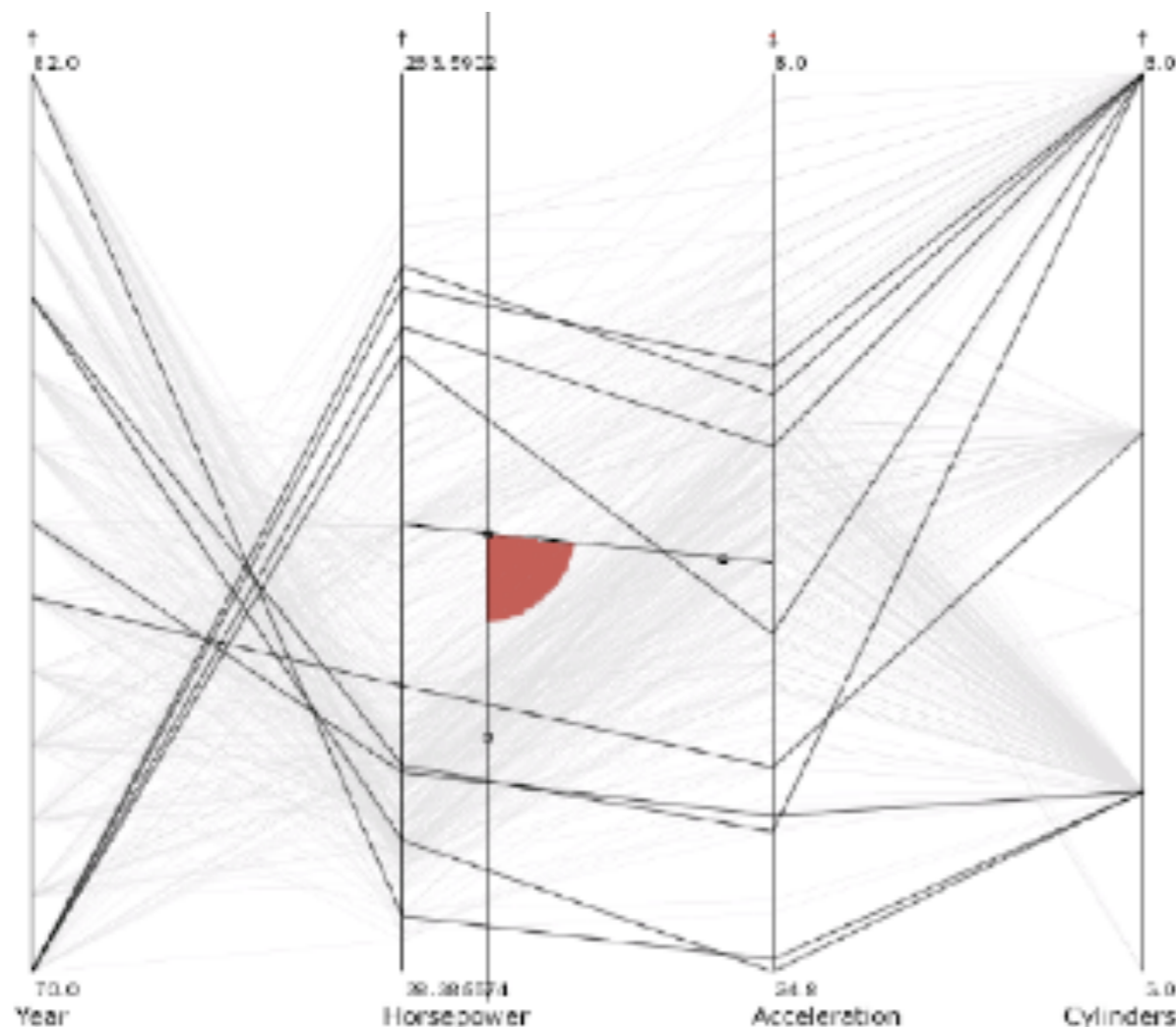
# Brushing a parallel coordinate plot



Robert Kosara, Poster: Indirect Multi-Touch Interaction for Brushing in Parallel Coordinates, IEEE Information Visualization Posters, 2010.

# Angular Brush

- Angular brush: brushing by specifying a slope range – highlight correlation and outliers between two dimensions

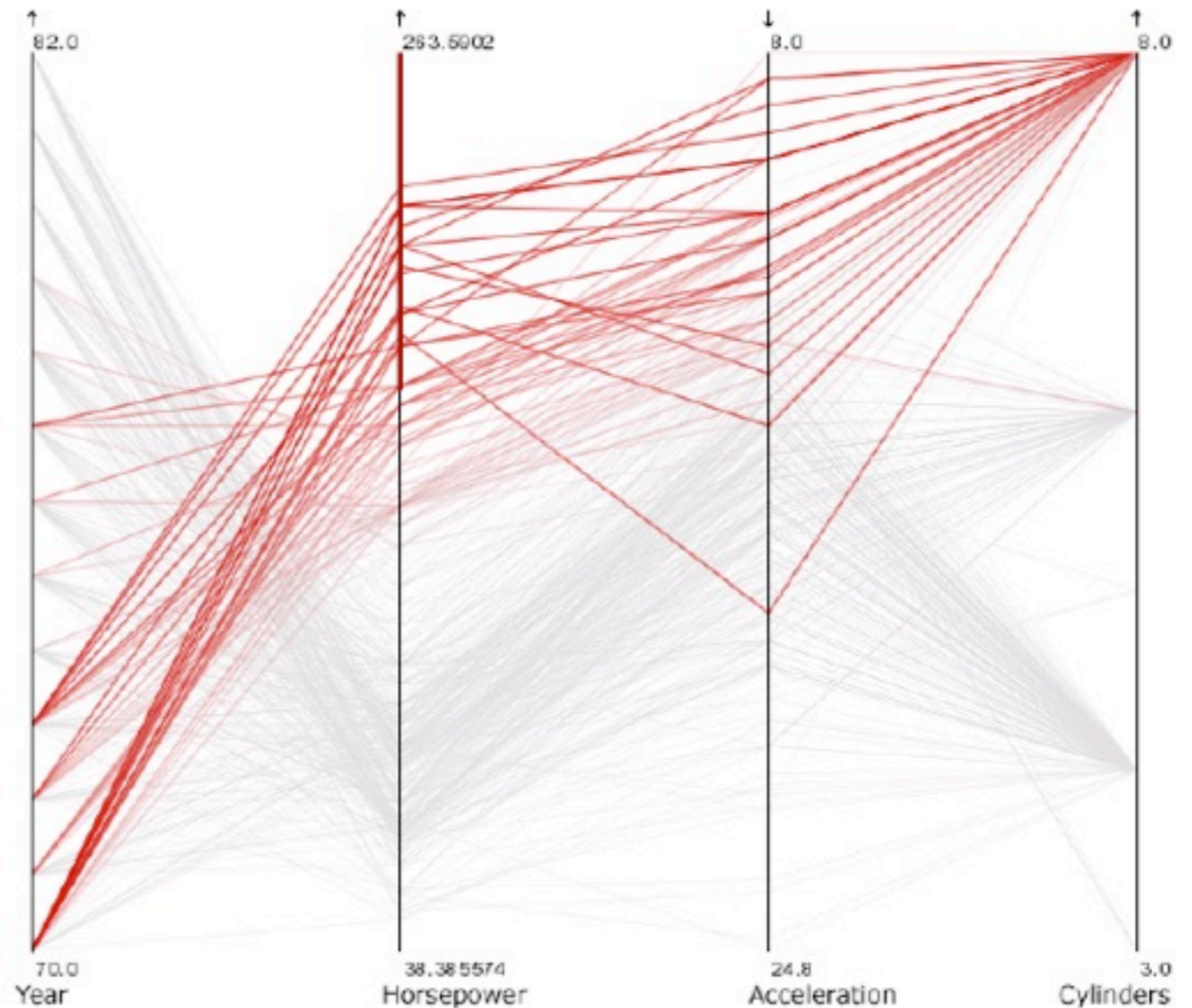


angular brush

Hauser et al. 2002

# Smooth Brush

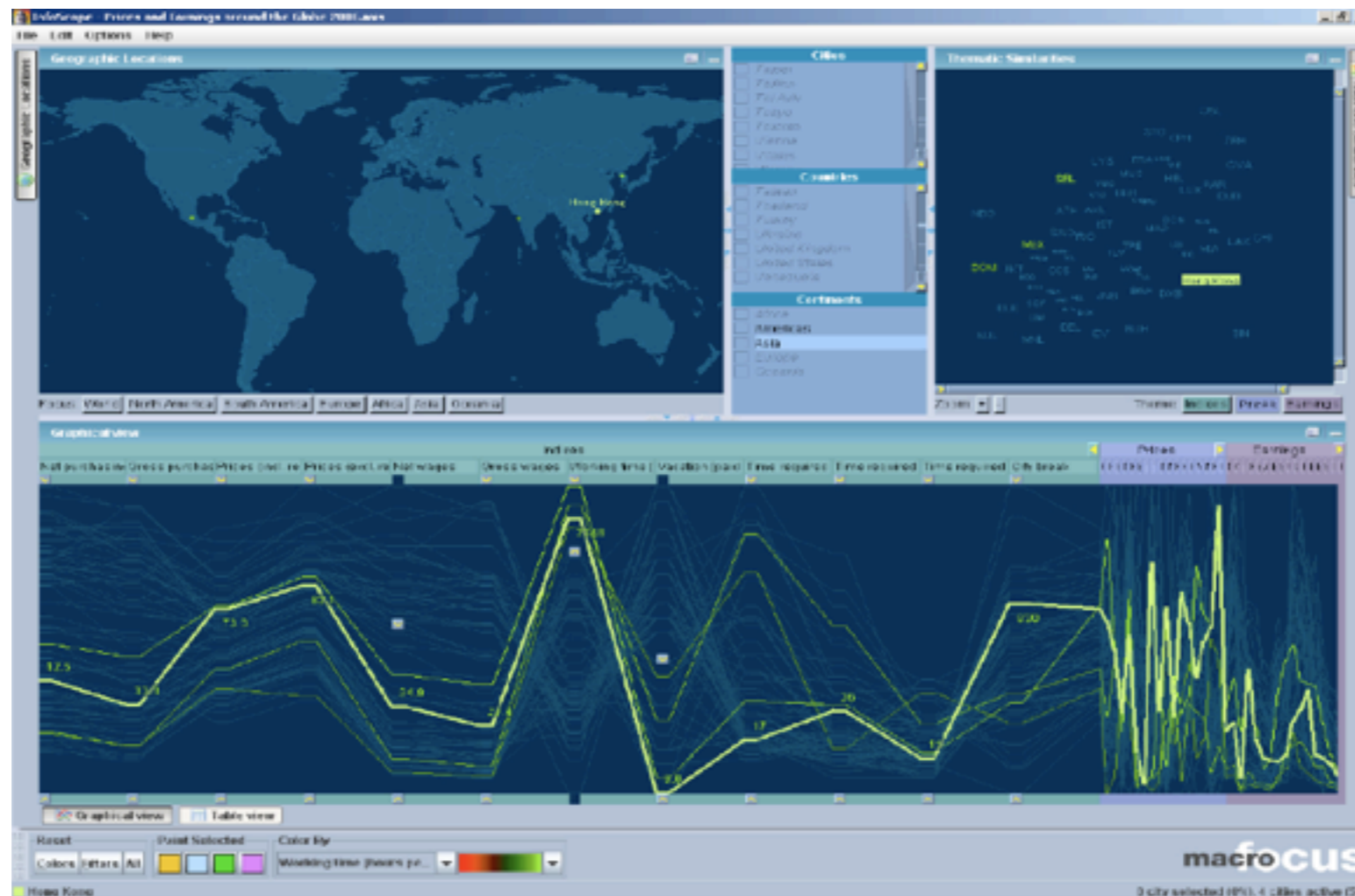
- Non-binary brushing
- Degree-of-interest defined by distance to brushed range
- Decreasing degree is mapped to decreasing drawing intensity



