

Multivariate Visual Representations 1



CS 7450 - Information Visualization
Sep. 13, 2011
John Stasko

Agenda



- General representation techniques for multivariate (>3) variables per data case
 - But not lots of variables yet...

How Many Variables?



- Data sets of dimensions 1, 2, 3 are common
- Number of variables per class
 - 1 - Univariate data
 - 2 - Bivariate data
 - 3 - Trivariate data
 - >3 - Hypervariate data **Focus Today**

Earlier

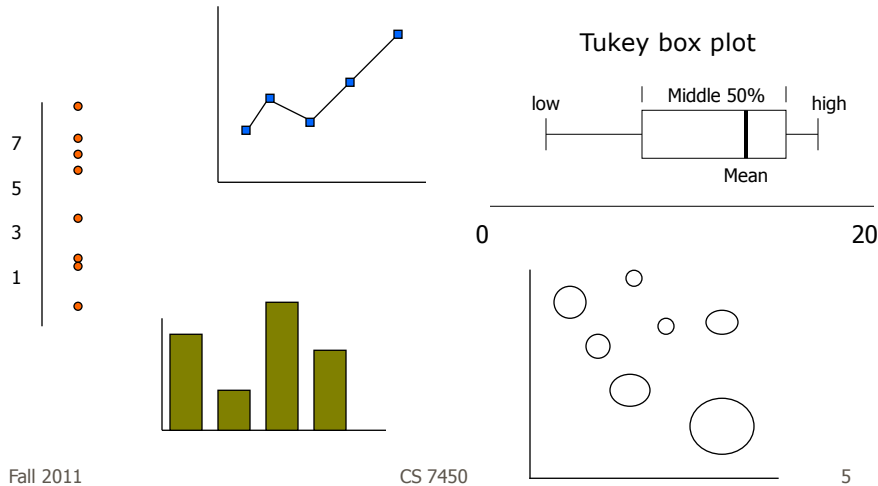


- We examined a number of tried-and-true techniques/visualizations for presenting multivariate (typically ≤ 3) data sets
 - Hinted at how to go above 3 dimensions

Representations



Some standard ways for low-d data



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Hypervariate Data



- How about 4 to 20 or so variables (for instance)?
 - Lower-dimensional hypervariate data
 - Many data sets fall into this category

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More Dimensions



- Fundamentally, we have 2 geometric (position) display dimensions
- For data sets with >2 variables, we must project data down to 2D
- Come up with visual mapping that locates each dimension into 2D plane
- Computer graphics: 3D- \rightarrow 2D projections

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Wait a Second



- A spreadsheet already does that
 - Each variable is positioned into a column
 - Data cases in rows
 - This is a projection (mapping)
- What about some other techniques?
 - Already seen a couple

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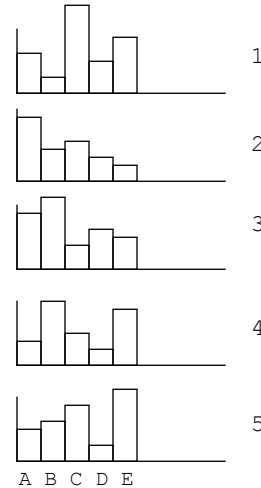
8

Multiple Views



Give each variable its own display

	A	B	C	D	E
1	4	1	8	3	5
2	6	3	4	2	1
3	5	7	2	4	3
4	2	6	3	1	5
5	3	4	5	1	7



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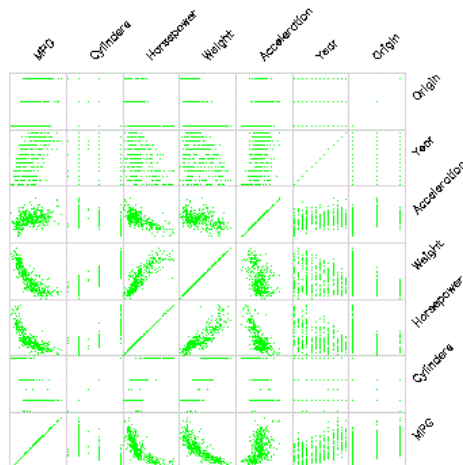
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Scatterplot Matrix



Represent each possible pair of variables in their own 2-D scatterplot



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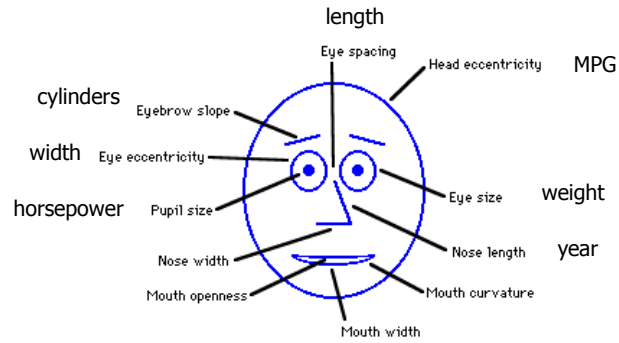
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Chernoff Faces



Encode different variables' values in characteristics of human face

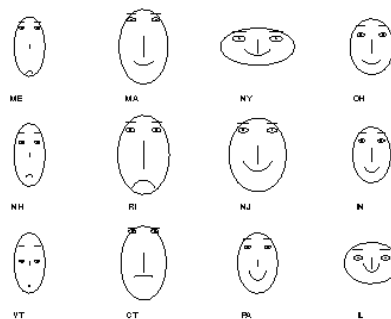


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Examples



Cute applets: <http://www.cs.uchicago.edu/~wiseman/chernoff/>
<http://hesketh.com/schampeon/projects/Faces/chernoff.html>

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Table Lens



- Spreadsheet is certainly one hypervariate data presentation
- Idea: Make the text more visual and symbolic
- Just leverage basic bar chart idea

Rao & Card
CHI '94

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Visual Mapping



	A	B	C	D	E	F
1	Sales rep	Quota	Variance to quota	% of quota	Forecast	Actual bookings
2	Albright, Gary	200,000	-16,062	92	205,000	183,938
3	Brown, Sheryll	150,000	84,983	157	260,000	234,983
4	Cartwright, Bonnie	100,000	-56,125	44	50,000	43,875
5	Caruthers, Michael	300,000	-25,125	92	324,000	274,875
6	Garibaldi, John	250,000	143,774	158	410,000	393,774
7	Girard, Jean	75,000	-48,117	36	50,000	26,883
8	Jones, Suzanne	140,000	-5,204	96	149,000	134,796
9	Larson, Terri	350,000	238,388	168	600,000	588,388
10	LeShan, George	200,000	-75,126	62	132,000	124,874
11	Levenson, Bernard	175,000	-9,267	95	193,000	165,733
12	Mulligan, Robert	225,000	34,383	115	275,000	259,383
13	Tetracelli, Sheila	50,000	-1,263	97	50,000	48,737
14	Wotisek, Gillian	190,000	-3,648	98	210,000	186,352
15						

