Multi-Dimensional Data Visualization

Slides courtesy of Chris North

- What is the Cleveland's ranking for quantitative data among the visual variables:
  - Angle, area, length, position, color

Where are we?

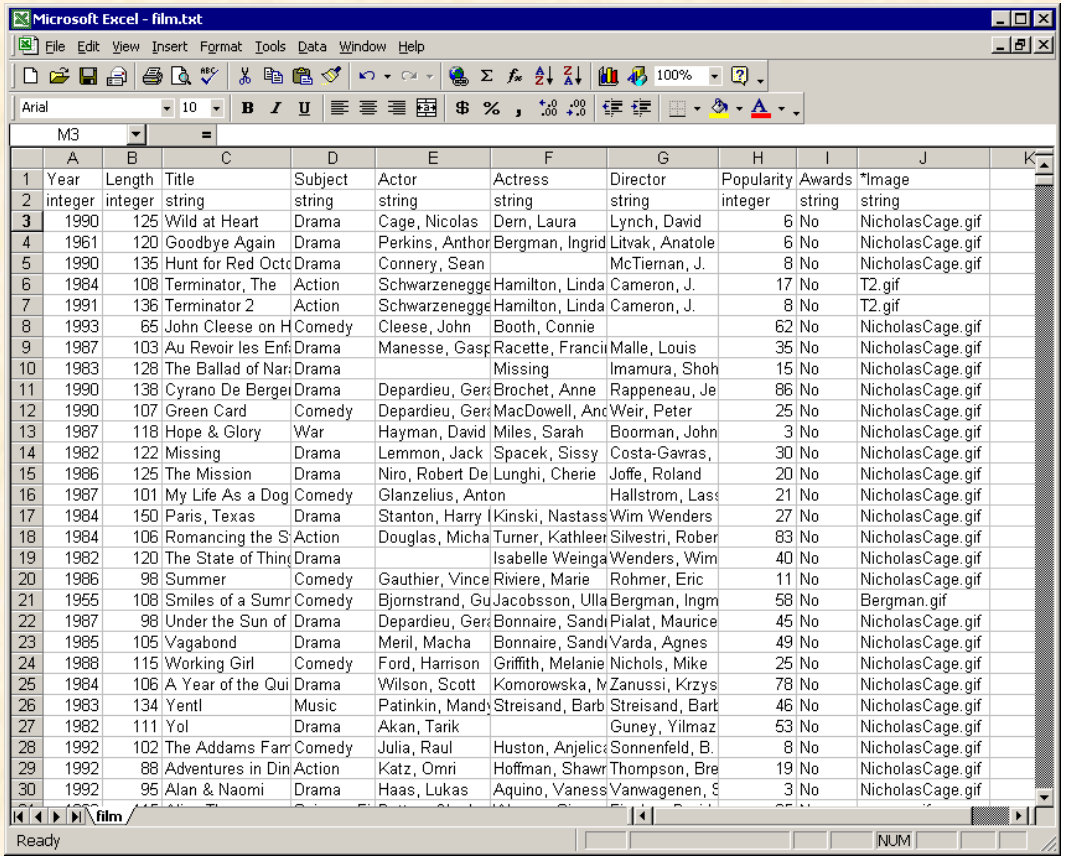
- ➢ Tabular (multi-dimensional)
- Spatial & Temporal
  - 1D / 2D
  - 3D
- Networks
  - Trees
  - Graphs
- Text & Documents

- ✓ Fundamentals / Eval
- Navigation strategies
- Overview strategies
- Interaction techniques

- Design
- Development
- Evaluation

The Simple Stuff

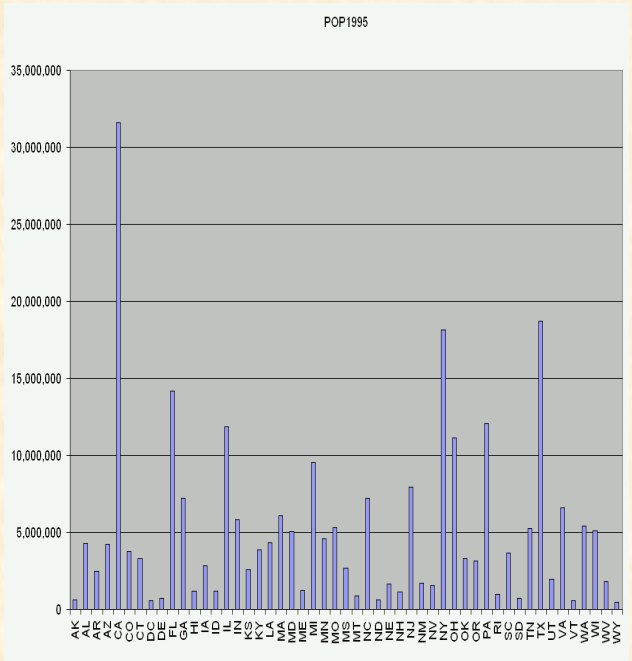
- Univariate
- Bivariate
- Trivariate

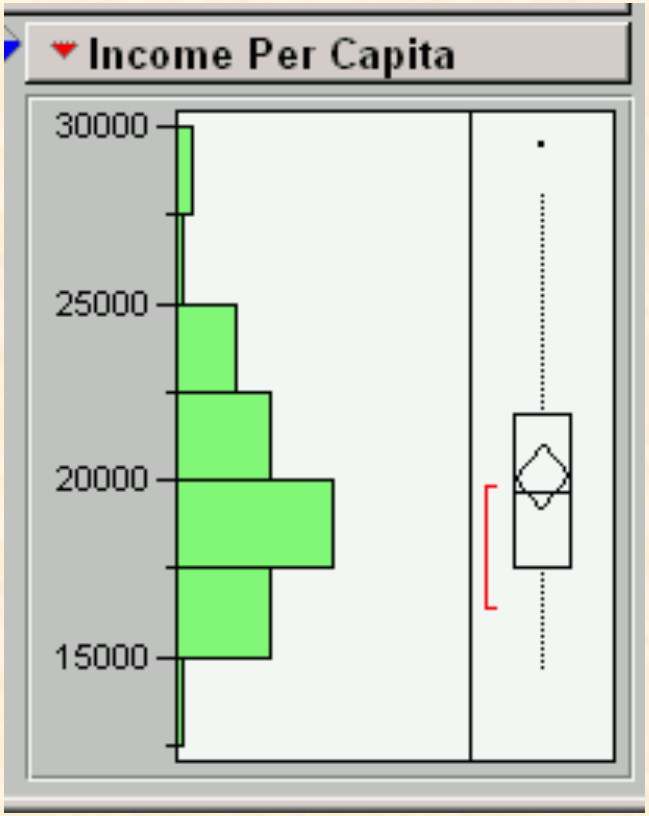


	A	B	C	D	E	F	G	H	I	J
1	Year	Length	Title	Subject	Actor	Actress	Director	Popularity	Awards	*Image
2	integer	integer	string	string	string	string	string	integer	string	string
3	1990	125	Wild at Heart	Drama	Cage, Nicolas	Dern, Laura	Lynch, David	6	No	NicholasCage.gif
4	1961	120	Goodbye Again	Drama	Perkins, Anthor	Bergman, Ingrid	Litvak, Anatole	6	No	NicholasCage.gif
5	1990	135	Hunt for Red Oct	Drama	Connery, Sean		McTiernan, J.	8	No	NicholasCage.gif
6	1984	108	Terminator, The	Action	Schwarzenegge	Hamilton, Linda	Cameron, J.	17	No	T2.gif
7	1991	136	Terminator 2	Action	Schwarzenegge	Hamilton, Linda	Cameron, J.	8	No	T2.gif
8	1993	65	John Cleese on H	Comedy	Cleese, John	Booth, Connie		62	No	NicholasCage.gif
9	1987	103	Au Revoir les Enf	Drama	Manesse, Gasp	Racette, Francii	Malle, Louis	35	No	NicholasCage.gif
10	1983	128	The Ballad of Nar	Drama		Missing	Imamura, Shoh	15	No	NicholasCage.gif
11	1990	138	Cyrano De Berger	Drama	Depardieu, Ger	Brochet, Anne	Rappeneau, Je	86	No	NicholasCage.gif
12	1990	107	Green Card	Comedy	Depardieu, Ger	MacDowell, And	Weir, Peter	25	No	NicholasCage.gif
13	1987	118	Hope & Glory	War	Hayman, David	Miles, Sarah	Boorman, John	3	No	NicholasCage.gif
14	1982	122	Missing	Drama	Lemmon, Jack	Spacek, Sissy	Costa-Gavras,	30	No	NicholasCage.gif
15	1986	125	The Mission	Drama	Niro, Robert De	Lunghi, Cherie	Joffe, Roland	20	No	NicholasCage.gif
16	1987	101	My Life As a Dog	Comedy	Glanzelius, Anton		Hallstrom, Lass	21	No	NicholasCage.gif
17	1984	150	Paris, Texas	Drama	Stanton, Harry I	Kinski, Nastass	Wim Wenders	27	No	NicholasCage.gif
18	1984	106	Romancing the S	Action	Douglas, Micha	Turner, Kathleer	Silvestri, Rober	83	No	NicholasCage.gif
19	1982	120	The State of Thin	Drama		Isabelle Weinga	Wenders, Wim	40	No	NicholasCage.gif
20	1986	98	Summer	Comedy	Gauthier, Vince	Riviere, Marie	Rohmer, Eric	11	No	NicholasCage.gif
21	1955	108	Smiles of a Sumr	Comedy	Bjornstrand, Gu	Jacobsson, Ulla	Bergman, Ingm	58	No	Bergman.gif
22	1987	98	Under the Sun of	Drama	Depardieu, Ger	Bonnaire, Sandi	Pialat, Maurice	45	No	NicholasCage.gif
23	1985	105	Vagabond	Drama	Meril, Macha	Bonnaire, Sandi	Varda, Agnes	49	No	NicholasCage.gif
24	1988	115	Working Girl	Comedy	Ford, Harrison	Griffith, Melanie	Nichols, Mike	25	No	NicholasCage.gif
25	1984	106	A Year of the Qui	Drama	Wilson, Scott	Komorowska, M	Zanussi, Krzys	78	No	NicholasCage.gif
26	1983	134	Yentl	Music	Patinkin, Mand	Streisand, Barb	Streisand, Barb	46	No	NicholasCage.gif
27	1982	111	Yol	Drama	Akan, Tarik		Guney, Yilmaz	53	No	NicholasCage.gif
28	1992	102	The Addams Fam	Comedy	Julia, Raul	Huston, Anjelic	Sonnenfeld, B.	8	No	NicholasCage.gif
29	1992	88	Adventures in Din	Action	Katz, Omri	Hoffman, Shawr	Thompson, Bre	19	No	NicholasCage.gif
30	1992	95	Alan & Naomi	Drama	Haas, Lukas	Aquino, Vaness	Vanwagenen, S	3	No	NicholasCage.gif