Hauser et al.  
2002

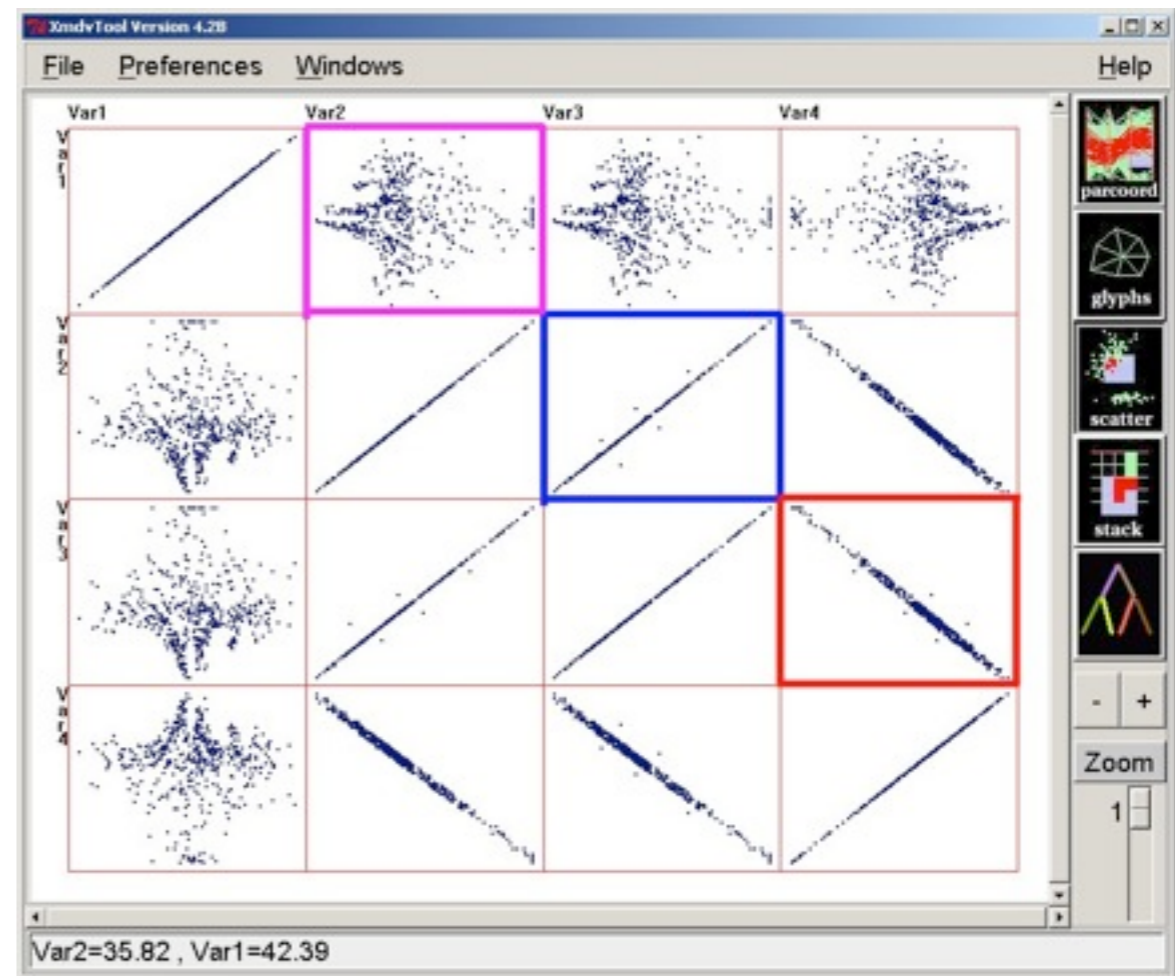
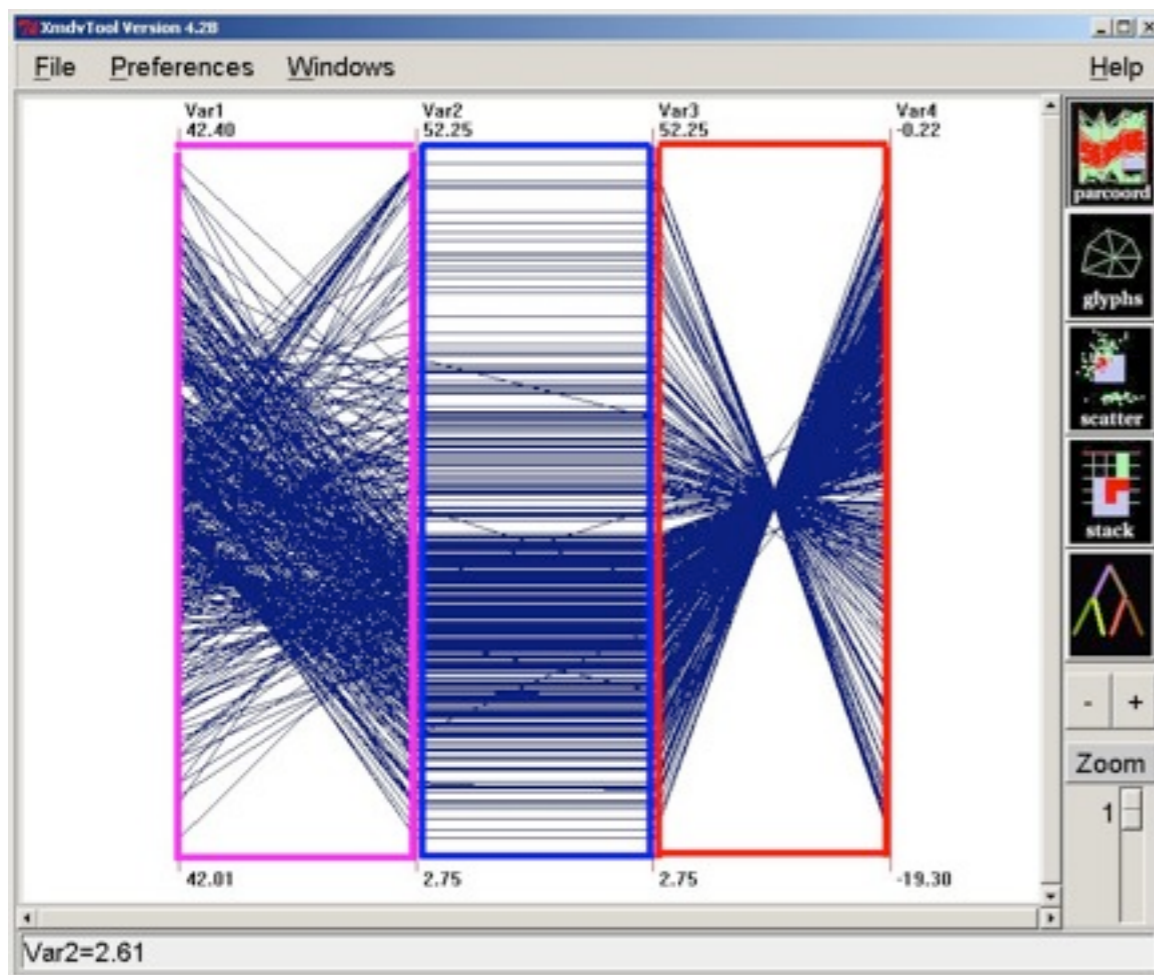
# Another Brushing Example

- Example for composite (AND) brush in Parallel Coordinate Plot – find the cities with high wages, small prices and many paid holiday days
- Demo InfoScope: <http://www.macrofocus.com/public/products/infoscope.html> (free trial and applet)