Change quantitative
values to bars



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Tricky Part



	A	B	C	D	E	F	G	H	I
		Manufactu	Type	Calories	Protein	Fat	Sodium	Fiber	Carbol
1	Cereal								
2	Frosted Mini-Wheats	K	C	100	3	0	0	3	
3	Raisin Squares	K	C	90	2	0	0	2	
4	Shredded Wheat	N	C	80	2	0	0	3	
5	Shredded Wheat 'n Bran	N	C	90	3	0	0	4	
6	Shredded Wheat spoon s	N	C	90	3	0	0	3	
7	Puffed Rice	Q	C	50	1	0	0	0	
8	Puffed Wheat	Q	C	50	2	0	0	1	
9	Maypo	A	H	100	4	1	0	0	
10	Quaker Oatmeal	Q	H	100	5	2	0	2.7	
11	Strawberry Fruit Wheats	N	C	90	2	0	15	3	
12	100% Natural Bran	Q	C	120	3	5	15	2	
13	Golden Crisp	P	C	100	2	0	45	0	
14	Smacks	K	C	110	2	1	70	1	
15	Great Grains Pecan	P	C	120	3	3	75	3	
16	Cream of Wheat (Quick)	N	H	100	3	0	80	1	
17	Corn Pops	K	C	110	1	0	90	1	
18	Muesli Raisins, Dates, & R	C		150	4	3	95	3	
19	Anna, Isakke	K		110	2	0	125	1	

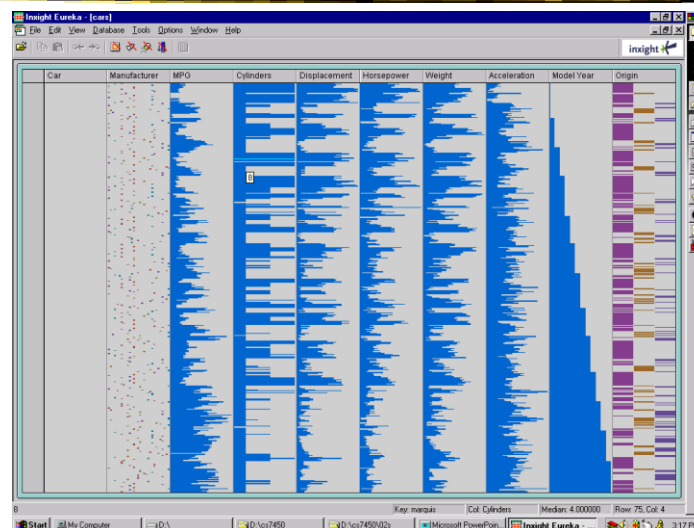
What do you do for nominal data?

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Details



Focus on
item(s)
while
showing
the context

Imxight Lureka [cereals]

File Edit View Database Web Tools Options Window Help

inxight

	Cereal	Manufa	Type	Calories	Protein	Fat	Sodium	Fiber	Carboh.	Sugars	Shelf	Potassi.	Vitamins	Weight	Cups
33	Fruity Bran	K	C	120	3	0	240	5	14	12	3	190	25	1.33	0.67
34	Just Right Cr.	K	C	110	2	1	170	1	17	6	3	60	100	1	-.1
35	Just Right Fr.	K	C	140	3	1	170	2	20	9	3	95	100	1.3	0.75

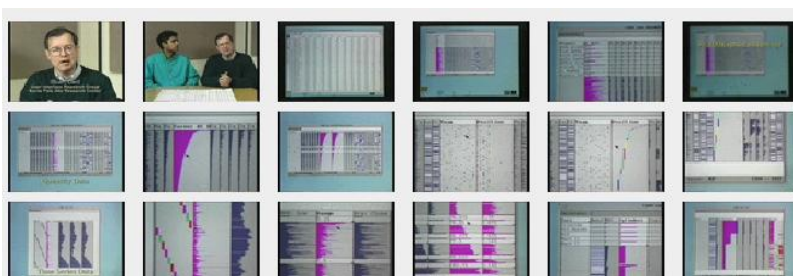
Key: Fruity Pebbles Col: Vitamins Median: 25.00000 Row: 53, Col: 13

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See It



<http://www.open-video.org/details.php?videoid=8304>

Video

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FOCUS



- Feature-Oriented Catalog User Interface
- Leverages spreadsheet metaphor again
- Items in columns, attributes in rows
- Uses bars and other representations for attribute values

Spence, Beilken, & Berlage
UIST '96

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The screenshot shows the FOCUS - [Printers.toc] application window. It features a menu bar (File, Edit, Window, Table, Help) and a toolbar with buttons for Reset, Show All, Delete, Auto Delete, Overview, and Keep Specifications. Below the toolbar is a 'Set' dropdown menu currently set to 'Supported Interfaces=Centronics'. The main area is a large table with columns for various printer attributes and rows for different printer models. The attributes listed on the left include Vendor, Contact, Technology, Color, Price (\$), Class, Resolution (vertical and horizontal dpi), Interfaces, Auto Switching, Centronics, RS-232C, RS-422A, LocalTalk, Ethernet, Token Ring, SCSI, Input, Paper Sizes, Memory, Processor, BYTE Rankings, Monochrome Size, High Quality (D), Draft (gpm), Postscript (gpm), Color Speed, Monochrome Data, and Color Quality Index. The table cells contain various data points, including model numbers, prices, resolutions, and interface support indicators (like 'C' for Centronics or 'E' for Ethernet).



Figure 1: An overview of the printer table.

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Characteristics



- Can sort on any attribute (row)
- Focus on an attribute value (show only cases having that value) by double-clicking on it
- Can type in queries on different attributes to limit what is presented too

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Limit by Query



FOCUS - [Printers.foc]

File Edit Window Table Help

Records: 9 qualified Show All Delete Refused

Attributes: 36 differ Show All Delete Identical

Set: vertical (dpi) = 600 OR horizontal (dpi) = 600 Exclude

Printers	DECcolorwriter 100	Primera Color Print	PrimeraPro Color Print	Spectra Star G1	Spectra Star G1x	Gentium 7025	Phase200e	Phase220e	Phase220i
Vendor	Digital	Fargo	Electron	General	Para	Genico	Tektronix		
Contact									
Technology: Thermal	Thermal								
Color									
Price (\$)	3999	995	1895	4495	4995	995	2995	3995	6390
Class									
Resolution									
vertical (dpi)	600	203		300		203	300	600	300
horizontal (dpi)	300	203	600	300	600	203	300		600
Emulations									
Interfaces									
Technology=Thermal									

Figure 4: A disjunction.