Univariate

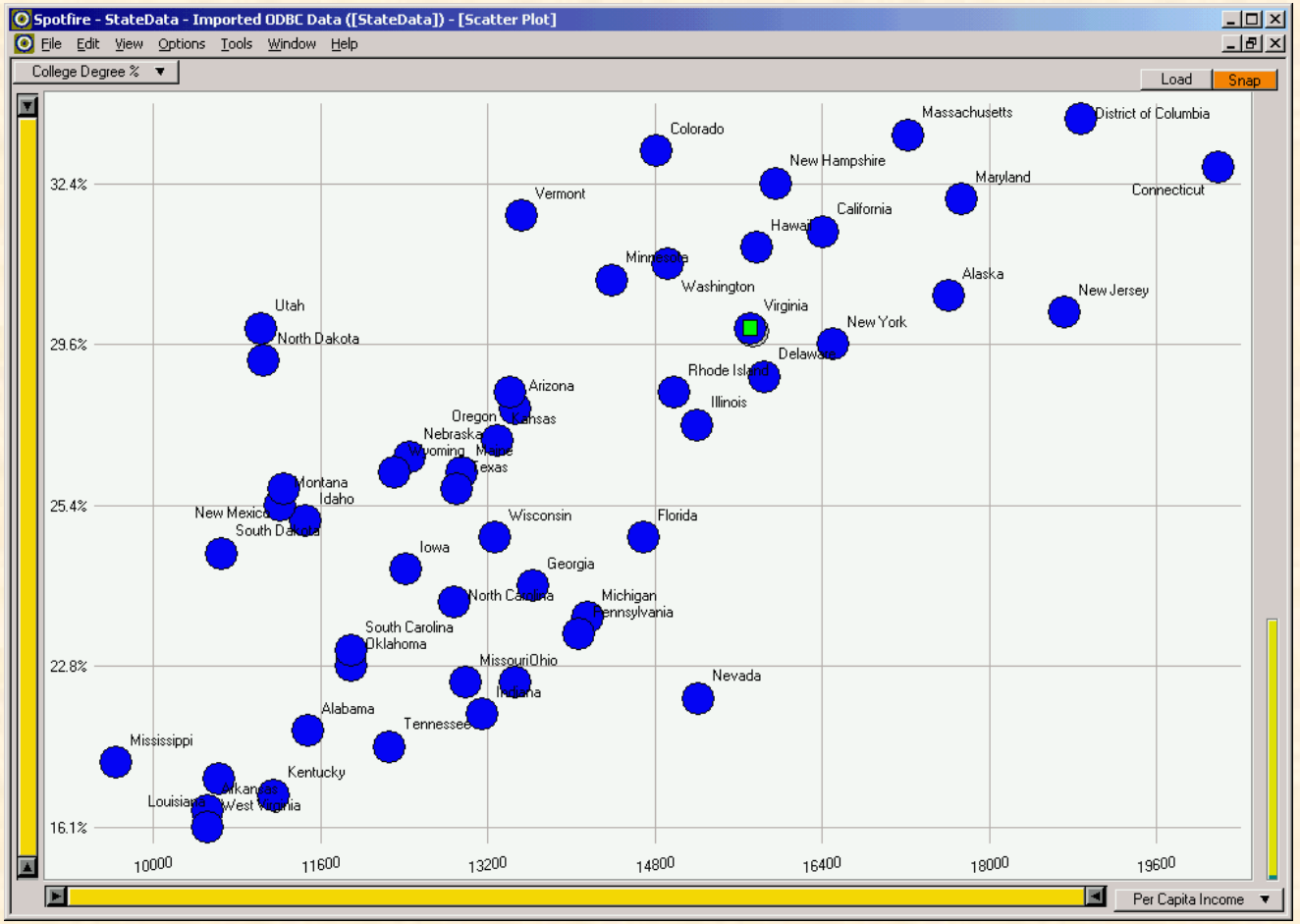
- Dot plot
- Bar chart (item vs. attribute)
- Tukey box plot
- Histogram





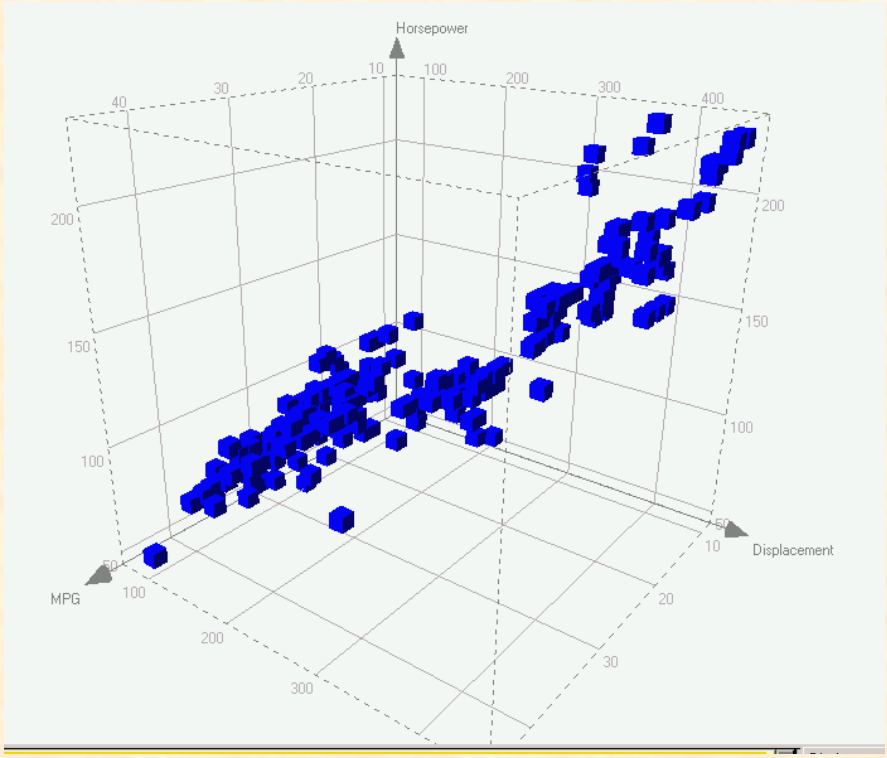
Bivariate

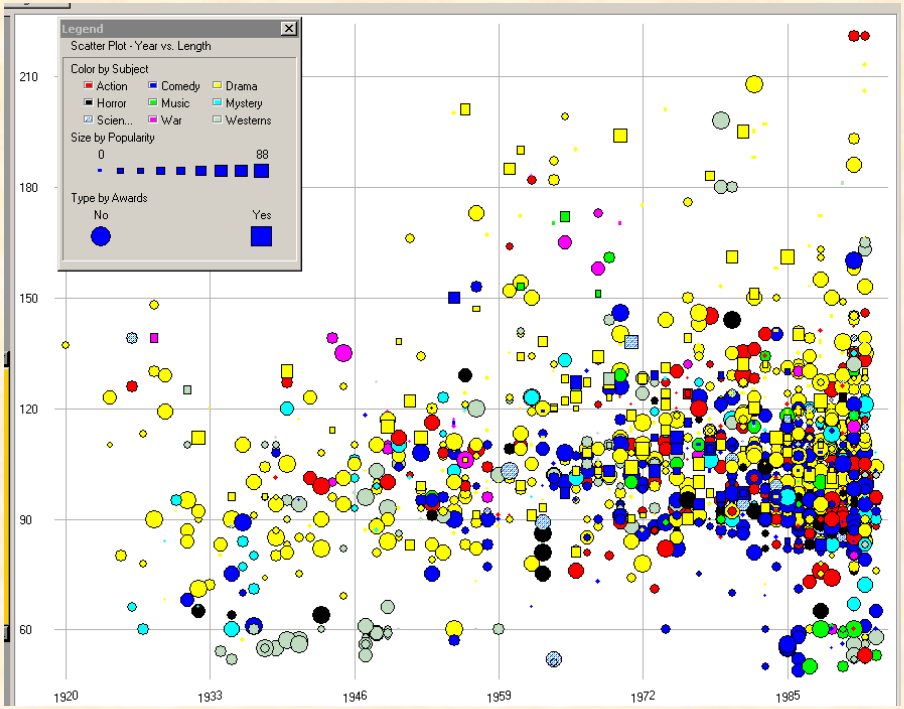
- Scatterplot
-



Trivariate

- 3D scatterplot, spin plot
- 2D plot + size (or color…)