# Correlation Patterns in Parallel Coordinates

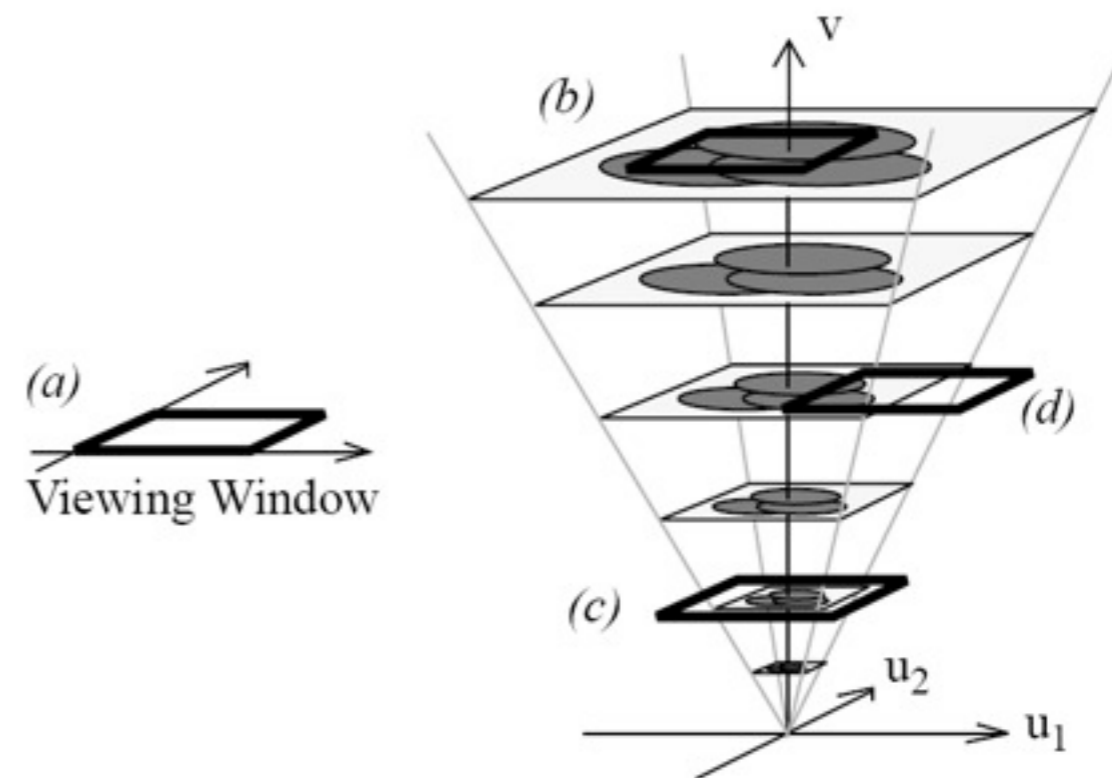
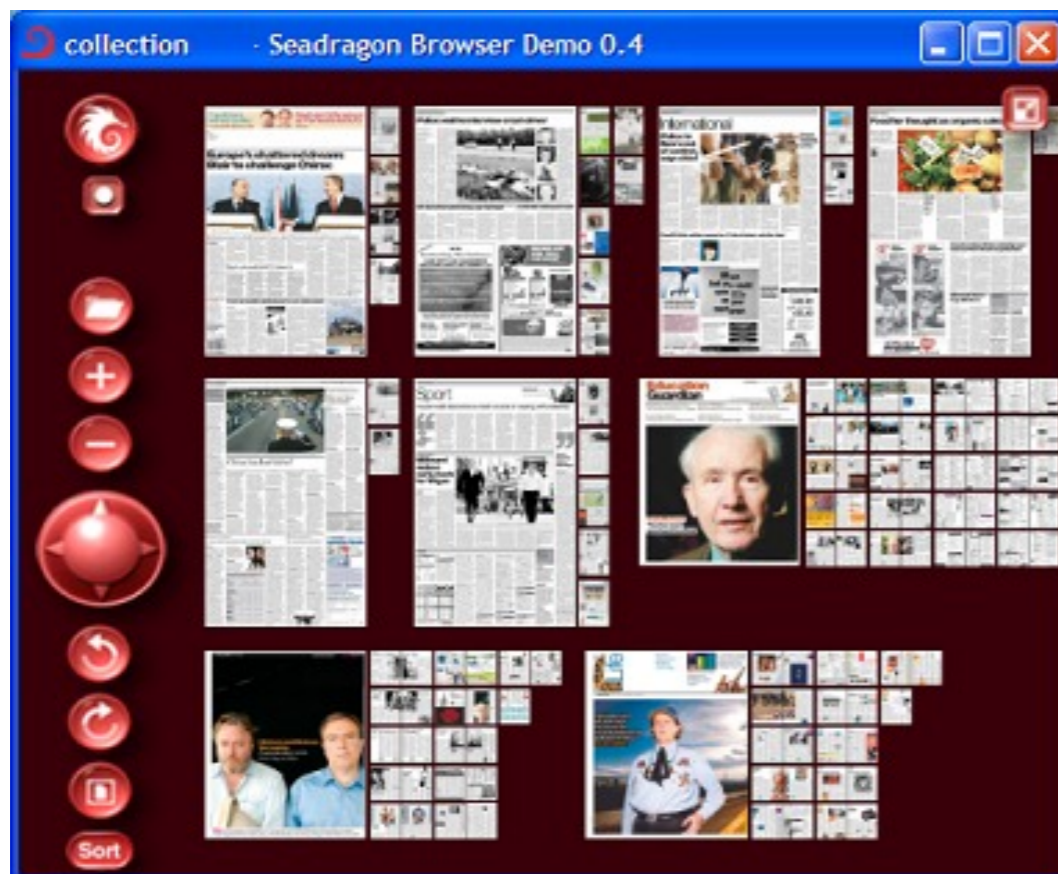
- Var1-Var2 has no correlation; Var2-Var3 has very strong positive correlation; Var3-Var4 has very strong negative (inverse) correlation



<http://www.evl.uic.edu/aej/526/kyoung/Training-parallelcoordinate.html> 8-(now dead)

# Zooming & Panning

- Moving from overview to detail: another way to filter data / focus on a subset of data
- Scale and translation of the viewport
- Geometrical versus semantic zooming
- Topic of a lecture to come (lecture 10: presentation I)



Furnas & Bederson 1995

# Dynamic Queries

- Shneiderman 1994
- Explore and search databases
- SQL example: `SELECT customer_id, customer_name, COUNT(order_id) as total FROM customers INNER JOIN orders ON customers.customer_id = orders.customer_id GROUP BY customer_id, customer_name HAVING COUNT(order_id) > 5 ORDER BY COUNT(order_id) DESC`
- Problems
  - Takes time to learn
  - Takes time to formulate and reformulate
  - User must know what she is looking for – only exact matches
  - Lots of ways to fail
  - SQL error messages helpful?
  - Zero hits – what component is to be changed?

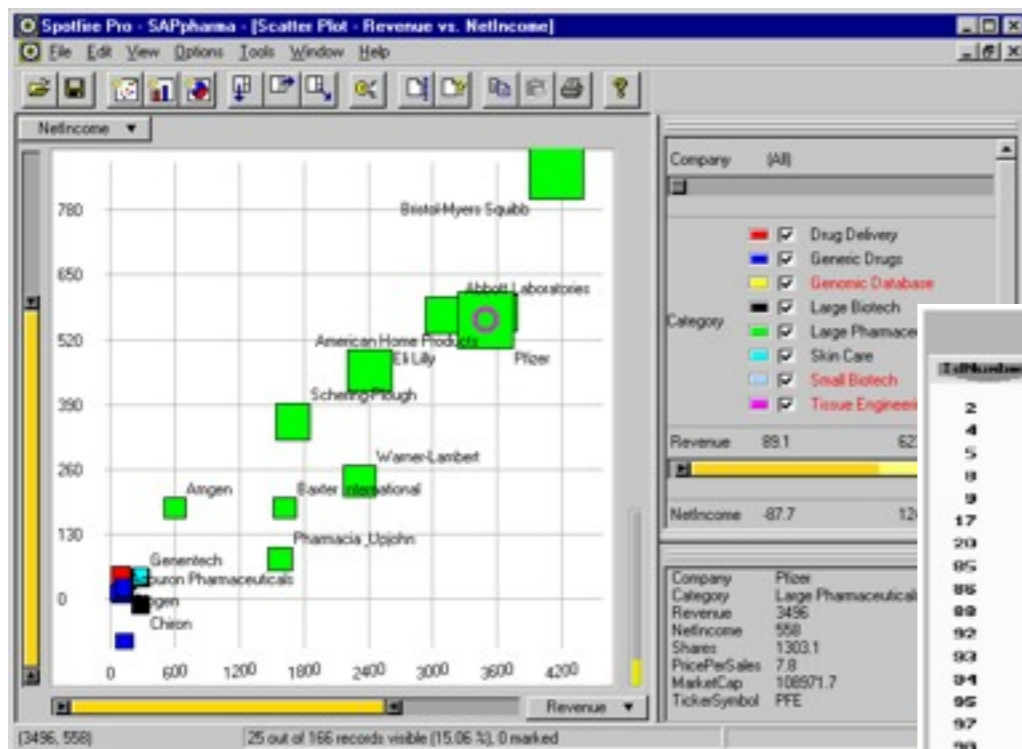
# Dynamic Queries

- Based on Direct Manipulation (DM)
- DM principles with regard to Dynamic Queries
  - Visual presentation of the query's components
  - Visual presentation of results
  - Rapid, incremental, and reversible control of the query
  - Selection by pointing, not typing
  - Immediate, continuous feedback
- Implementation approach
  - Graphical query formulation: Users formulate queries by adjusting sliders, pressing buttons, bounding box selection...
  - Search results displayed are continuously updated (< 100 ms)



# Examples

- Visual representations of data to query?
- Some examples: geographic data, starfields, tables etc.



Shneiderman 1994

HELPER CENTER USER GUIDE CENTER HELP CENTER ONLY  
University of Maryland Human-Computer Interaction Lab  
(Course Publ. 1992)  
National Center for Health Statistics

Dynamic Browser : DC Home Finder

IdNumber	Dwelling	Address	City
2	House	5258 S. Capitol St.	Beltsville, MD
4	House	5538 S. Lincoln St.	Beltsville, MD
5	House	5185 Jones Street	Beltsville, MD
8	House	5807 Jones Street	Beltsville, MD
9	House	4872 Jones Street	Beltsville, MD
17	House	5408 S. Capitol St.	Beltsville, MD
20	House	5496 S. Capitol St.	Beltsville, MD
85	Condo	5458 S. Lincoln St.	Laurel, MD
86	Condo	5051 S. Lincoln St.	Laurel, MD
88	Condo	5158 Hamilton Street	Laurel, MD
92	Condo	5132 Hamilton Street	Laurel, MD
93	Condo	5221 S. Lincoln St.	Laurel, MD
94	Condo	5043 S. Lincoln St.	Laurel, MD
95	Condo	4870 Jones Street	Laurel, MD
97	Condo	4877 Jones Street	Laurel, MD
98	Condo	4896 S. Capitol St.	Laurel, MD
99	Condo	5048 S. Capitol St.	Laurel, MD
100	Condo	4597 31st Street	Laurel, MD
101	Condo	5308 S. Lincoln St.	Laurel, MD
103	Condo	5562 Glass Road	Laurel, MD
105	Condo	5548 Hamilton Street	Laurel, MD
152	House	7670 31st Street	Upper Marlboro, MD

# HomeFinder

- One of the first DQ interfaces
- Williamson & Shneiderman 1983(!)

The yellow dots above are homes in the DC area for sale. You may get more information on a home by selecting it. You may drag the 'A' and 'B' distance markers to your office or any other location you want to live near. Select distances, bedrooms, and cost ranges by dragging the corresponding slider boxes on the right. Select specific home types and services by pressing the labeled buttons on the right.