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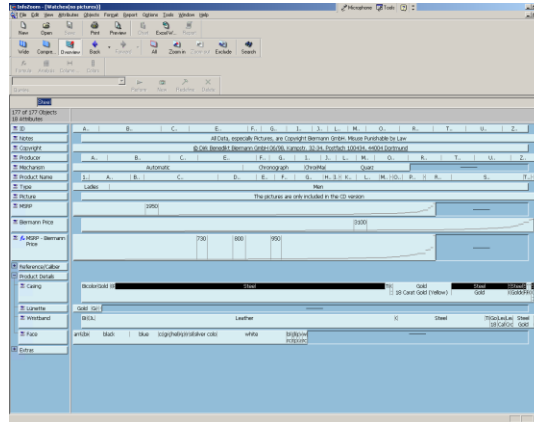
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Manifestation



InfoZoom



Commercial product to be demo'ed coming up

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Categorical data?



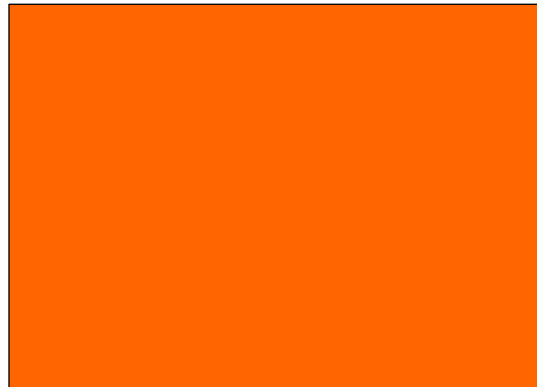
- How about multivariate categorical data?
- Students
 - Gender: Female, male
 - Eye color: Brown, blue, green, hazel
 - Hair color: Black, red, brown, blonde, gray
 - Home country: USA, China, Italy, India, ...

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Mosaic Plot

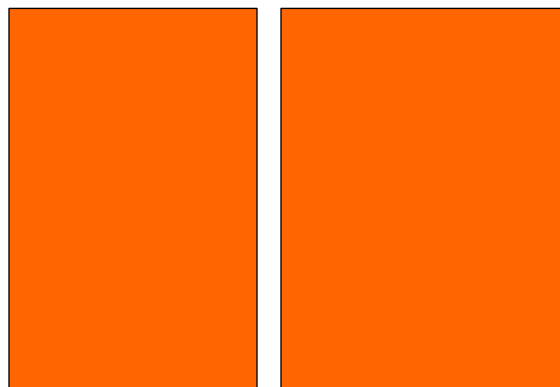


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Mosaic Plot



Women

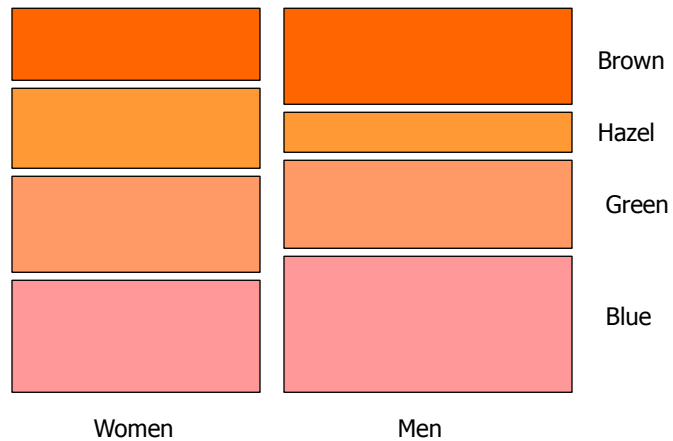
Men

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Mosaic Plot

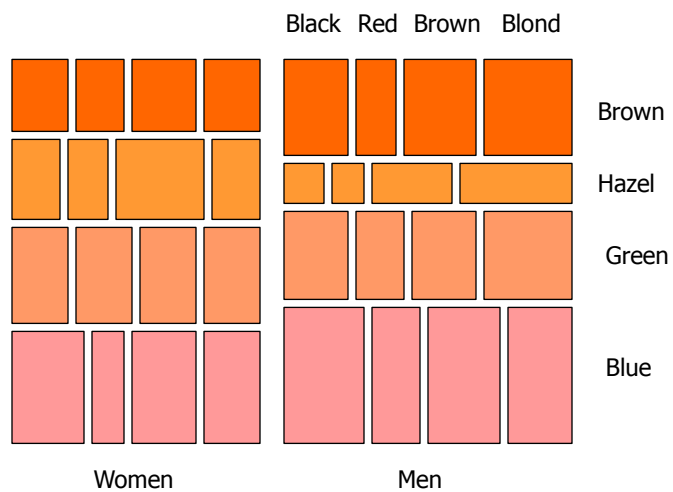


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Mosaic Plot



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Attribute Explorer



- General hypervariate data representation combined with flexible interaction

Spence & Tweedie
Inter w Computers '98

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Characteristics



- Multiple histogram views, one per attribute (like trellis)
- Each data case represented by a square
- Square is positioned relative to that case's value on that attribute
- Selecting case in one view lights it up in others
- Query sliders for narrowing
- Use shading to indicate level of query match (darkest for full match)

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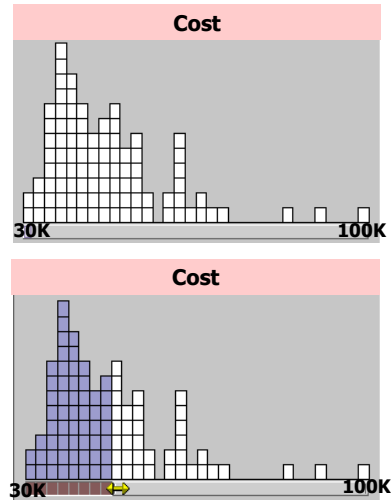
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Features



- Attribute histogram
- All objects on all attribute scales
- Interaction with attributes limits



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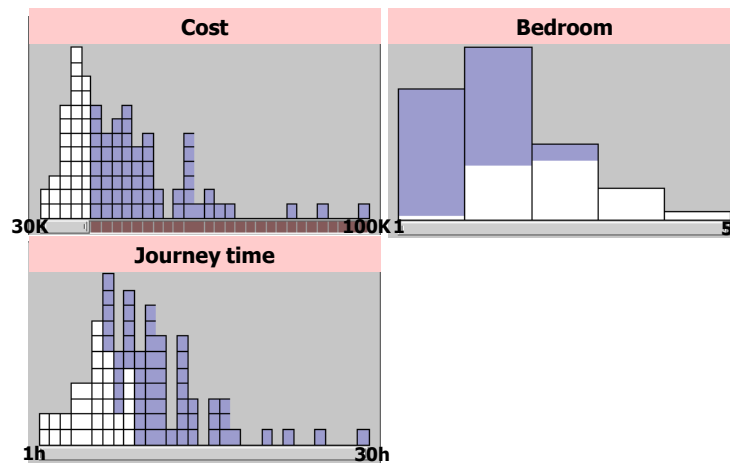
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Features