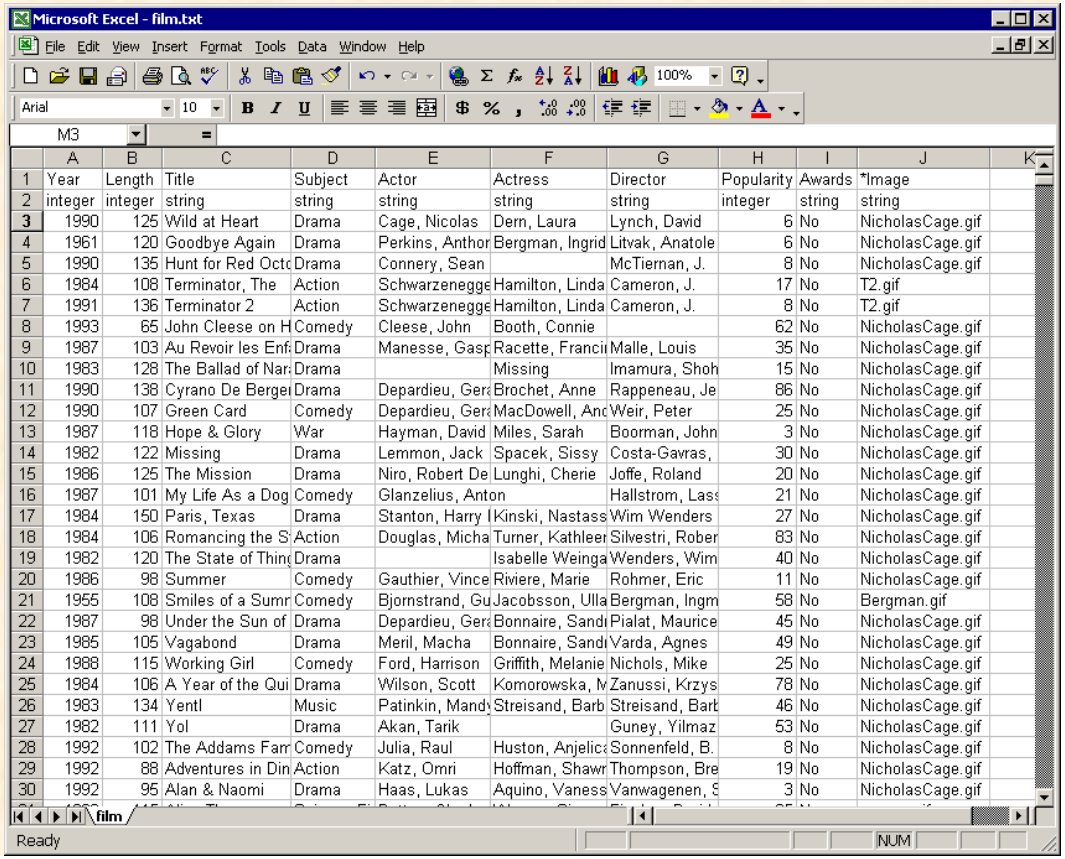




Multi-Dimensional Data

- Each attribute defines a dimension
- Small # of dimensions easy
  - Data mapping, Cleveland's rules
- What about many dimensional data? n-D

What does 10-D space look like?



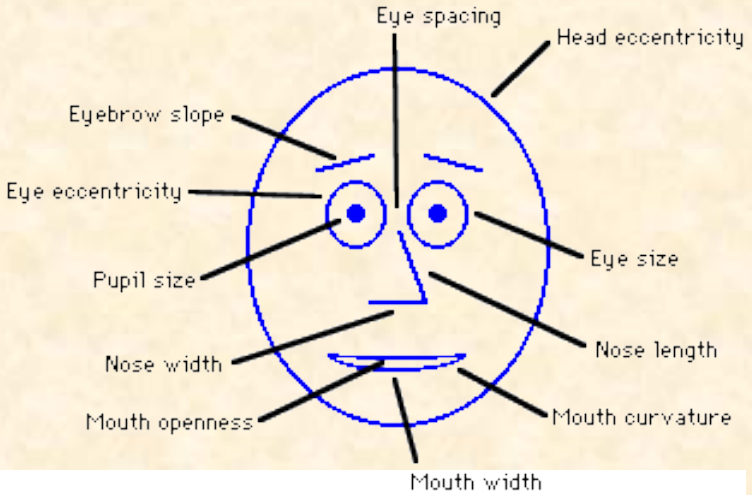
	A	B	C	D	E	F	G	H	I	J
1	Year	Length	Title	Subject	Actor	Actress	Director	Popularity	Awards	*Image
2	integer	integer	string	string	string	string	string	integer	string	string
3	1990	125	Wild at Heart	Drama	Cage, Nicolas	Dern, Laura	Lynch, David	6	No	NicholasCage.gif
4	1961	120	Goodbye Again	Drama	Perkins, Anthor	Bergman, Ingrid	Litvak, Anatole	6	No	NicholasCage.gif
5	1990	135	Hunt for Red Oct	Drama	Connery, Sean		McTiernan, J.	8	No	NicholasCage.gif
6	1984	108	Terminator, The	Action	Schwarzenegge	Hamilton, Linda	Cameron, J.	17	No	T2.gif
7	1991	136	Terminator 2	Action	Schwarzenegge	Hamilton, Linda	Cameron, J.	8	No	T2.gif
8	1993	65	John Cleese on H	Comedy	Cleese, John	Booth, Connie		62	No	NicholasCage.gif
9	1987	103	Au Revoir les Enf	Drama	Manesse, Gasp	Racette, Francii	Malle, Louis	35	No	NicholasCage.gif
10	1983	128	The Ballad of Nar	Drama		Missing	Imamura, Shoh	15	No	NicholasCage.gif
11	1990	138	Cyrano De Berger	Drama	Depardieu, Ger	Brochet, Anne	Rappeneau, Je	86	No	NicholasCage.gif
12	1990	107	Green Card	Comedy	Depardieu, Ger	MacDowell, And	Weir, Peter	25	No	NicholasCage.gif
13	1987	118	Hope & Glory	War	Hayman, David	Miles, Sarah	Boorman, John	3	No	NicholasCage.gif
14	1982	122	Missing	Drama	Lemmon, Jack	Spacek, Sissy	Costa-Gavras,	30	No	NicholasCage.gif
15	1986	125	The Mission	Drama	Niro, Robert De	Lunghi, Cherie	Joffe, Roland	20	No	NicholasCage.gif
16	1987	101	My Life As a Dog	Comedy	Glanzelius, Anton		Hallstrom, Lass	21	No	NicholasCage.gif
17	1984	150	Paris, Texas	Drama	Stanton, Harry I	Kinski, Nastass	Wim Wenders	27	No	NicholasCage.gif
18	1984	106	Romancing the S	Action	Douglas, Micha	Turner, Kathleer	Silvestri, Rober	83	No	NicholasCage.gif
19	1982	120	The State of Thin	Drama		Isabelle Weinga	Wenders, Wim	40	No	NicholasCage.gif
20	1986	98	Summer	Comedy	Gauthier, Vince	Riviere, Marie	Rohmer, Eric	11	No	NicholasCage.gif
21	1955	108	Smiles of a Sumr	Comedy	Bjornstrand, Gu	Jacobsson, Ulla	Bergman, Ingm	58	No	Bergman.gif
22	1987	98	Under the Sun of	Drama	Depardieu, Ger	Bonnaire, Sandi	Pialat, Maurice	45	No	NicholasCage.gif
23	1985	105	Vagabond	Drama	Meril, Macha	Bonnaire, Sandi	Varda, Agnes	49	No	NicholasCage.gif
24	1988	115	Working Girl	Comedy	Ford, Harrison	Griffith, Melanie	Nichols, Mike	25	No	NicholasCage.gif
25	1984	106	A Year of the Qui	Drama	Wilson, Scott	Komorowska, M	Zanussi, Krzys	78	No	NicholasCage.gif
26	1983	134	Yentl	Music	Patinkin, Mand	Streisand, Barb	Streisand, Barb	46	No	NicholasCage.gif
27	1982	111	Yol	Drama	Akan, Tarik		Guney, Yilmaz	53	No	NicholasCage.gif
28	1992	102	The Addams Fam	Comedy	Julia, Raul	Huston, Anjelic	Sonnenfeld, B.	8	No	NicholasCage.gif
29	1992	88	Adventures in Din	Action	Katz, Omri	Hoffman, Shawr	Thompson, Bre	19	No	NicholasCage.gif
30	1992	95	Alan & Naomi	Drama	Haas, Lukas	Aquino, Vaness	Vanwagenen, S	3	No	NicholasCage.gif