Dynamic HomeFinder

Reset Quit

Save Print

Dist to A:  
1 30  
19

Dist to B:  
1 30  
6

Bedrooms:  
1 7  
2 4

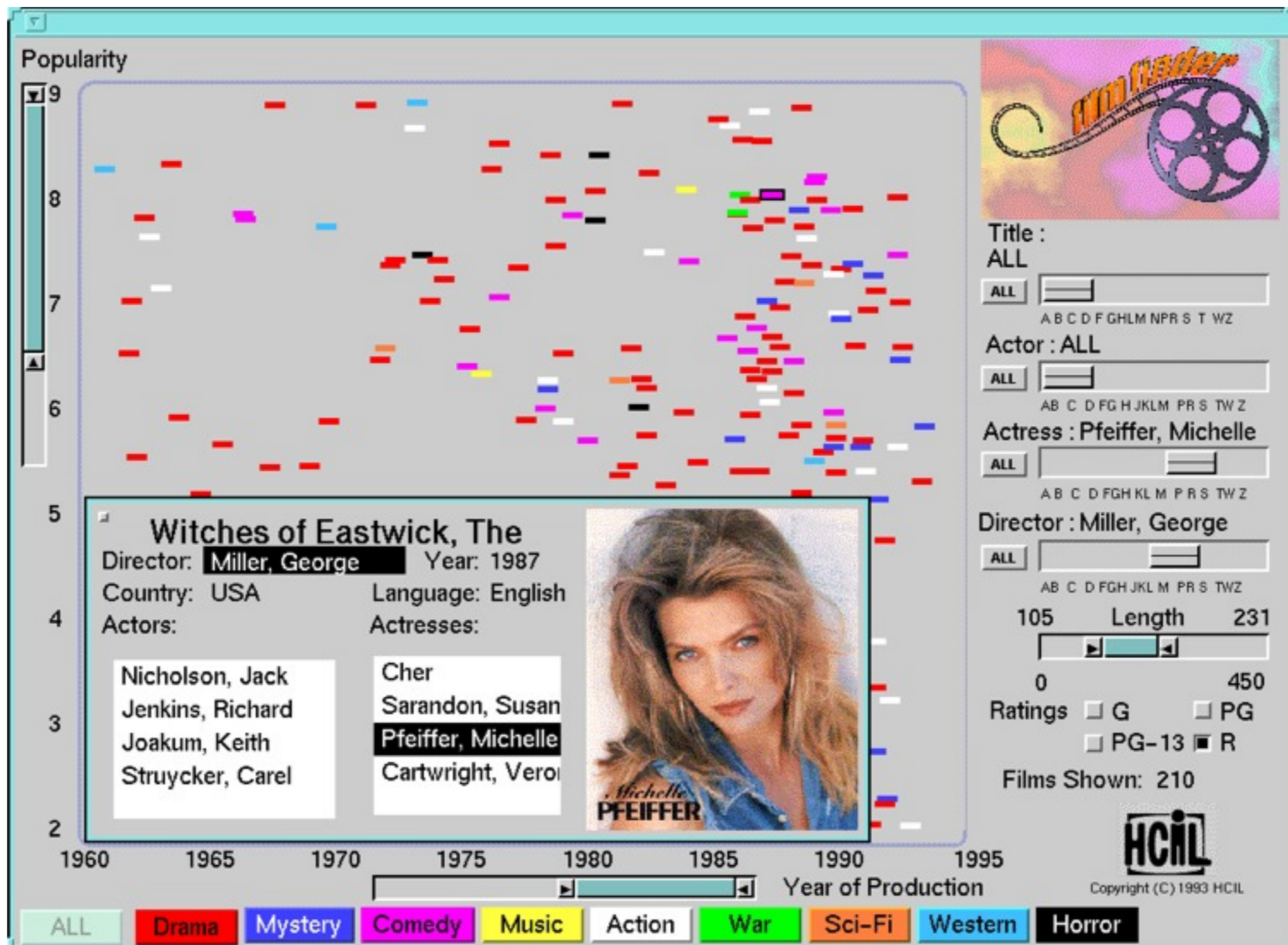
Cost:  
\$50k \$500k  
16 38

Look at:  
Hse TH Cnd

Features:  
Grg Fp1  
CAC New

# FilmFinder

- Ahlberg & Shneiderman 1994



# Dynamic Queries Online

- Online examples: <http://immo.search.ch> and diamond search (<http://www.bluenile.com>)

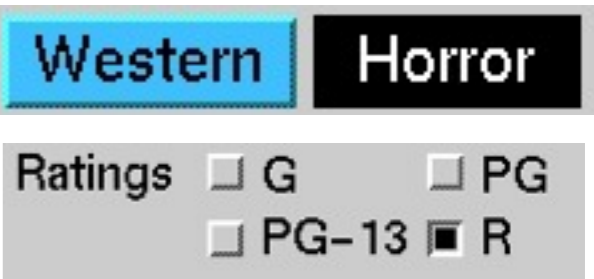
The screenshot shows the 'immo.search.ch' website interface. At the top, there are navigation links and a search bar. Below the search bar, there are filters for 'Wohnung' (Apartment), 'Preis' (Price) set to 240k, and 'Zimmer' (Rooms) set to 2-3. A list of search results is shown on the left, with columns for 'ID', 'Preis', 'Zimmer', 'Fläche', and 'm²'. A map view is visible on the right side of the page.

The screenshot shows the 'Search for Diamonds' interface. It includes a 'Refine Search Criteria' section with a table for selecting diamond characteristics. The table has columns for Shape, Carat, Cut, Color, Clarity, and Price. The 'Shape' column has radio buttons for Round, Princess, Emerald, Asscher, Marquise, Oval, Radiant, Pear, Heart, and Cushion. The 'Carat' column has a range from 0.50 to 0.99. The 'Cut' column has radio buttons for Signature Ideal, Ideal, Very Good, Good, and Fair. The 'Color' column has radio buttons for D, E, F, G, H, I, and J. The 'Clarity' column has radio buttons for IF, VS1, VS2, VSI, SI1, SI2, and S12. The 'Price' column shows a range from \$2,672 to \$764,360.

Your Search Results: 2,821 Diamonds

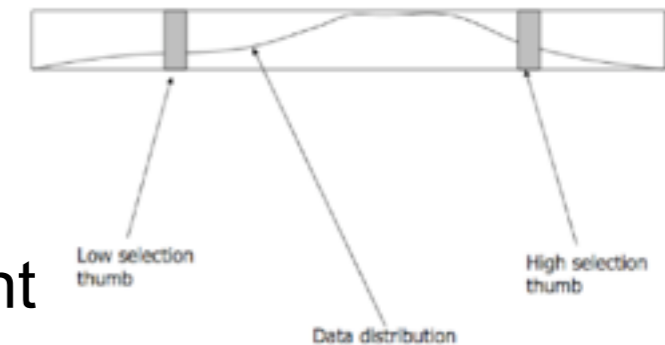
Compare	Shape	Carat	Cut	Color	Clarity	Polish	Symmetry	Report	Price	Details
<input type="checkbox"/>	Round	0.72	Very Good	G	VS1	VG	VG	GIA	\$2,872	view details
<input type="checkbox"/>	Round	0.75	Very Good	H	VS1	EX	VG	GIA	\$2,873	view details
<input type="checkbox"/>	Round	0.77	Very Good	E	SI1	VG	EX	GIA	\$2,874	view details
<input type="checkbox"/>	Round	0.79	Very Good	F	VS2	EX	ID	AQBL	\$2,874	view details
<input type="checkbox"/>	Round	0.79	Very Good	F	VS2	EX	ID	AQSL	\$2,874	view details
<input type="checkbox"/>	Round	0.79	Good	D	VS2	EX	VG	GIA	\$2,876	view details
<input type="checkbox"/>	Oval	0.71	Very Good	F	VS2	G	G	GIA	\$2,877	view details
<input type="checkbox"/>	Round	0.89	Very Good	G	SI2	EX	VG	GIA	\$2,877	view details
<input type="checkbox"/>	Round	0.78	Very Good	H	VS1	G	VG	AQBL	\$2,878	view details
<input type="checkbox"/>	Round	0.80	Good	H	VS1	VG	EX	GIA	\$2,879	view details
<input type="checkbox"/>	Round	0.53	Very Good	D	VS1	EX	EX	AQBL	\$2,879	view details
<input type="checkbox"/>	Oval	0.80	Good	F	SI2	G	G	GIA	\$2,879	view details
<input type="checkbox"/>	Round	0.75	Very Good	F	SI1	EX	VG	GIA	\$2,879	view details
<input type="checkbox"/>	Oval	0.93	Good	H	SI2	VG	G	GIA	\$2,880	view details
<input type="checkbox"/>	Oval	0.91	Very Good	I	SI1	G	G	GIA	\$2,882	view details
<input type="checkbox"/>	Oval	0.92	Fair	I	SI1	G	G	GIA	\$2,882	view details

# Dynamic Query Controls



- Check boxes and buttons (Nominal with low cardinality)
- Sliders and range slider (ordinal and quantitative data)
- Alph slider (ordinal data) (Ahlberg & Shneiderman 1994)

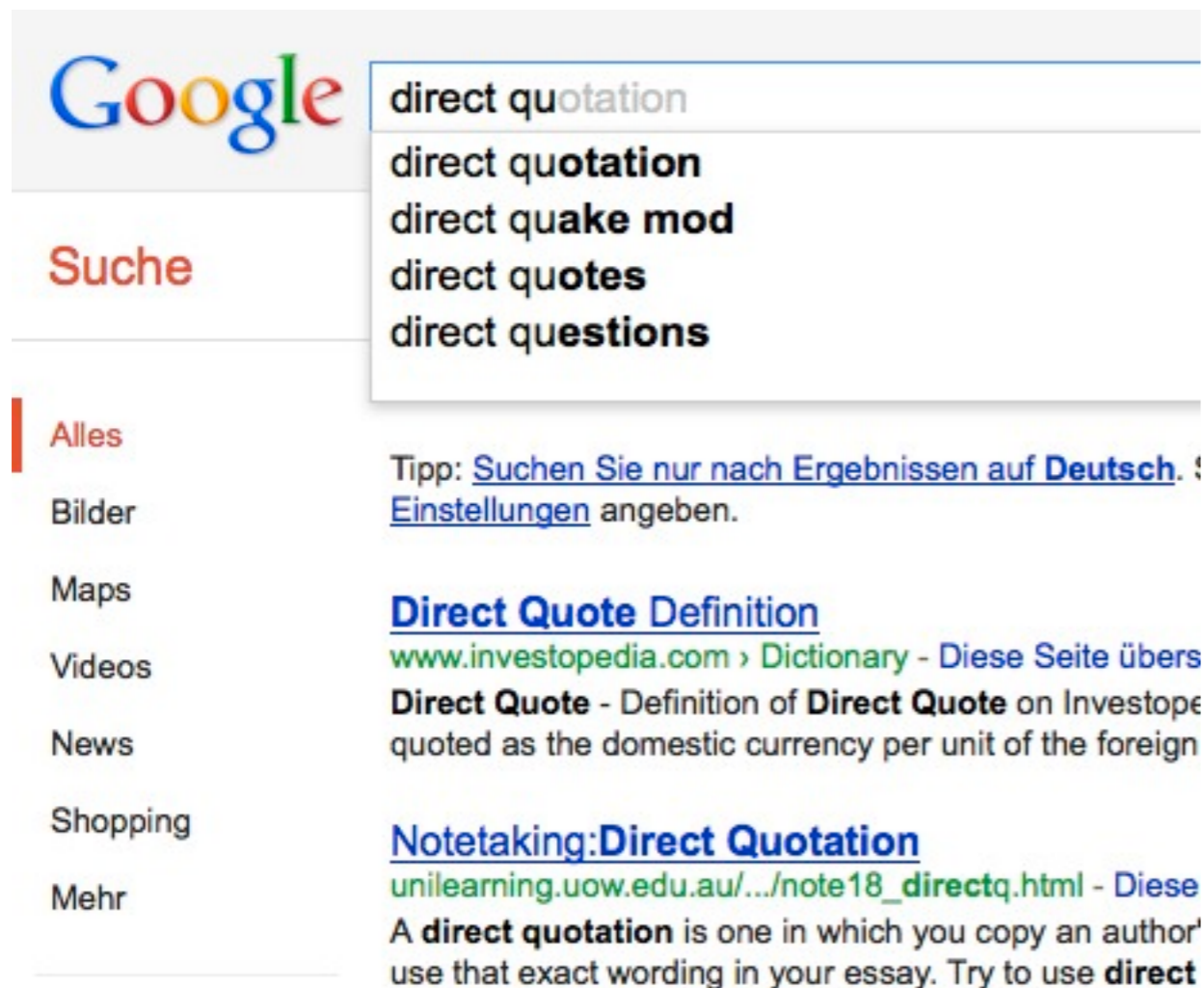
- Small-sized widget to search sorted lists
- Online-text output
- Two-tiled slider thumb for dragging operations with different granularities
- Letter index visualizing the distribution of initial letters – jump to a position in the slider
- Locating an items out of a list of 10,000 items ~ 28s for novice users
- Pros and cons to text entry?