- Inter-relations between attributes – brushing



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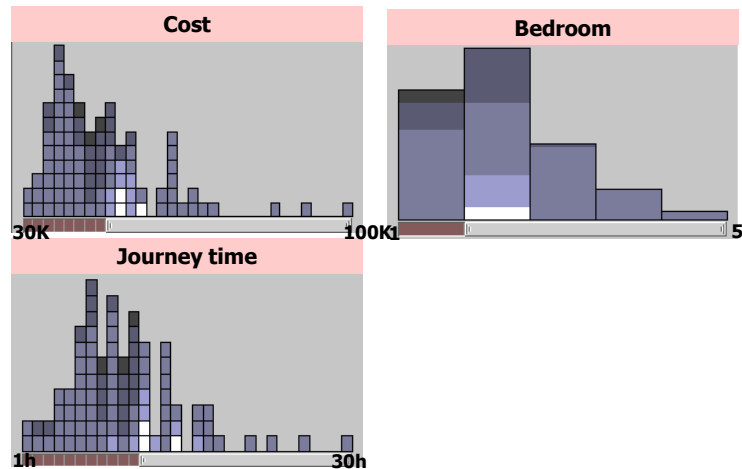
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Features



- Color-encoded sensitivity



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Attribute Explorer



Video

<http://www.open-video.org/details.php?videoid=8162>

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Summary



- Summary
 - Attribute histogram
 - Attribute relationship
 - Sensitivity information
 - Especially useful in “zero-hits” situations or when you are not familiar with the data at all
- Limitations
 - Limits on the number of attributes

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MultiNav



- Each different attribute is placed in a different row
- Sort the values of each row
 - Thus, a particular item is not just in one column
- Want to support browsing

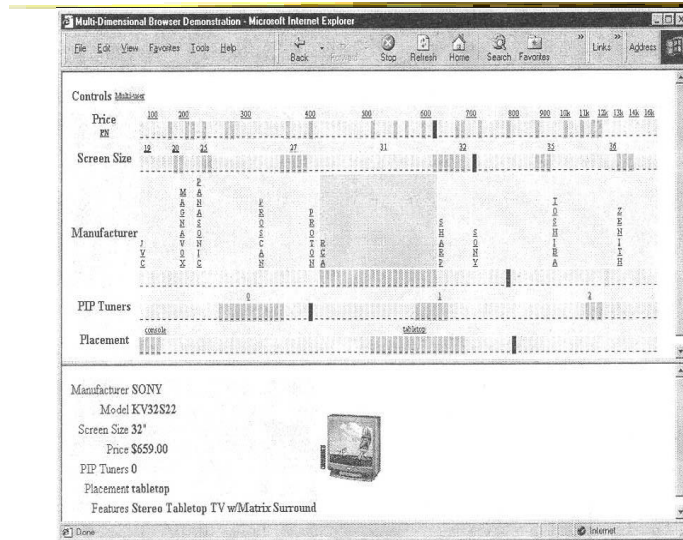
Lanning et al
AVI '00

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Interface



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Alternate UI

- Can slide the values in a row horizontally
- A particular data case then can be lined up in one column, but the rows are pushed unequally left and right

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Attributes as Sliding Rods



Choose Back Filter 5 of 32 items selected

Table

Manufacturer: Kodak
 Fuji HP Kodak

Macro: false
 false

Offer Price (\$): 599.95

LCD Display: true
 false true

DC220 MEGAPIXEL DIGITAL CAMERA

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Information-Seeking Dialog



zuperpages.com: Electronics - Stereos, DVD Players, & More Shopping Page - Netscape

Home → Shopping Pages → Electronics

Mullinav Televisions

Interactive Tools: Table Layout

Manufacturer: MAGNAVOX
 RCA

Number of Picture-in-Picture Tuners: 1
 0 1 2

Placement: tabletop
 tabletop

Screen Size (inches): 27
 20 27 32 36

Price (\$): 300.00 Drag

Save for later: Add

MAGNAVOX TP2780C

This value-priced 27-inch stereo TV comes with all the essentials, including S-Video input, rear AV input jacks, parental-control channel lockout, favorite-channel

To Reduce the Product Space: Highlight Feature Values (e.g., Price Feature, Highlight 3200) or drag to view only those products.

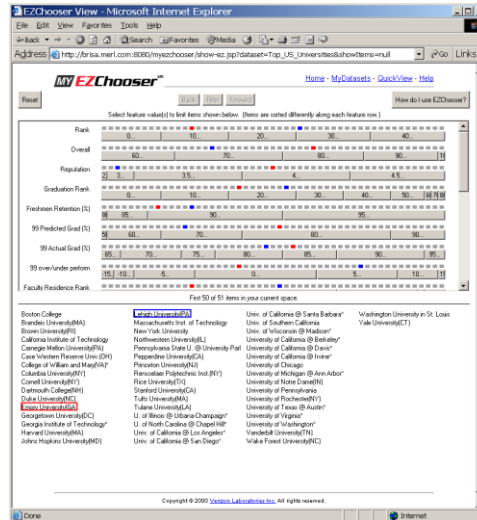
Delete Product View List Reduce Product Space Full Product Space

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Instantiation



Demo

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Limitations



- Number of cases (horizontal space)
- Nominal & textual attributes don't work quite as well

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Parallel Coordinates



- What are they?
 - Explain...

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Parallel Coordinates



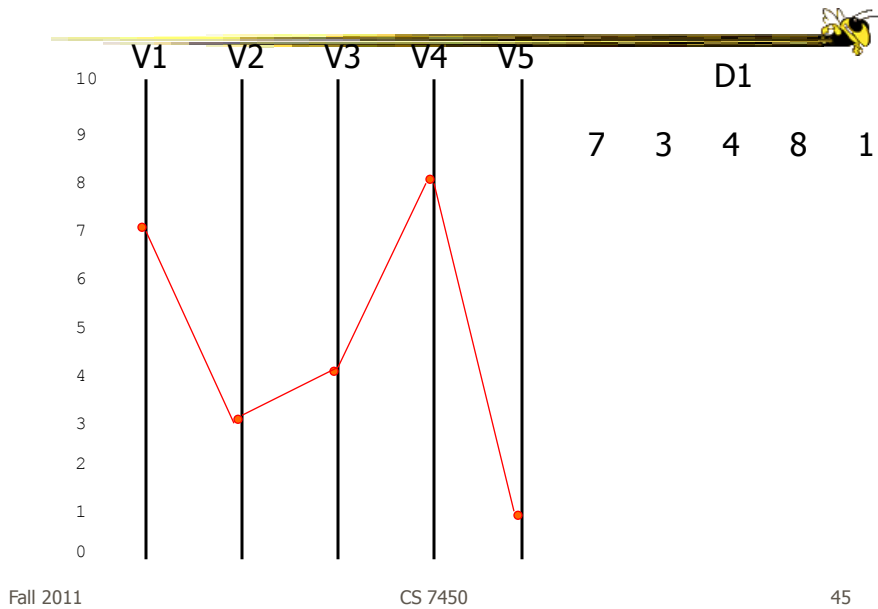
	V1	V2	V3	V4	V5
D1	7	3	4	8	1
D2	2	7	6	3	4
D3	9	8	1	4	2