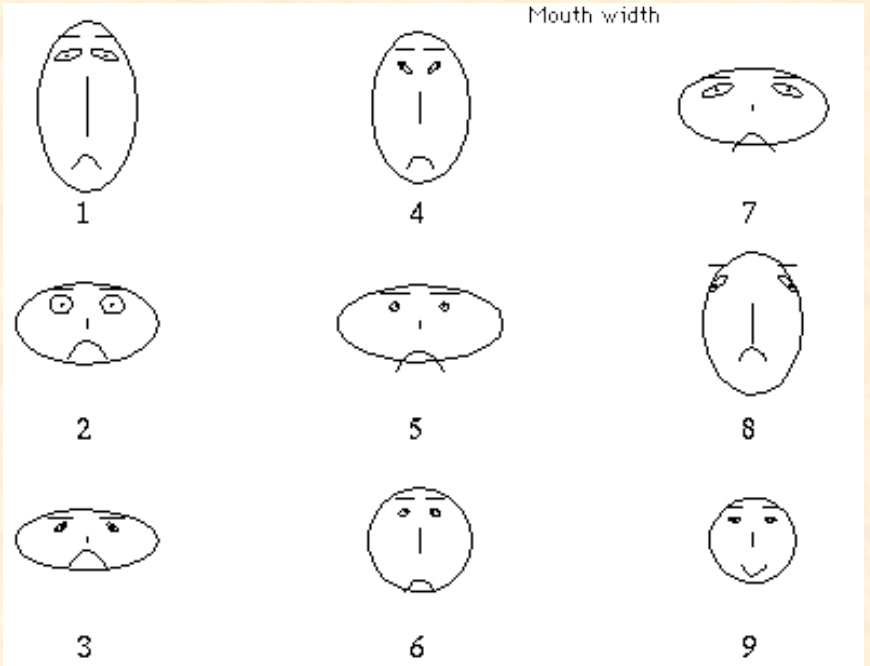
Map n-D space onto 2-D screen

- Visual representations:
  - Complex glyphs
    - E.g. star glyphs, faces, embedded visualization, …
  - Multiple views
    - E.g. plot matrices, brushing histograms, Spotfire, …
  - Non-orthogonal axes
    - E.g. Parallel coords, star coords, …
  - Tabular layout
    - E.g. TableLens, …
- Interactions:
  - Dynamic Queries
  - Brushing & Linking
  - Selecting for details, …

Glyphs: Chernoff Faces

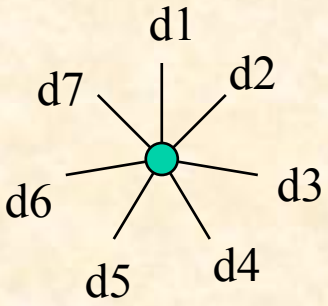
- 10 Parameters:
  - Head Eccentricity
  - Eye Eccentricity
  - Pupil Size
  - Eyebrow Slope
  - Nose Size
  - Mouth Vertical Offset
  - Eye Spacing
  - Eye Size
  - Mouth Width
  - Mouth Openness





- http://hesketh.com/schampeo/projects/Faces/chernoff.html

Glyphs: Stars



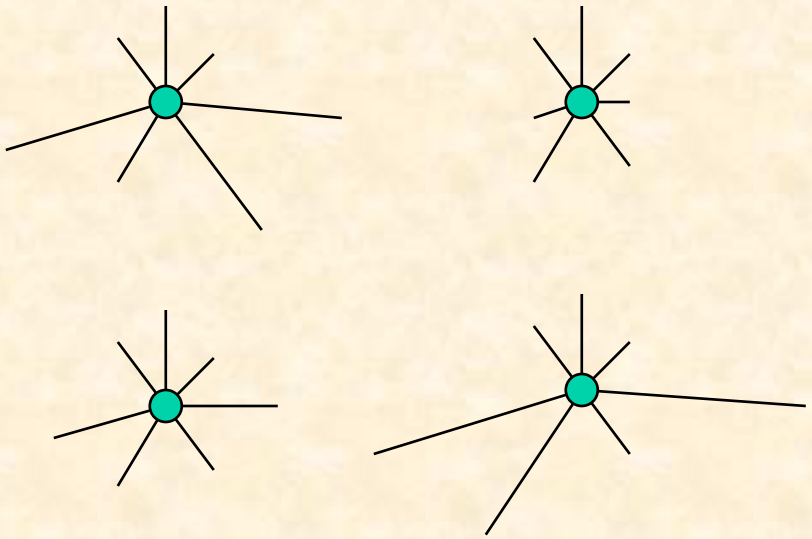
Evaluation of Alternative Glyph Designs for Time Series Data in a Small Multiple Setting

Johannes Fuchs[1] **Fabian Fischer**[1] **Florian Mansmann**[1]
[1]University of Konstanz
fuchs@dbvis.inf.uni-konstanz.de
(fabian.fischer|florian.mansmann)@uni-konstanz.de

Enrico Bertini[2]
[2]NYU Poly
ebertini@poly.edu

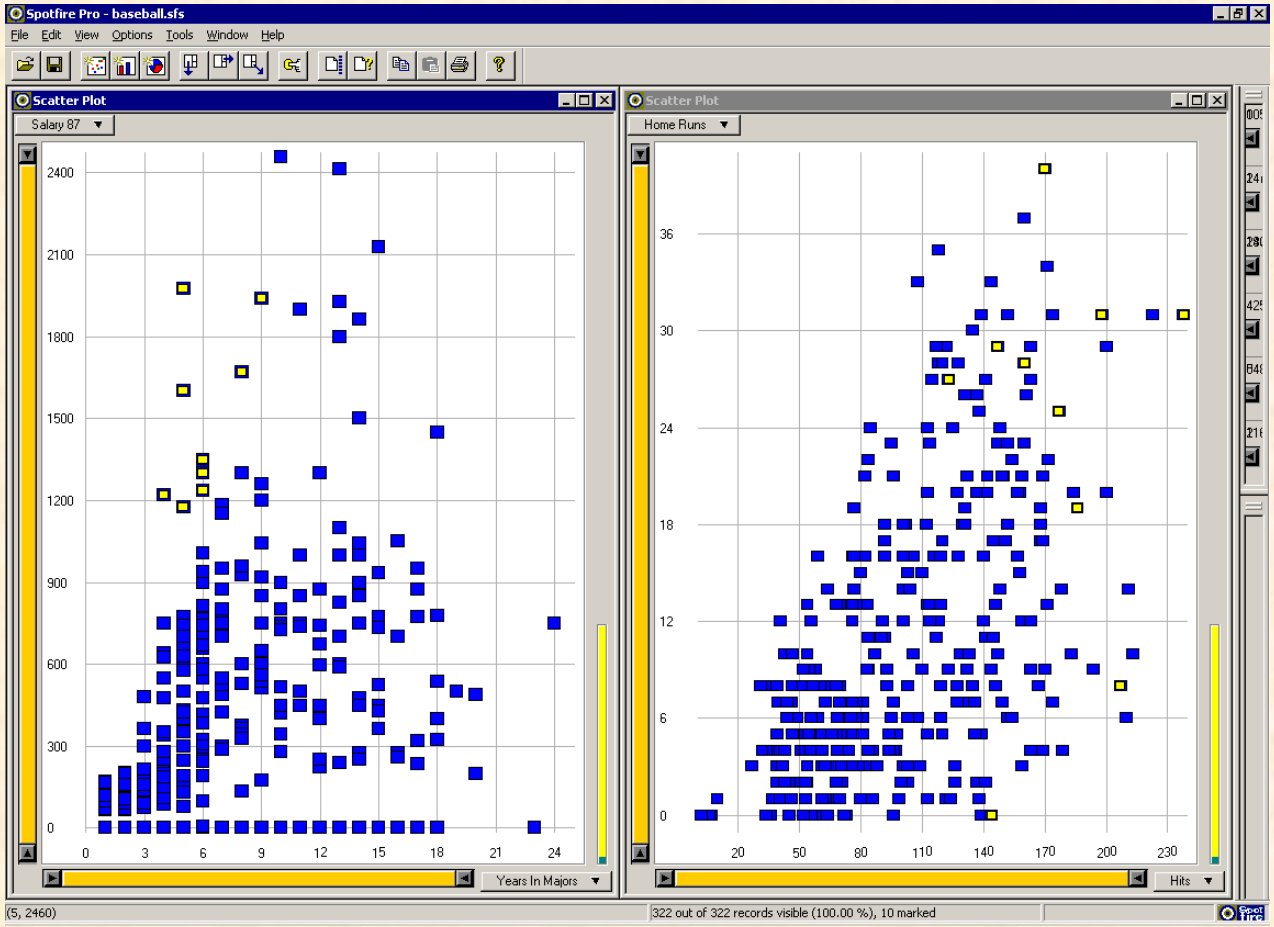
Petra Isenberg[3]
[3]INRIA
petra.isenberg@inria.fr