- Redesigned Alph slider for PDAs / MP3 player - movie
- Extend data sliders with data visualization (Eick 1994)

# DQ in current search interfaces

- DQ have become widespread with fast search algorithms and increased computing capacity
  - search happens while typing in search terms in google search
  - new routes are calculated while point is dragged in google maps



Google

Suche

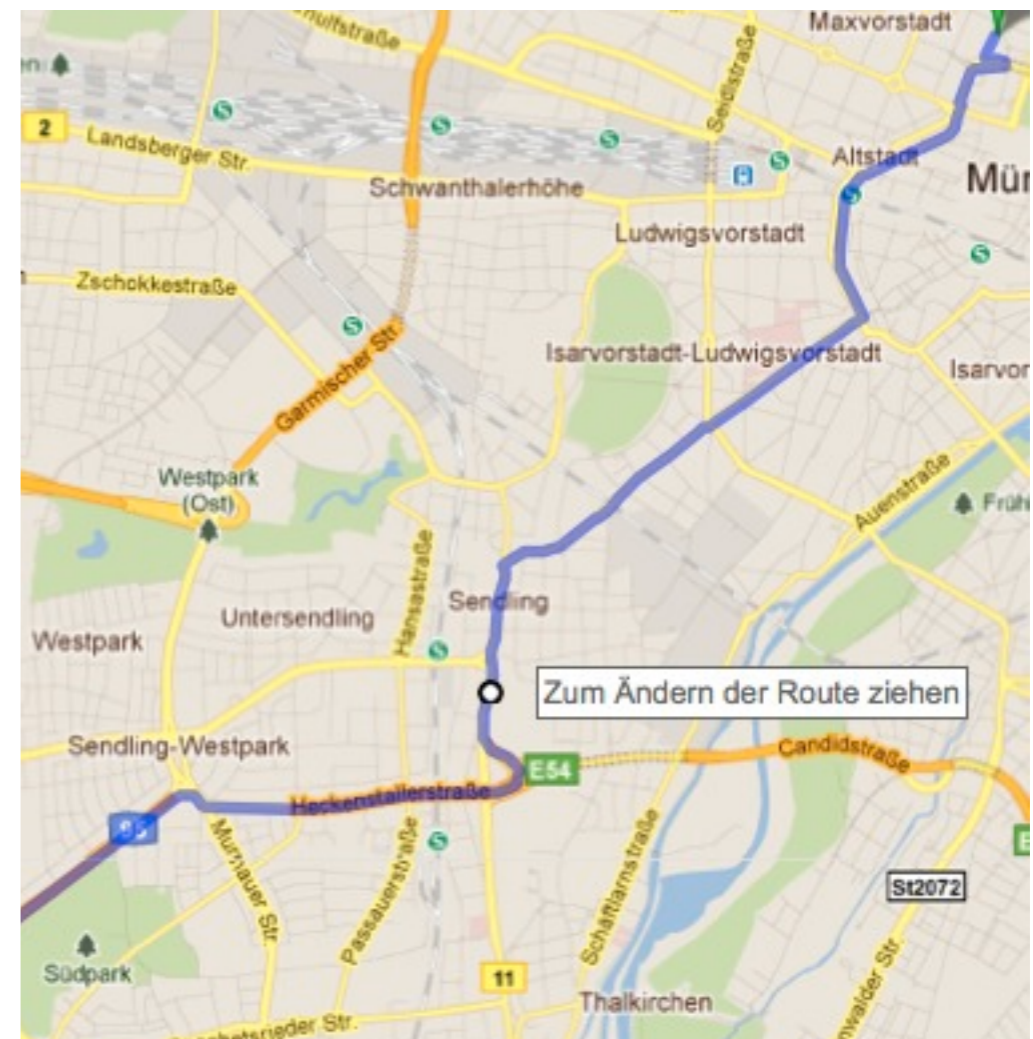
Alles  
Bilder  
Maps  
Videos  
News  
Shopping  
Mehr

direct quotation  
direct quotation  
direct quake mod  
direct quotes  
direct questions

Tipp: [Suchen Sie nur nach Ergebnissen auf Deutsch.](#) [Einstellungen](#) angeben.

[Direct Quote Definition](#)  
[www.investopedia.com > Dictionary](#) - Diese Seite übers **Direct Quote** - Definition of **Direct Quote** on Investop  
quoted as the domestic currency per unit of the foreign

[Notetaking:Direct Quotation](#)  
[unlearning.uow.edu.au/.../note18\\_directq.html](#) - Diese  
A **direct quotation** is one in which you copy an author's  
use that exact wording in your essay. Try to use **direct**



# Summary Dynamic Queries

- Users can rapidly, safely playfully explore a data space – no false input possible
  - Users can rapidly generate new queries based on incidental learning
  - Visual representation of data supports data exploration
  - Analysis by continuously developing and testing hypotheses (detect clusters, outliers, trends in multivariate data)
  - Provides straightforward undo and reversing of actions

Potential problems with DQ as implemented in the FilmFinder?

Limit of query complexity – filters are always conjunctive

Performance is limited for very large data sets and client / server applications

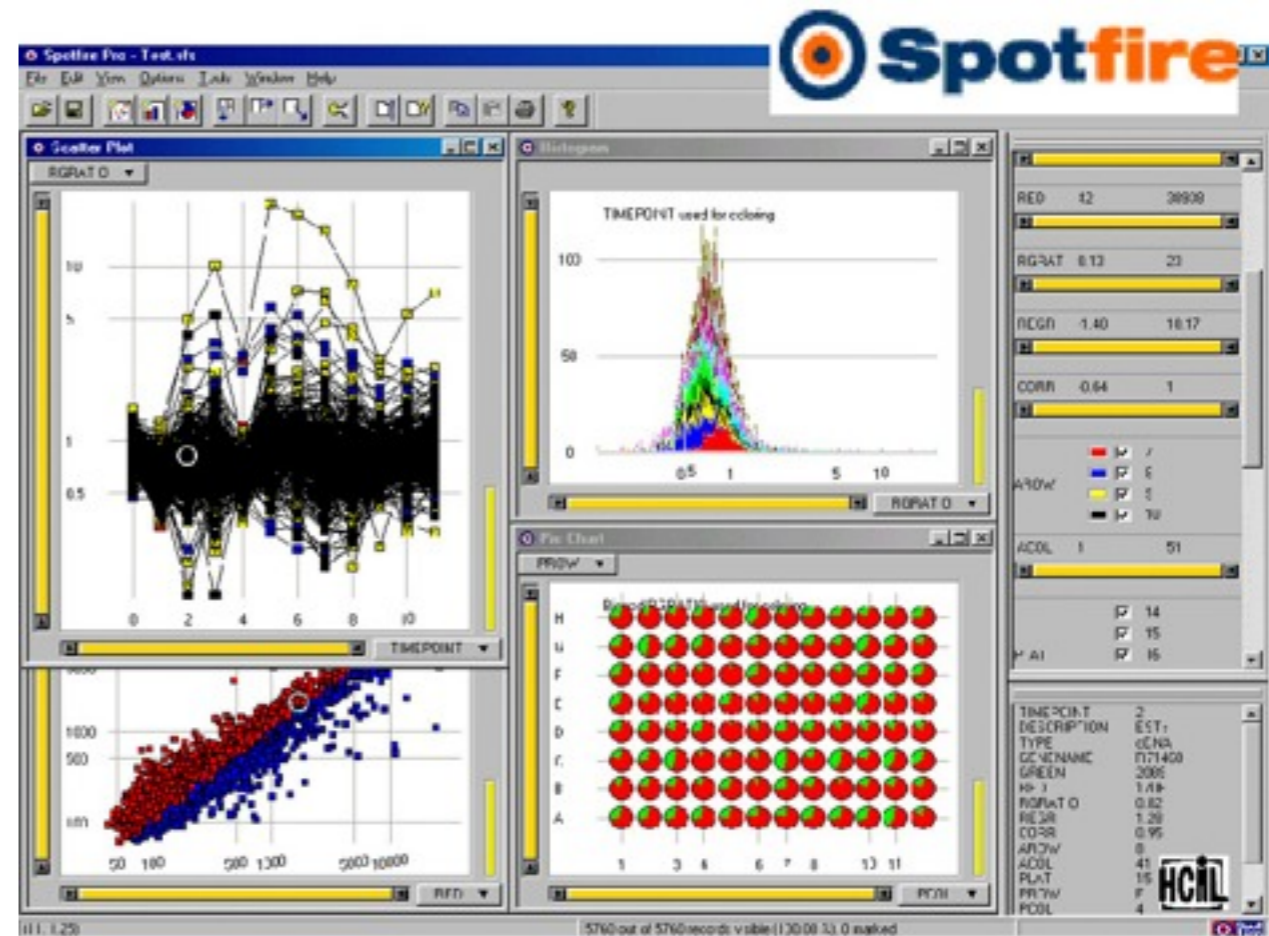
Controls require valuable display space

Information is pruned

Only single range queries and single selection in the alphaslider

# Dynamic Queries

- Starfield displays and Dynamic Queries provided the basis for SpotFire
- Christopher Ahlberg
  - 1991: Visiting student from Sweden at the HCIL University of Maryland
  - 1996: Founder of SpotFire
  - 2007: SpotFire was sold for 195 Mio. \$
- Well done!