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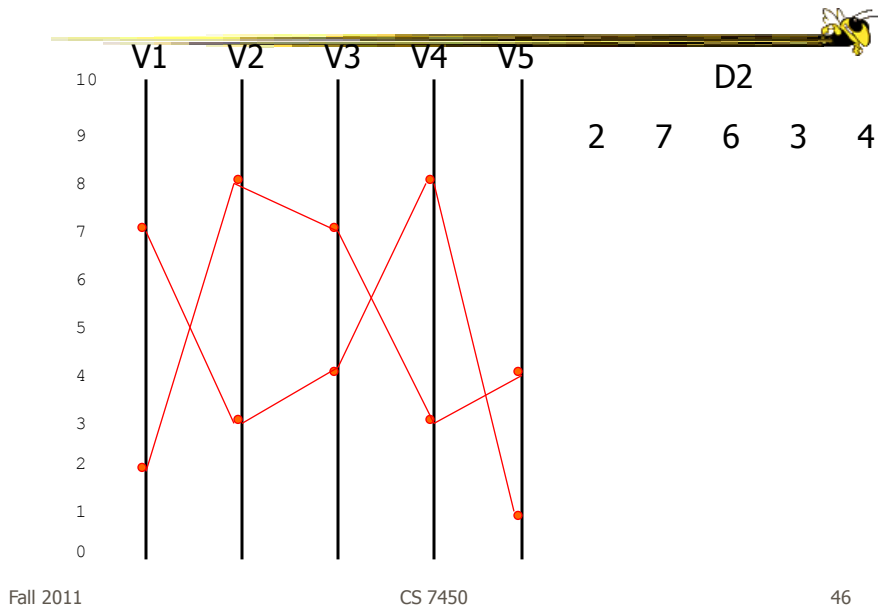
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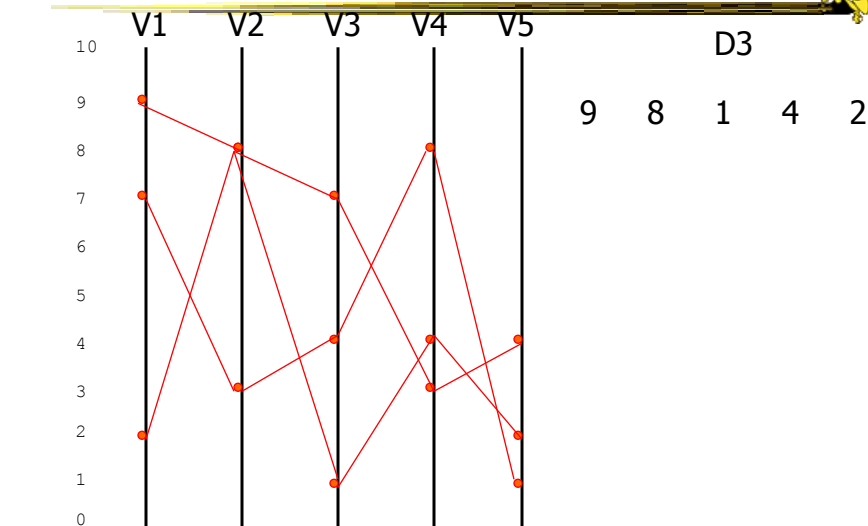
Parallel Coordinates



Parallel Coordinates



Parallel Coordinates

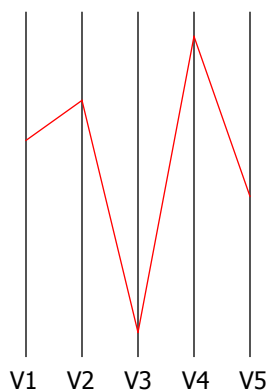


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Parallel Coordinates



Encode variables along
a horizontal row

Vertical line specifies different
values that variable can take

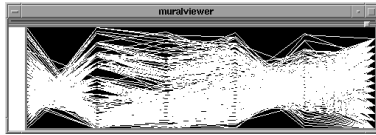
Data point represented as a
polyline

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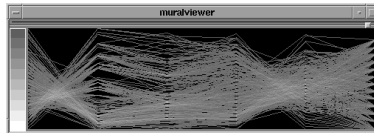
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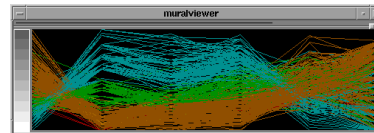
Parallel Coords Example



Basic



Grayscale



Color

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Issue



- Different variables can have values taking on quite different ranges
- Must normalize all down (e.g., 0- \rightarrow 1)

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Application



- System that uses parallel coordinates for information analysis and discovery
- Interactive tool
 - Can focus on certain data items
 - Color

Taken from:

A. Inselberg, "Multidimensional Detective"
InfoVis '97, 1997.

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Discuss



- What was their domain?
- What was their problem?
- What were their data sets?

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The Problem



- VLSI chip manufacture
- Want high quality chips (high speed) and a high yield batch (% of useful chips)
- Able to track defects
- Hypothesis: No defects gives desired chip types
- 473 batches of data

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The Data



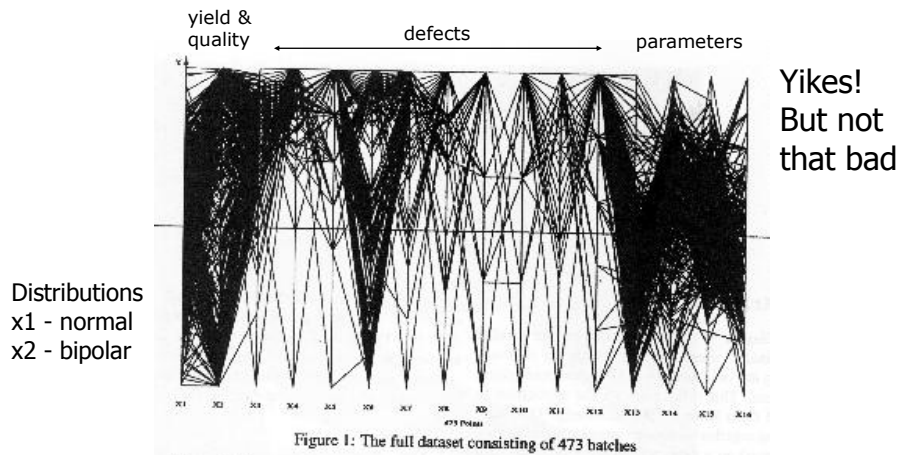
- 16 variables
 - X1 - yield
 - X2 - quality
 - X3-X12 - # defects (inverted)
 - X13-X16 - physical parameters