http://hal.inria.fr/docs/00/78/15/04/PDF/Fuchs_2013_EOA.pdf



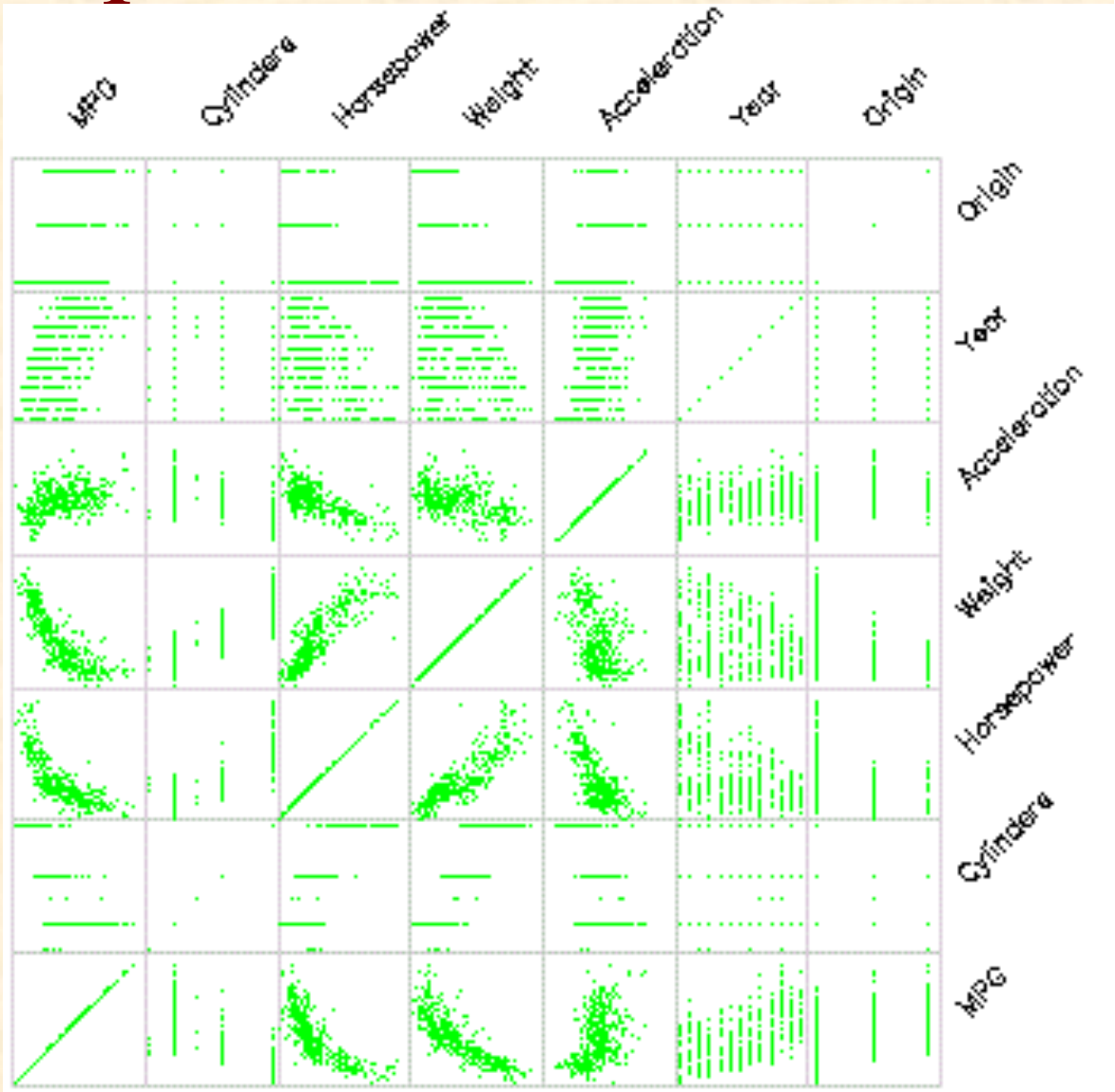
Multiple Views with Brushing-and-linking

Robert Kosara: brush and linking, Parallel Coordinates: http://vimeo.com/13437693



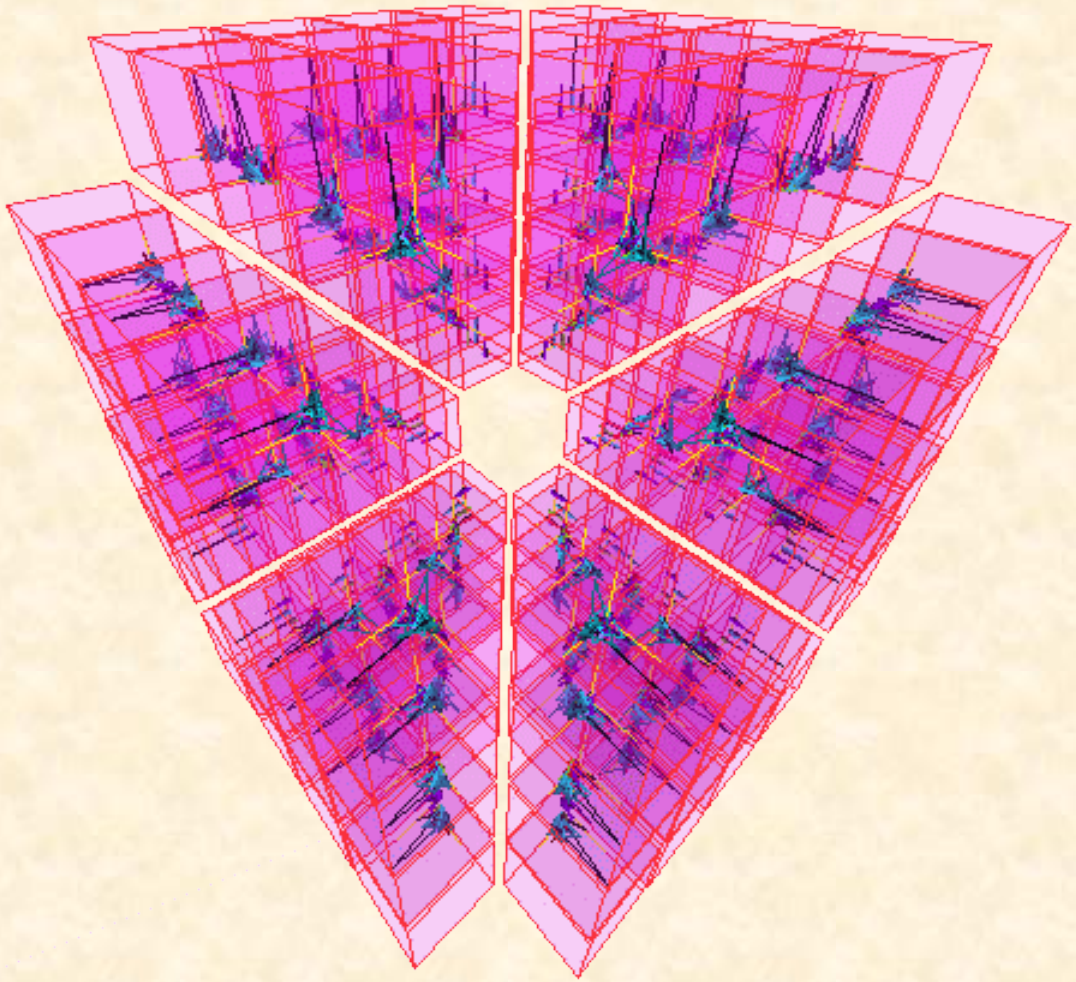
Scatterplot Matrix

- All pairs of attributes
- Brushing and linking



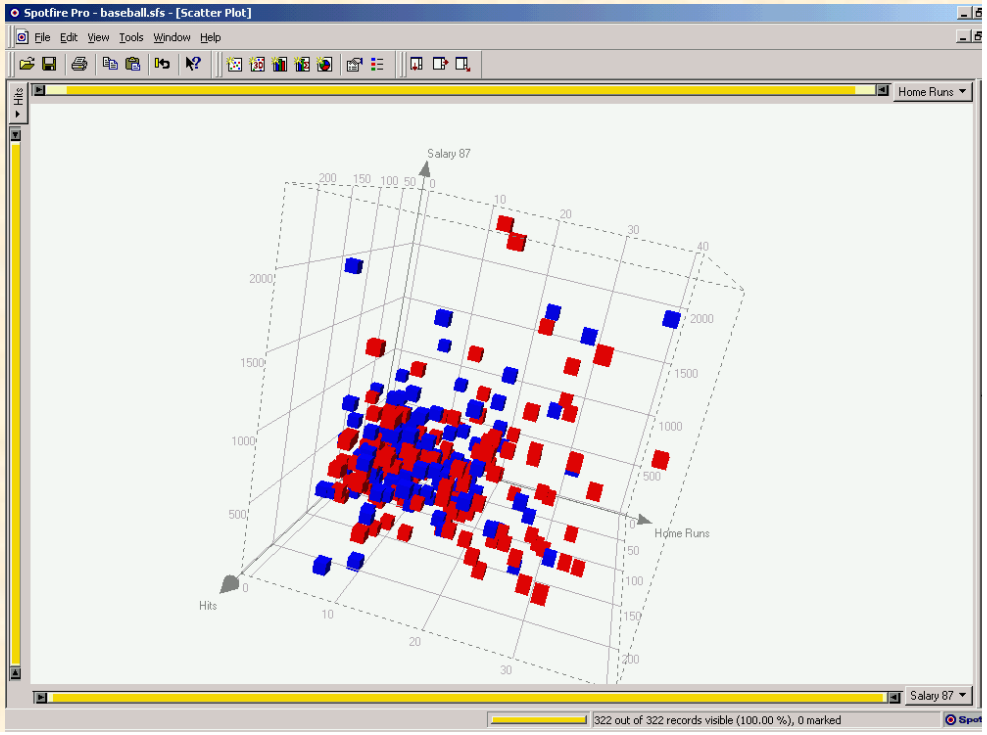
- http://noppa5.pc.helsinki.fi/koe/3d3.html