# Attribute Explorer

- Tweedie et al. 1994
- Example for DQ, brushing & linking and fuzzy search
- Linked histograms to search and explore multivariate data
- Filtering data via range sliders
- Color-coding to highlight and discriminate data cases across views
- Sensitivity information: visualizes how well data cases meet the filter requirements
- Particularly useful for zero-hits situations

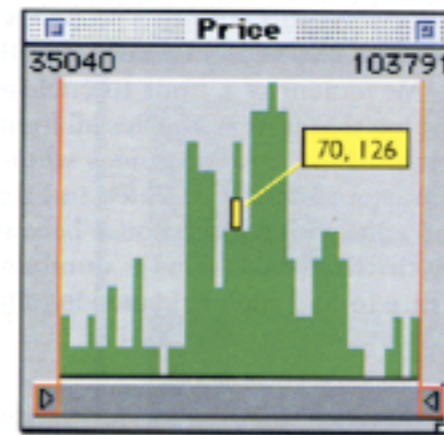
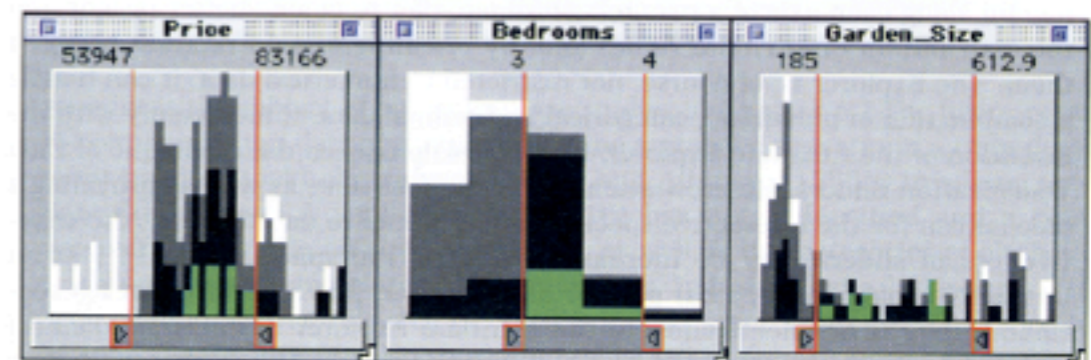


FIGURE 3.55 A histogram representing the prices of a collection of houses. The contribution of one house is shown in yellow



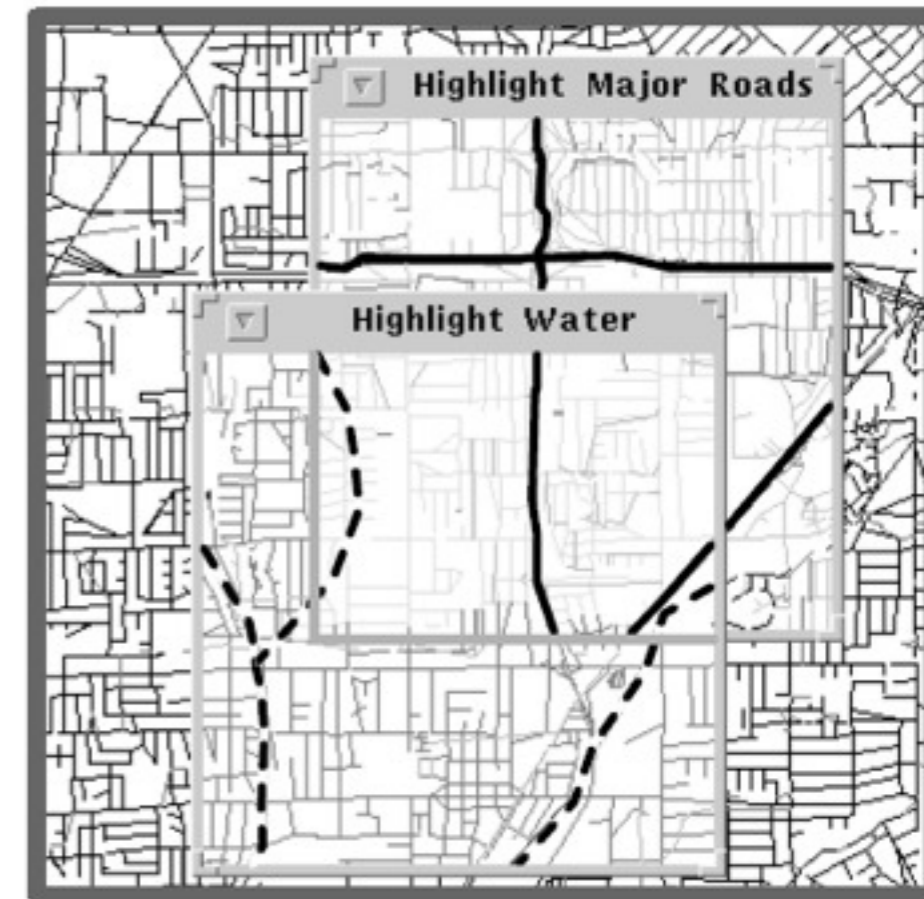
FIGURE 3.56 Limits on Price identify a subset of houses, coded green



Spence 2004

# Dynamic Queries and Movable Filters

- Fishkin and Stone 1995
- Dynamic Queries (DQ)
  - Disjunctive queries can only be performed by sequential querying
  - Effect of DQ is global – no way to limit filtering to only a portion of the data
  - Number of possible queries is fixed in advance
- Combine approach with magic lens filters
  - Arbitrarily-shaped region with an operator that manipulates the view of underlying objects
  - Filters are spatially bounded – global context is maintained
  - Filters that overlap compose their effects in the overlap region



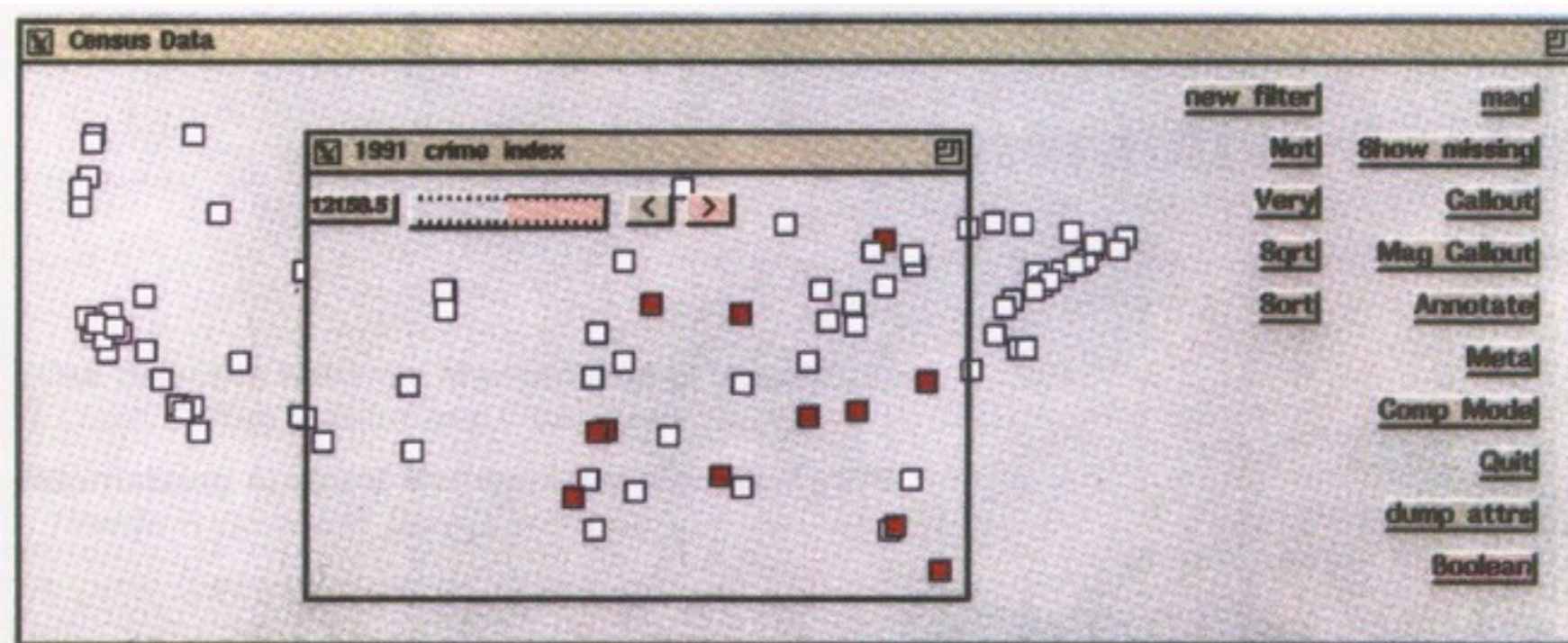
Stone et al. 1994

# Idea & Implementation

- Each lens acts as a filter that screens on some attribute of the data
- Lens components
  - Filtering function (what to filter)
  - Composition mode (how to combine the filter result with lenses underneath, i.e. AND, OR, NOT)
- Composition modes are implemented as buttons on the lens
- Grouping: Replace a stack of lenses by a single compound lens, which also has a composition mode
- Compound lenses may contain other compound lenses
- Boolean queries and grouping allow queries of arbitrary complexity
- Multiple concurrent queries on different portions of the data space

# Simple Range Filter

- Example: US census data, each box represents a city (position mapped to physical location)
- Lens filter (Crime index 1999) covers the center of the country
- Slider to manipulate the value of the query
- Arrow buttons show the direction of the query, i.e. screen data for less than or greater than the slider value
- Red-coded cities pass the filter



Fishkin & Stone 1995

# Composition Modes

- AND (conjunctive), OR (disjunctive)
- SELF: lens only displays the effect of its own filter; other lenses are ignored
- NOP: filter effect of lens is disabled

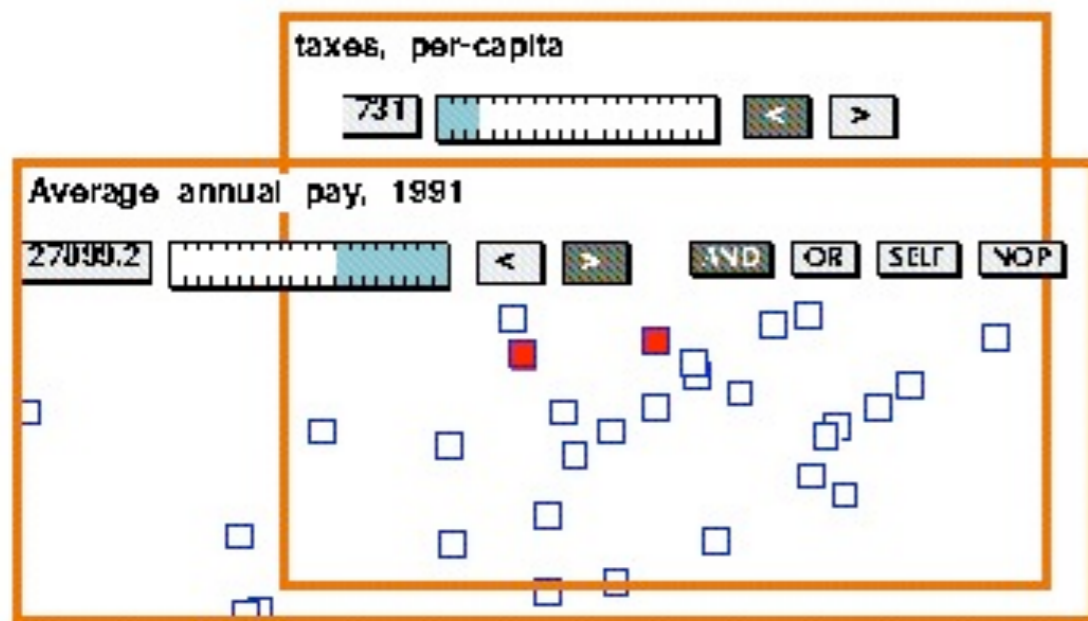


Figure 1(a) High salaries AND low taxes.