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Parallel Coordinate Display

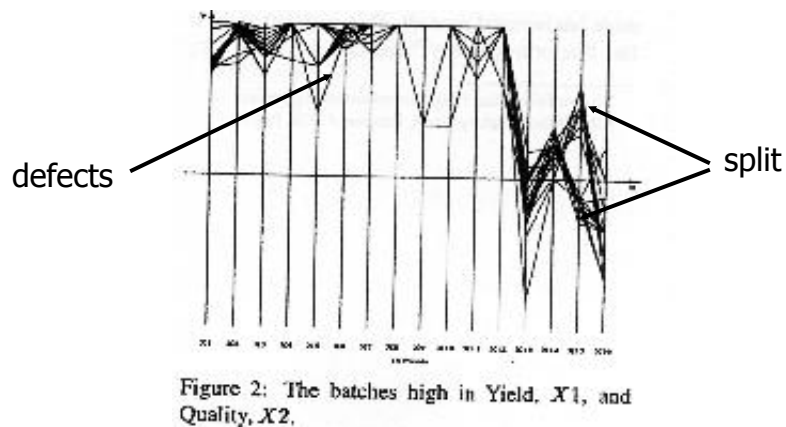


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Top Yield & Quality



Have some defects

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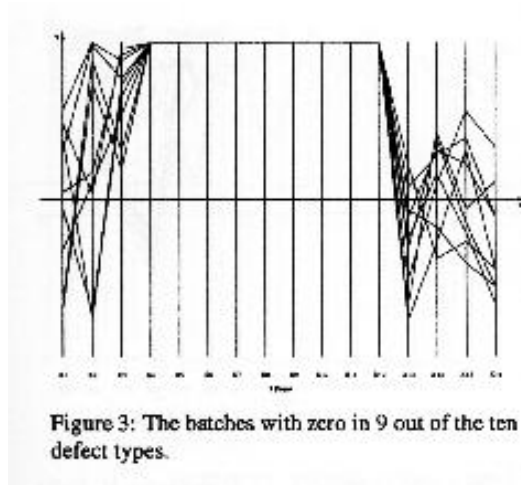
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Minimal Defects



Not the
highest
yields and
quality



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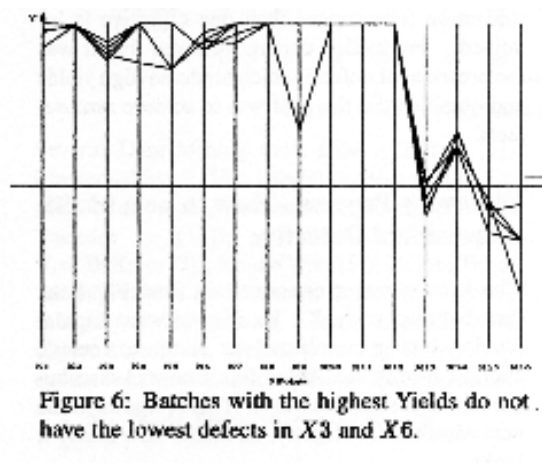
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Best Yields



Appears that
some defects
are necessary
to produce
the best chips

Non-intuitive!



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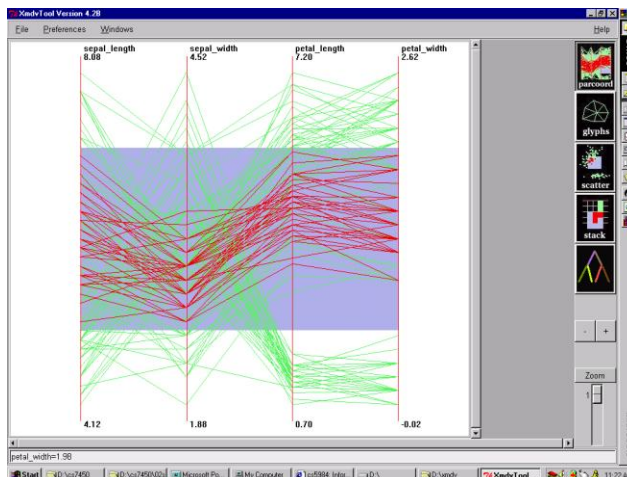
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XmdvTool



Toolsuite created
by Matthew Ward
of WPI

Includes parallel
coordinate views

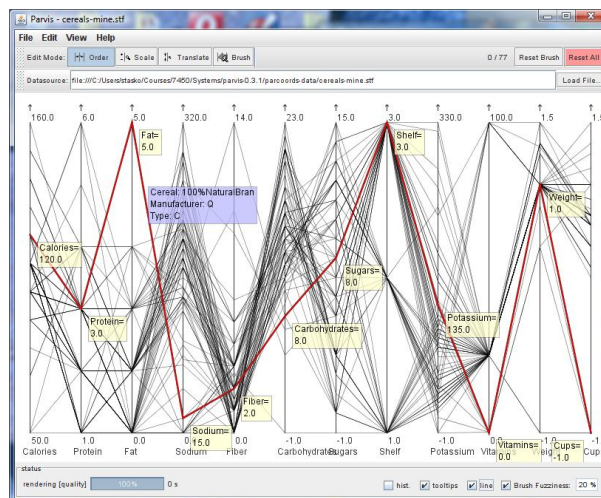


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ParVis System



Demo

<http://www.mediavirus.org/parvis/>

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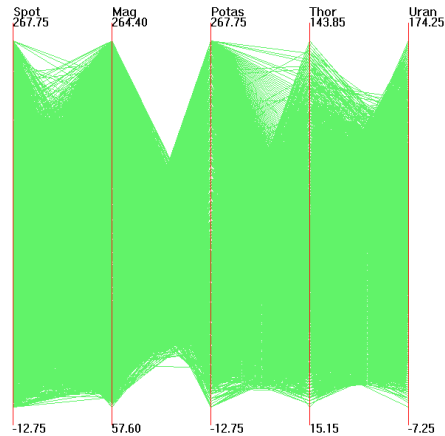
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Challenges



Too much data



Out5d dataset (5 dimensions, 16384 data items)

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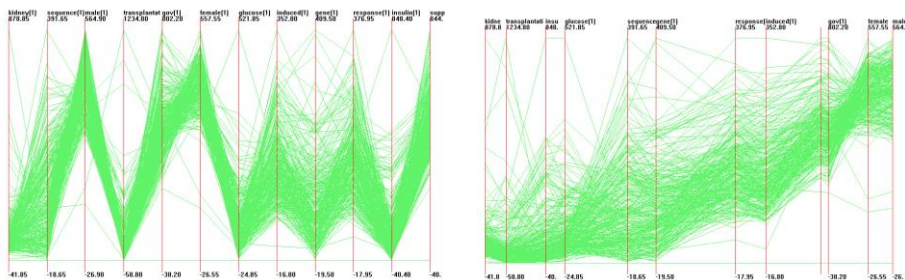
(courtesy of J. Yang)

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Dimensional Reordering



Which dimensions are most like each other?