… on steroids



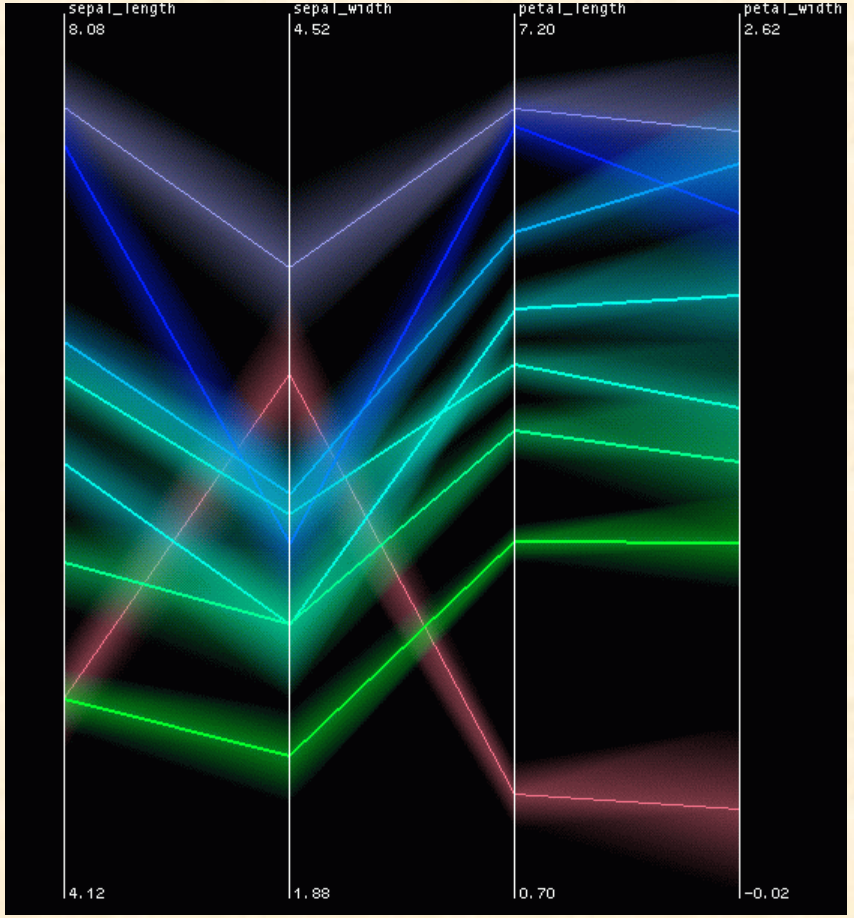
Different Arrangements of Axes

- Axes are good
  - Lays out all points in a single space
  - "position" is 1st in Cleveland's rules
  - Uniform treatment of dimensions
- Space > 3D ?
- Must trash orthogonality