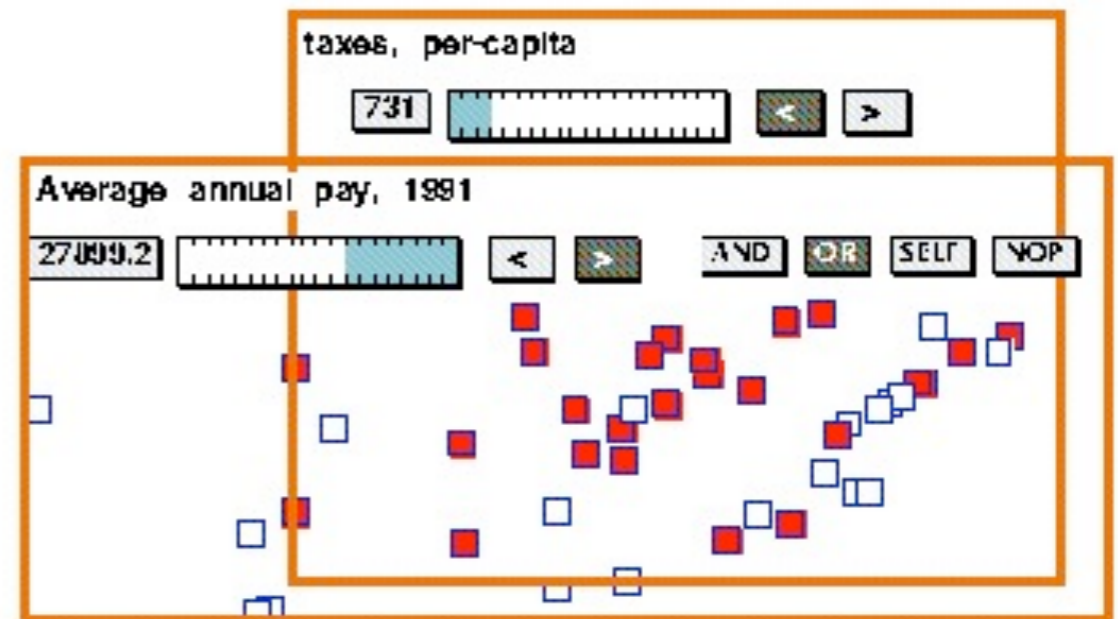


Figure 1(b) High salaries OR low taxes. Both conjunctive (AND) and disjunctive (OR) queries are incorporated in our system.

Fishkin & Stone 1995

# Alternate Views

- Lenses to generate alternate views of the data
- Magnification, verbal description, sorted views etc.
- Cities listed without boxes are missing the value for the filter attribute (missing data)

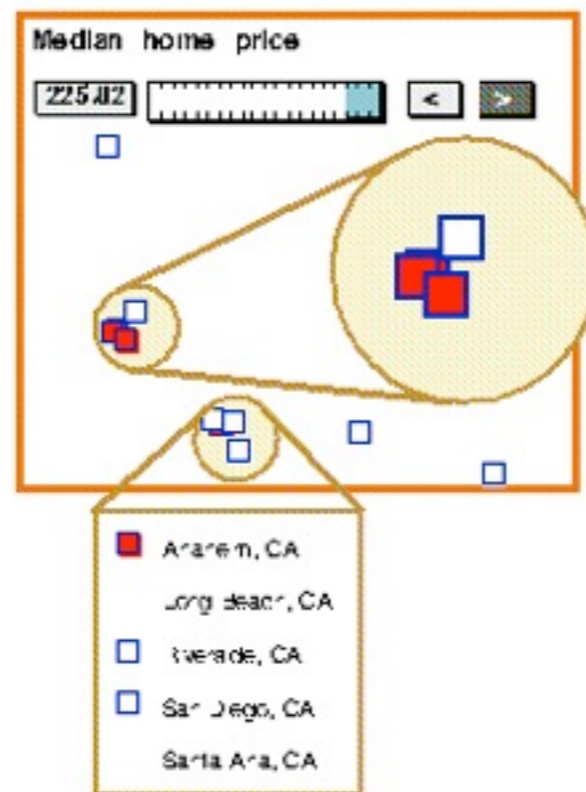
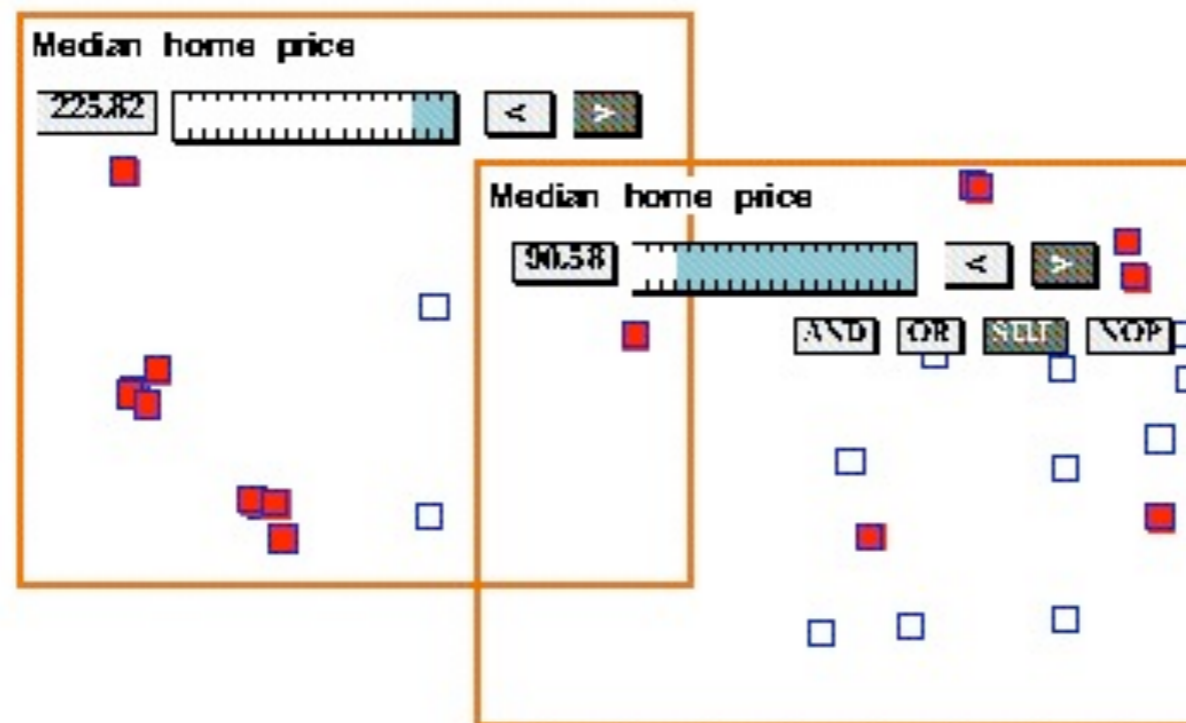


Figure 2. Semantic filters can be augmented with visual filters. Here, a magnifying lens and a call-out lens show clumped cities while maintaining context elsewhere.

Fishkin & Stone 1995

# Local Effects

- “Which cities in California and Texas have relatively low housing prices?”
- With Dynamic Queries we can filter data by global prices (range slider affecting the entire starfield)
- Problem: Houses on the west coast are typically more expensive than houses in the midwest!
- Movable filters allow for concurrent queries on the two areas



Fishkin & Stone 1995

Figure 3. To find relatively high housing prices in California and Texas, two different filters are positioned simultaneously.

# Real-Valued Queries

- Assign a real valued score (range [0...1]) to each datum
  - Cases with a score of 0 fail the filter entirely
  - Cases with intermediate scores partly satisfy the filter
  - Cases with a score of 1 entirely satisfy the filter
- The higher the score the higher is the box filled with red color

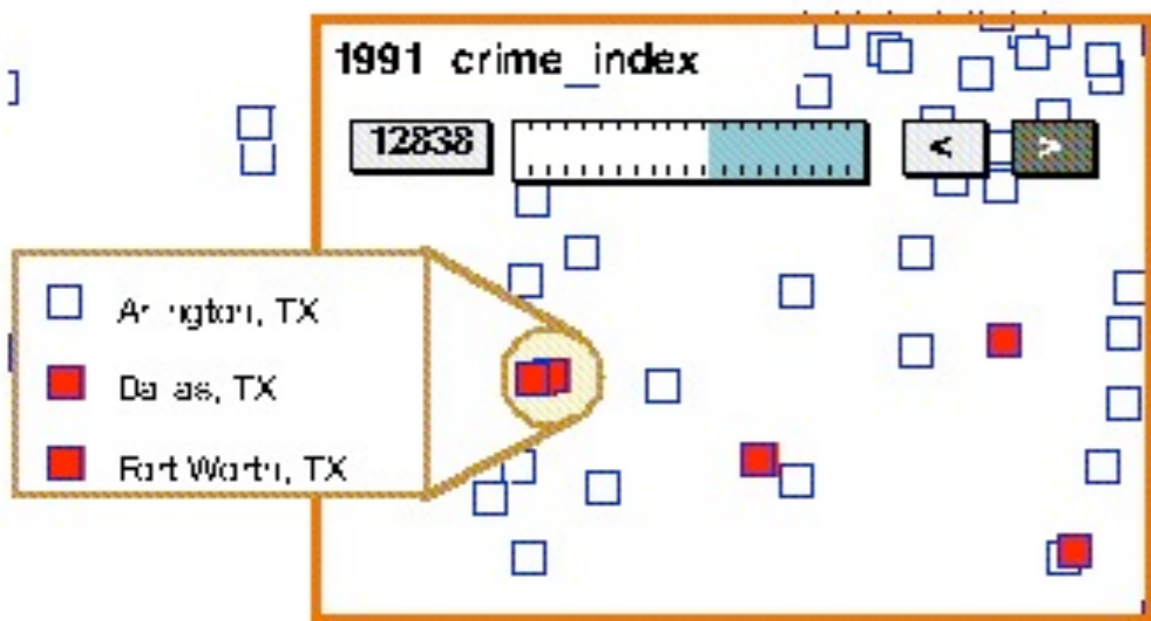


Figure 4(a) boolean query on crime rate for three cities in Texas.