Same dimensions ordered according to similarity

Yang et al
InfoVis '03

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Dimensional Reordering



Can you reduce clutter and highlight other interesting features in data by changing order of dimensions?

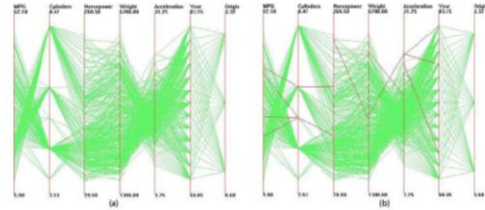


Figure 1: Parallel coordinates visualization of Cars dataset. Outliers are highlighted with red in (b).

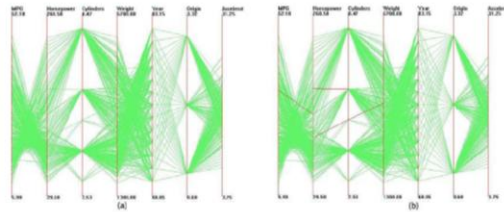


Figure 2: Parallel coordinates visualization of Cars dataset after clutter-based dimension reordering. Outliers are highlighted with red in (b).

Peng et al
InfoVis '04

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Reducing Density

Jerding and Stasko, '95, '98
Wegman & Luo, '96

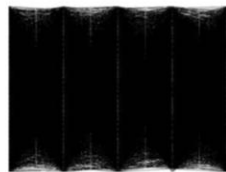
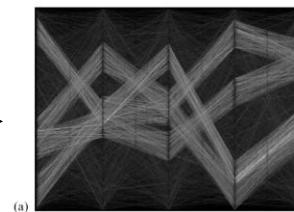
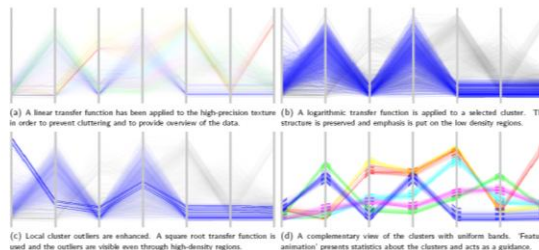


Figure 1 – Parallel Coordinates visualization of the *Sirtf* data set (7,500 five-attribute records).



(a)

Artero et al, '04



(c) Local cluster outliers are enhanced. A square root transfer function is used and the outliers are visible even through high-density regions. (d) A complementary view of the clusters with uniform bands. Feature animation: presents statistics about the clusters and acts as a guidance.

Johansson et al, '05

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Improved Interaction



- How do we let the user select items of interest?
- Obvious notion of clicking on one of the polylines, but how about something more than that

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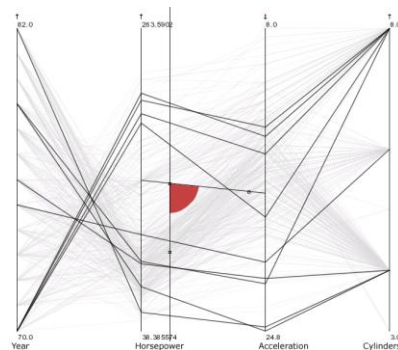
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Attribute Ratios



- Angular Brushing
 - Select subsets which exhibit a correlation along 2 axes by specifying angle of interest



Hauser, Ledermann, & Doleisch
InfoVis '02

(earlier demo)

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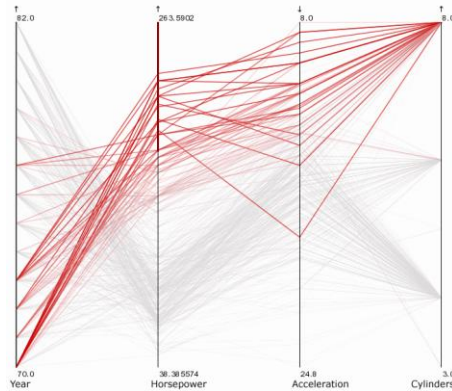
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Range Focus



- Smooth Brushing
 - Specify a region of interest along one axis



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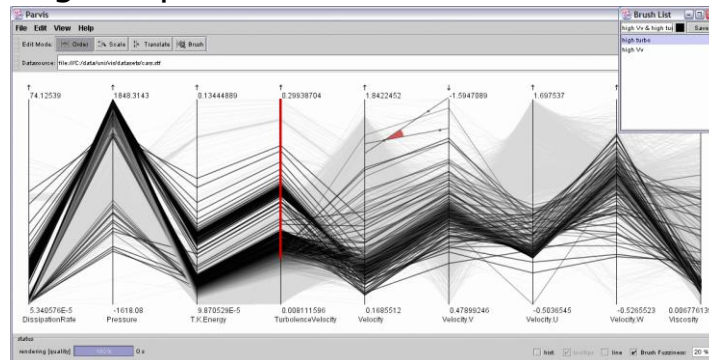
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Combining



- Composite Brushing
 - Combine brushes and DOI functions using logical operators

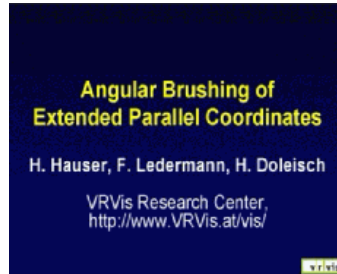


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Video



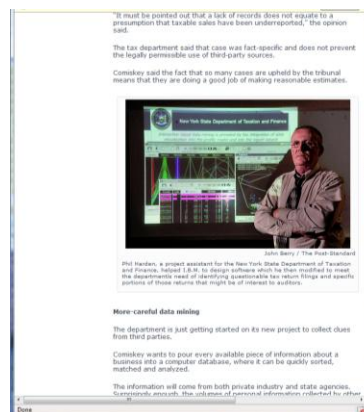
<http://www.vrvis.at/via/research/ang-brush/parvis4.mov>

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Application



http://www.syracuse.com/news/index.ssf/2010/01/data_mining_helps_new_york_cat.html

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Different Kinds of Data



- How about categorical data?
 - Can parallel coordinates handle that well?