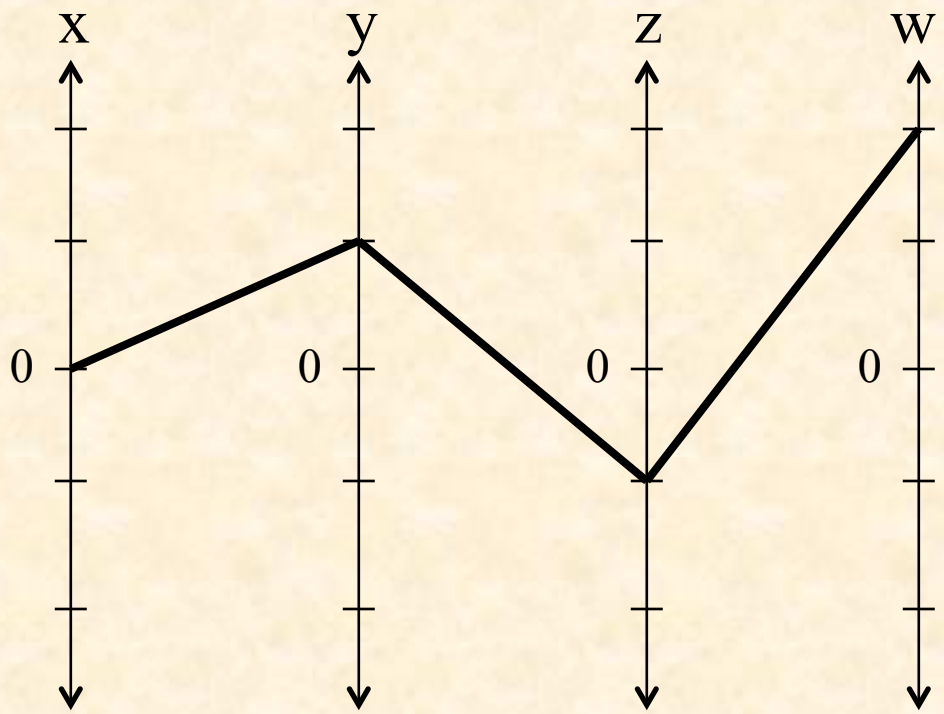
Parallel Coordinates

- Inselberg, “Multidimensional detective” (parallel coordinates)
  -

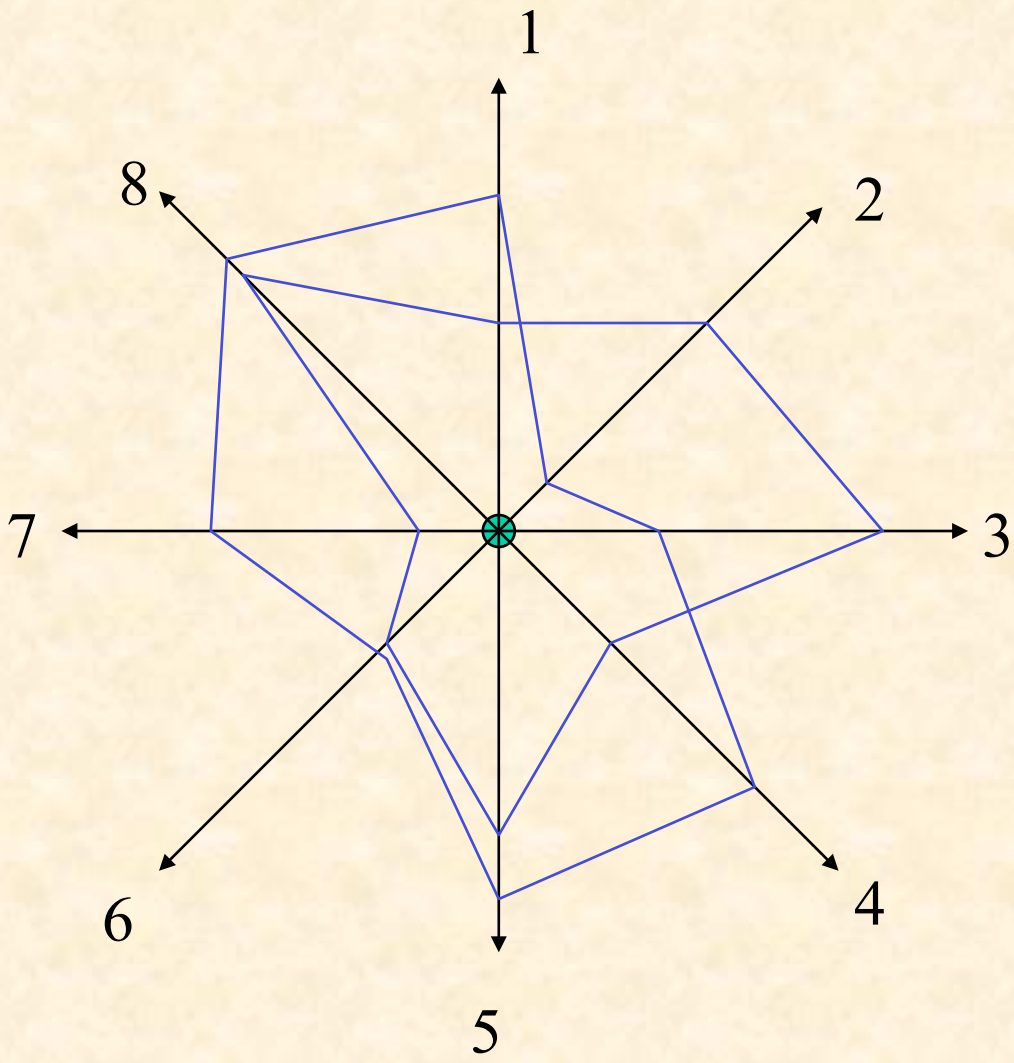


Parallel Coordinates

- Forget about Cartesian orthogonal axes
- (0,1,-1,2)=



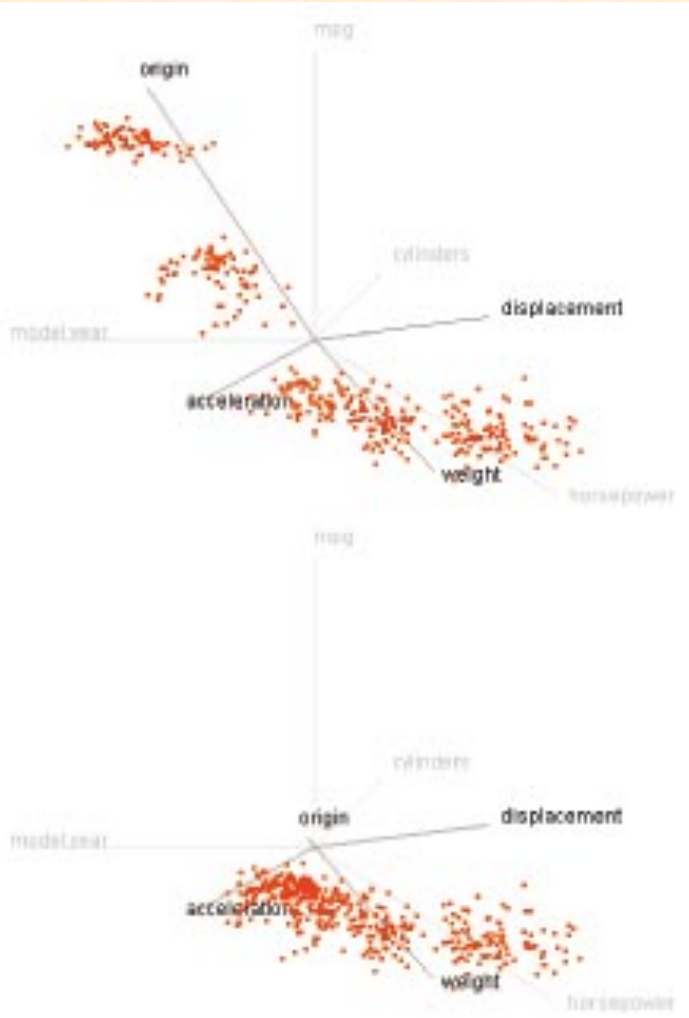
Star Plot



Parallel Coordinates with axes arranged radially

Star Coordinates

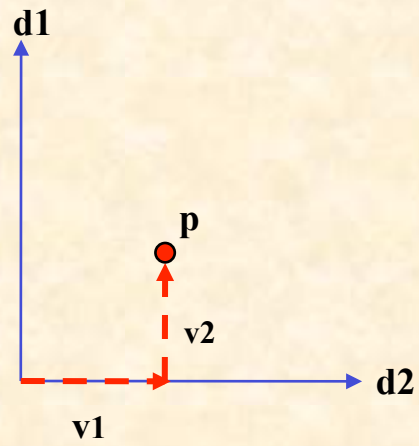
- Kandogan, “Star Coordinates”
  -



Star Coordinates

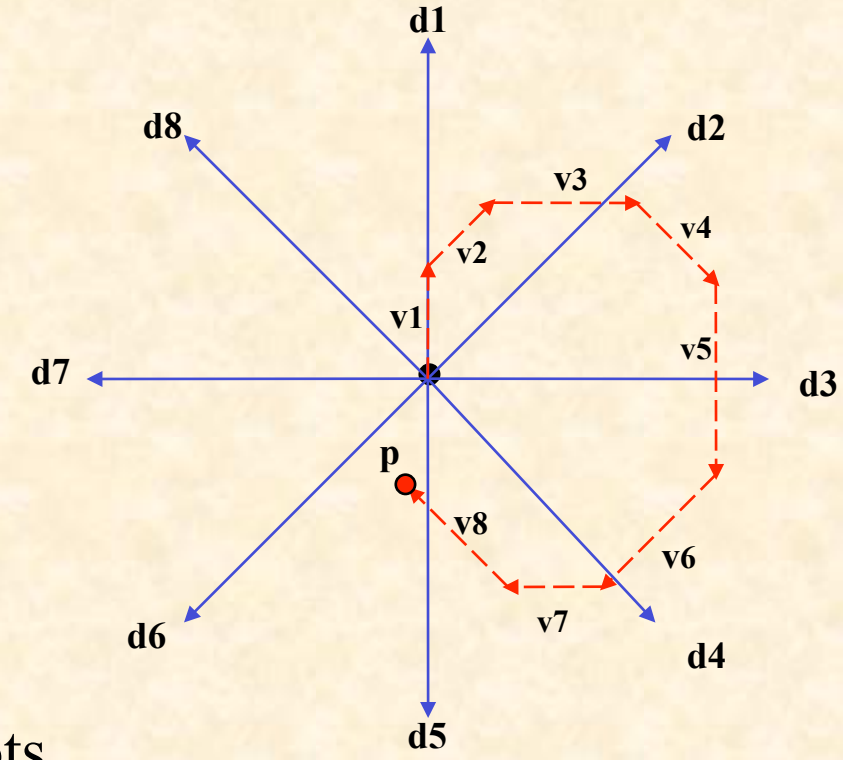
Cartesian

P=(v1, v2)



Star Coordinates

P=(v1,v2,v3,v4,v5,v6,v7,v8)



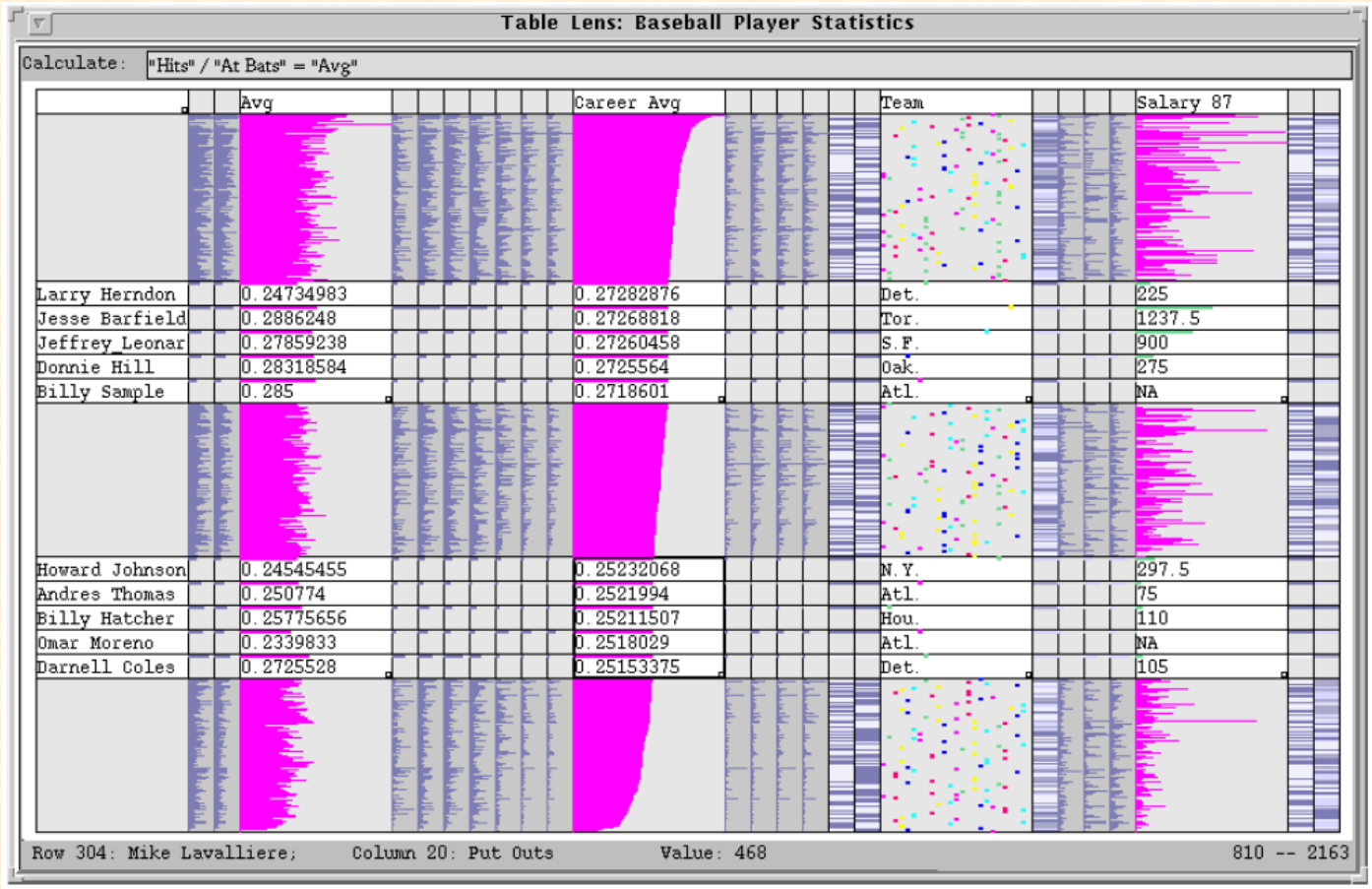
Mapping:

- Items → dots
- Σ attribute vectors → (x,y)

Analysis

Table Lens

- Rao, “Table Lens” http://www.ramanarao.com/papers/tablelens-chi94.pdf



FOCUS / InfoZoom

- Spenke, “FOCUS”
  - Finding correlations between the measurements and the occurrence of a thrombosis