Fishkin & Stone 1995

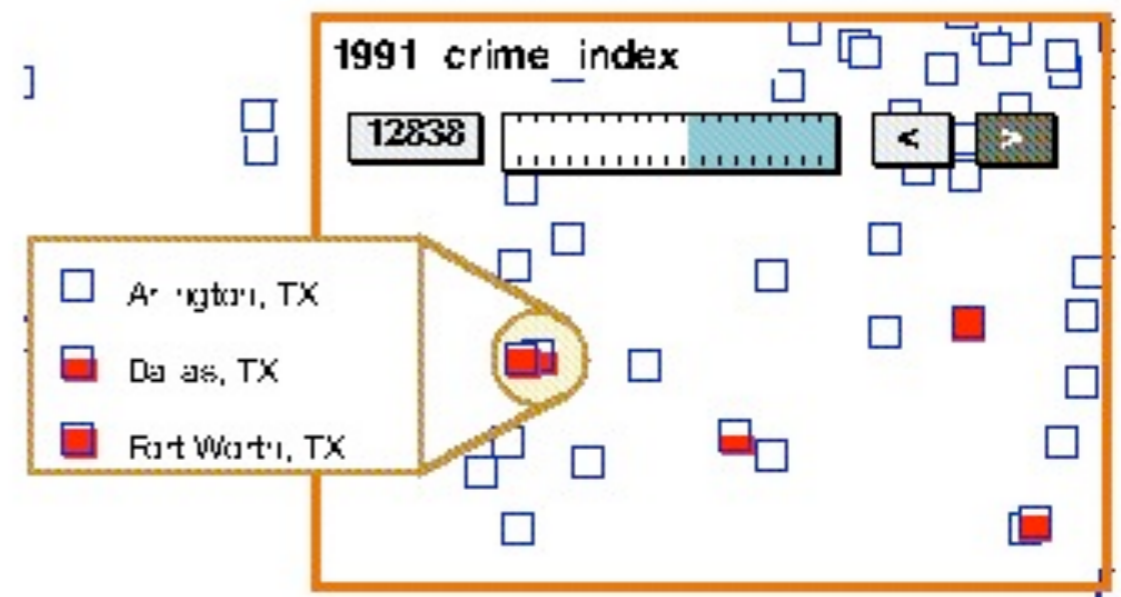


Figure 4(b) Real-valued query on crime rate for the same cities. Extending our filters from boolean-valued to real-valued allows distinctions to be maintained.



# Real-Valued Queries

- Real-valued query lens overlaid by a sorting lens



Fishkin & Stone 1995

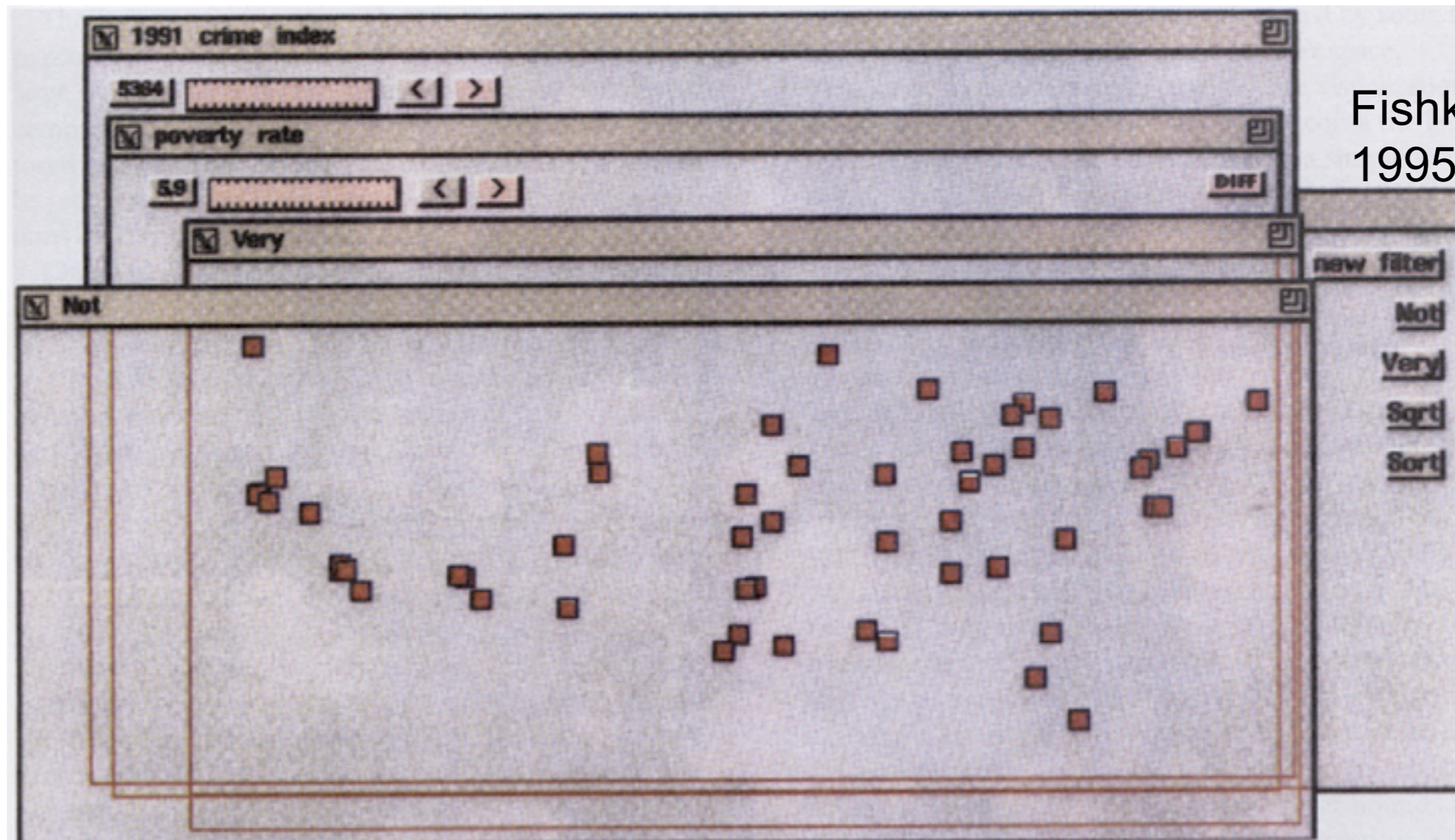
Figure 5. A sorting lens sorts cities by crime rate in Florida.

# Real-valued Composition Modes

- Real-valued composition modes and operators
  - MIN and MAX: work the same on 0.0 and 1.0 as AND and OR on 0 and 1, but can also incorporate values in-between
  - NOT: returns for each case 1.0 minus the case's input value
  - Fuzzy logic operators: e.g. “very”, “somewhat”, “more or less”
  - Mathematical operators: e.g. difference ,log
- Example
  - Is crime rate and poverty positively correlated?
  - One real-valued crime filter
  - One real-valued poverty filter - composition operator DIFF (absolute value of the difference between the two filter outputs)
  - VERY filter (where are the differences very different? Very(x) defined as  $x^2$ )
  - NOT filter (where are the differences NOT very different?)

# Dynamic Queries and Movable Filters

- Filter result: the redder the city, the greater the extent to which poverty and crime rates are NOT VERY DIFFerent – strong positive correlation between poverty and crime rate



Fishkin & Stone  
1995

# Dynamic Queries and Movable Filters

- Missing data is visualized by a special lens

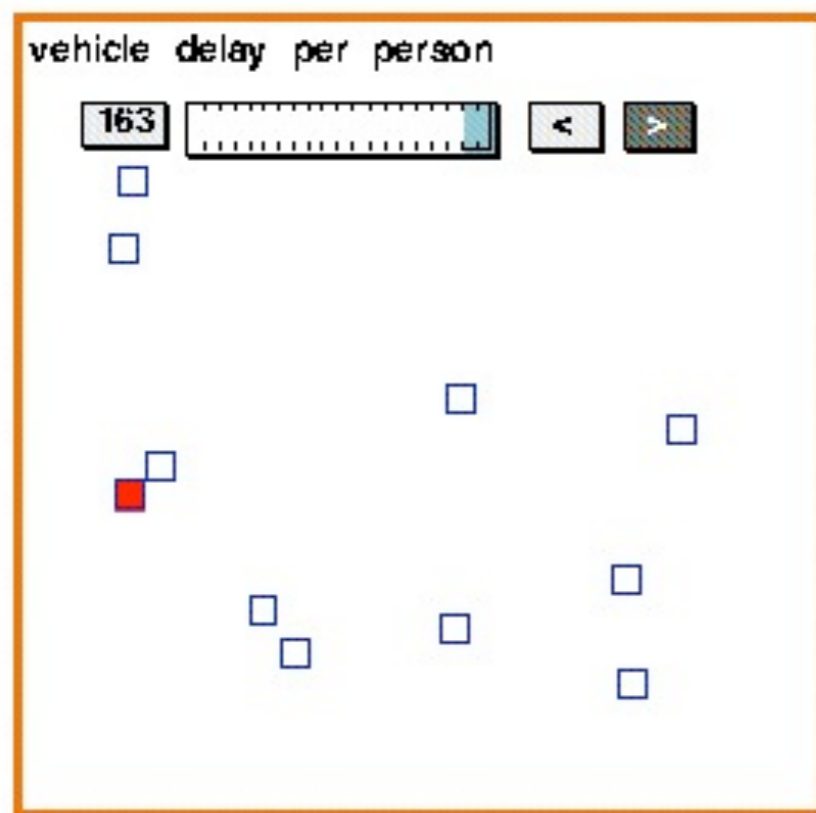


Figure 6(a). A filter finds only one city (San Francisco) with a high score.

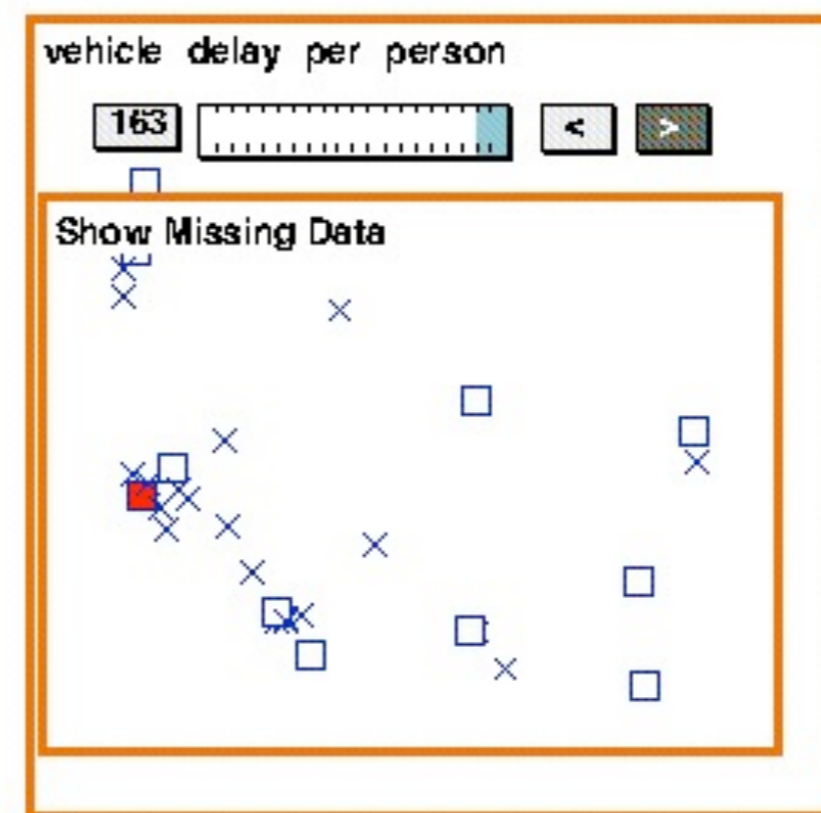


Figure 6(b). A missing data lens shows that attribute values are missing for many cities. Cities with missing data are marked with an 'X'.

Fishkin & Stone 1995

# Additional Sources

- Alan Dix et al.: Human Computer Interaction., 3. Auflage, 2003.
- Lecture material CS 7450 John Stasko, 2006