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Parallel Sets



- Visualization method adopting parallel coordinates layout but uses frequency-based representation
- Visual metaphor
 - Layout similar to parallel coordinates
 - Continuous axes replaced with boxes
- Interaction
 - User-driven: User can create new classifications

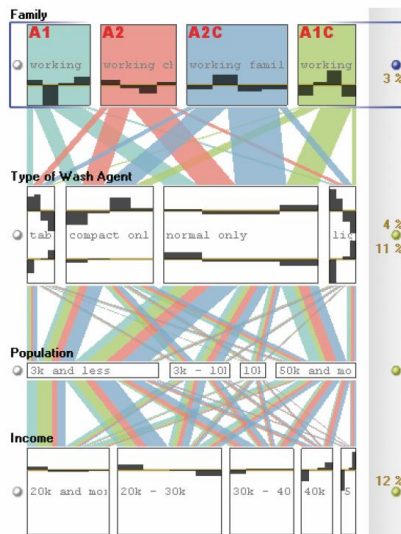
Kosara, Bendix, & Hauser
TVCG '05

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Representation



Color used for different categories

Those values flow into the other variables

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Example

Titanic passengers data set

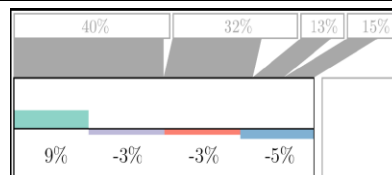
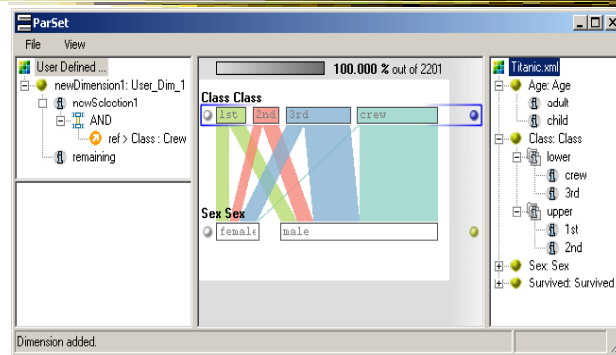
Class	Sex				
	female		male		
first	145	44.6%	180	55.4%	325
	30.8%	6.6%	10.4%	8.2%	14.8%
second	106	37.2%	179	62.8%	285
	22.6%	4.8%	10.4%	8.1%	12.9%
third	196	27.8%	510	72.2%	706
	41.7%	8.9%	29.5%	23.2%	32.1%
crew	23	2.6%	862	97.4%	885
	4.9%	1.1%	49.8%	39.1%	40.2%
	470		1731		2201
		21.4%		78.6%	100%

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Titanic Data Set



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Interactions

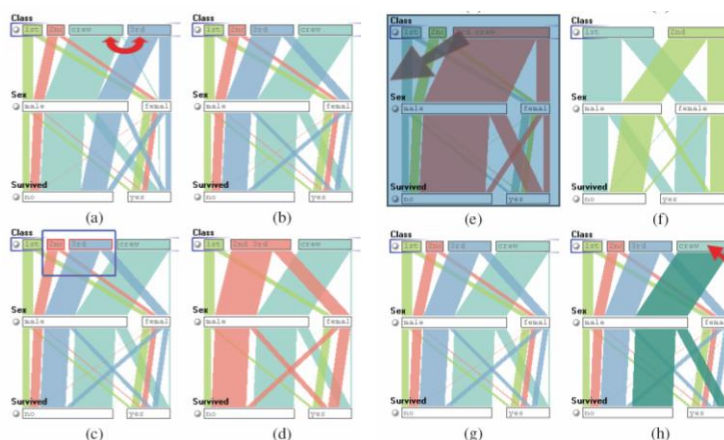
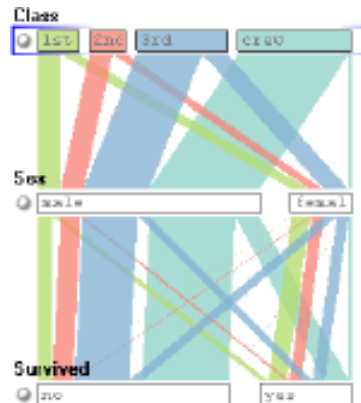


Fig. 7. Basic interaction elements in Parallel Sets: reordering categories (a, b) helps to generate a more meaningful layout; grouping categories (c, d) enables a hierarchical analysis/exploration; excluding categories from the visualization (e, f) allows for interactive filtering; and category highlighting (g, h) enables the selective investigation of high-dimensional relations.

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Video

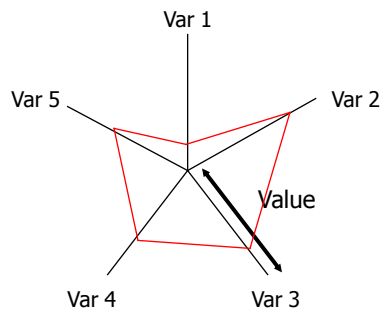


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InfoVis '05
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Star Plots



Space out the n variables at equal angles around a circle

Each “spoke” encodes a variable’s value

Alternative Rep.

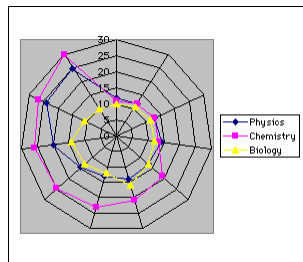
Data point is now a “shape”

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Star Plot examples



Connecticut



New Hampshire



Pennsylvania



Maine



New Jersey



Rhode Island



Massachusetts



New York



Vermont

<http://seamonkey.ed.asu.edu/~behrens/asu/reports/compre/comp1.html>

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Star Coordinates



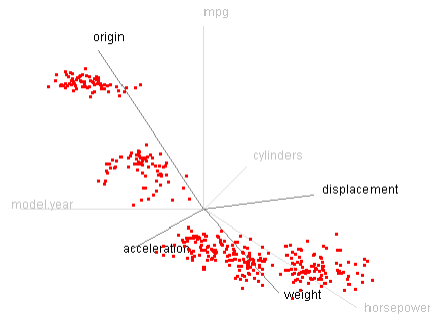
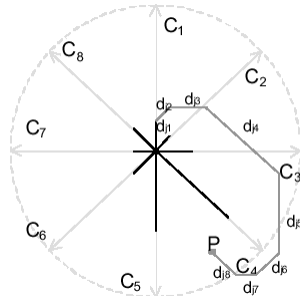
- Same ideas as star plot
- Rather than represent point as polyline, just accumulate values along a vector parallel to particular axis
- Data case then becomes a point

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Star Coordinates



E. Kandogan, "Star Coordinates: A Multi-dimensional Visualization Technique with Uniform Treatment of Dimensions", InfoVis 2000 Late-Breaking Hot Topics, Oct. 2000

Demo

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Star Coordinates



- Data cases with similar values will lead to clusters of points
- (What's the problem though?)
- Multi-dimensional scaling or projection down to 2D

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Parallel Coordinates



- Technique
 - Strengths?
 - Weaknesses?

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Project



- Teams & Topics due Thursday
 - Bring 2 copies

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Upcoming



- Multivariate Visual Representations 2
 - Reading:
Keim et al, '02
- Tufte's Design Principles
 - Reading
Tufte, *Envisioning Information* (if you have it)
- Read ahead
 - S. Few book chapters 5-12