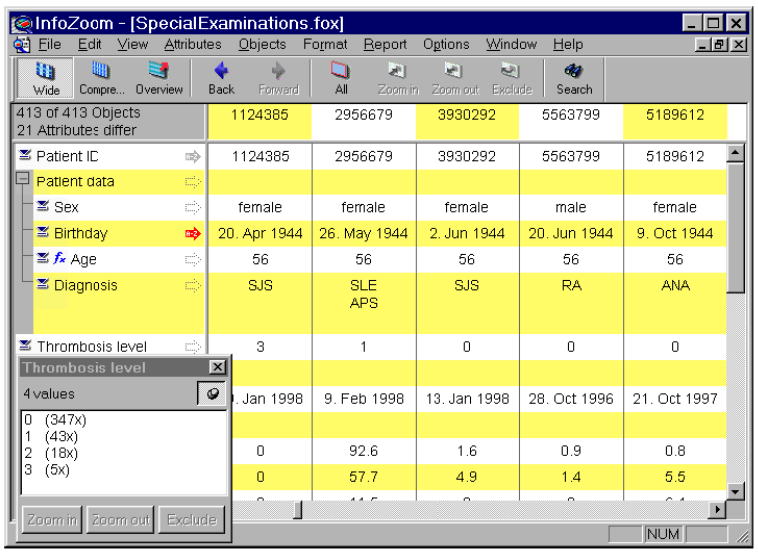
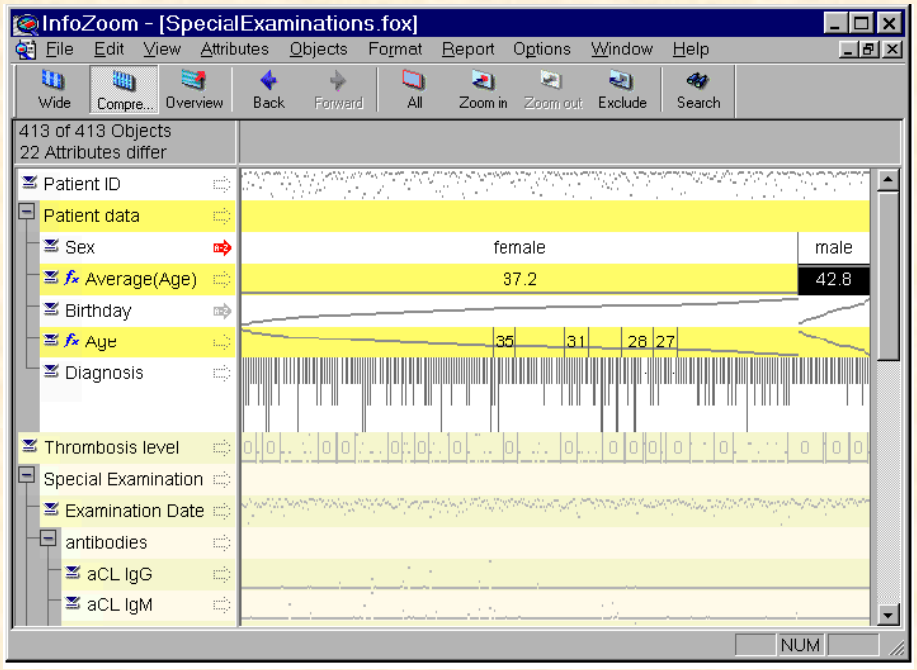


Figure 1: Wide Table Mode



Visualization and Interactive Analysis of Blood Parameters with InfoZoom

Michael Spenke
GMD — German National Research Center for Information Technology
FIT — Institute for Applied Information Technology, http://www.gmd.de/fit

VisDB & Pixel Bar Charts

- Keim, “VisDB”
  -

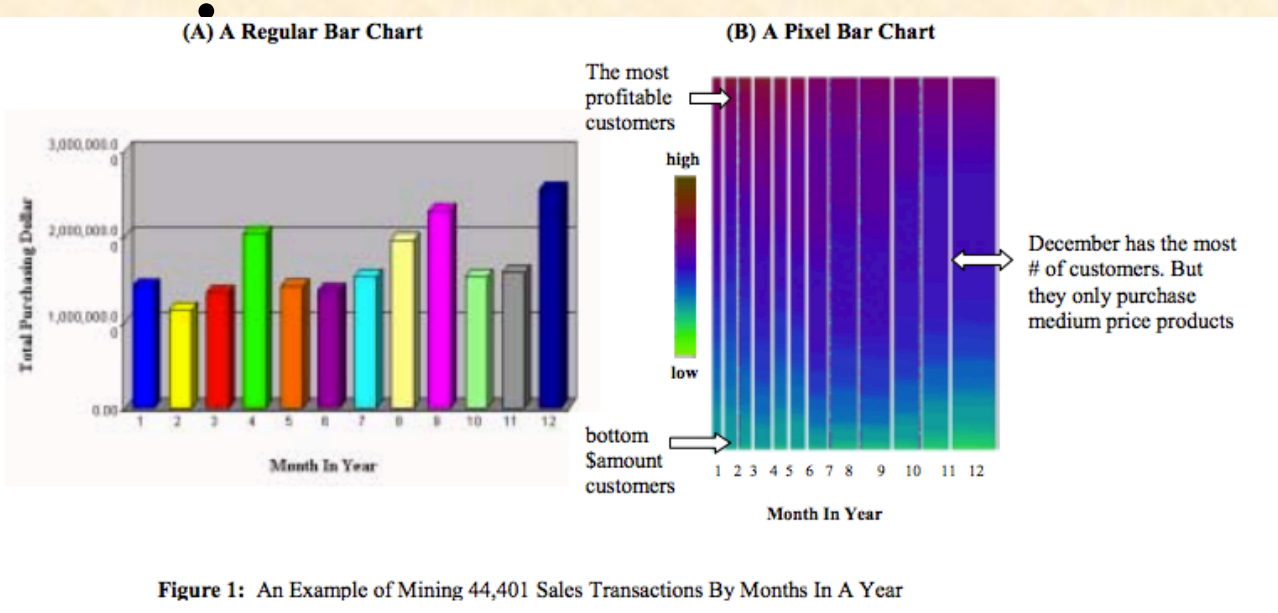


Figure 1: An Example of Mining 44,401 Sales Transactions By Months In A Year

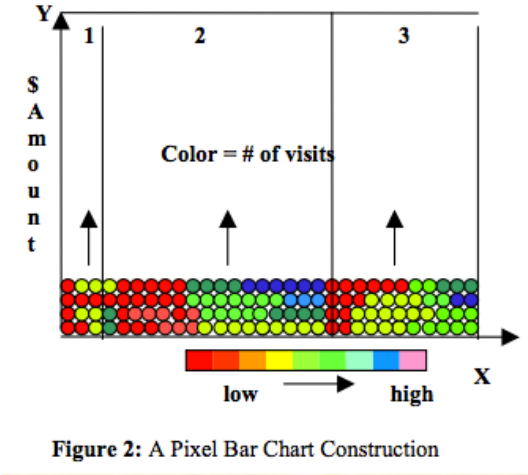
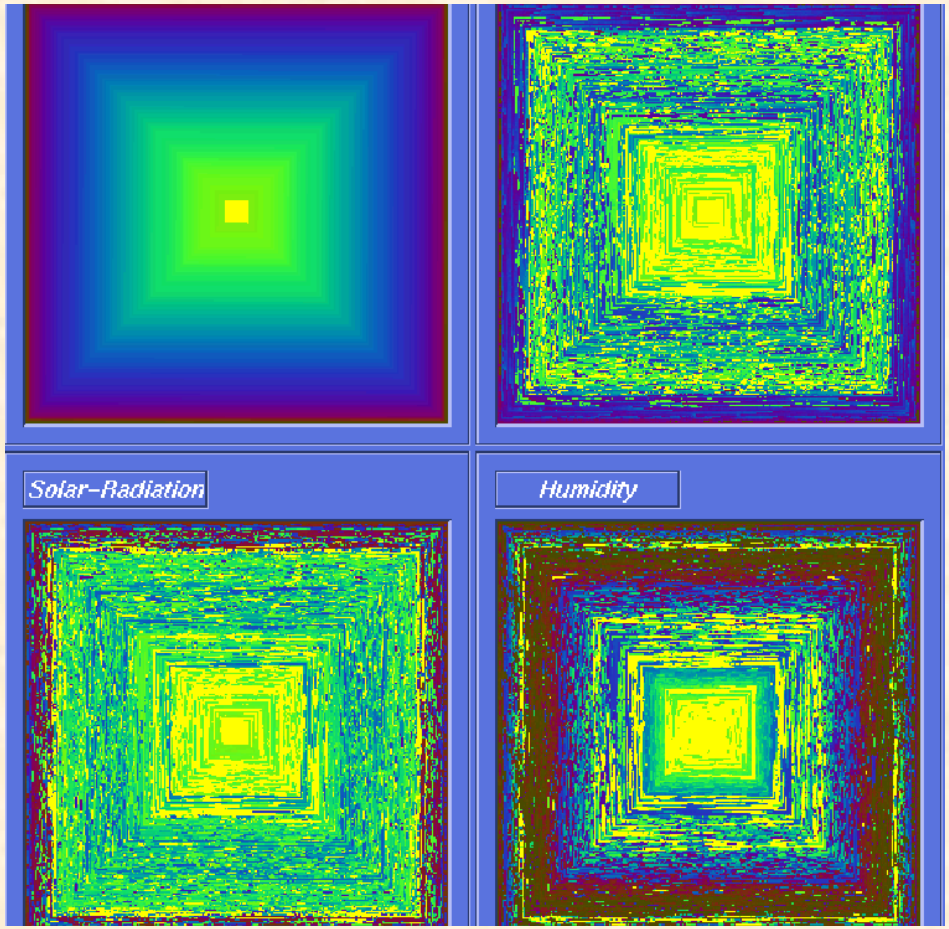


Figure 2: A Pixel Bar Chart Construction

<pixel object,
dividing attribute,
Y-ordering attribute,
X-ordering attribute,
coloring attribute>

<customer,
month,
dollar amount ,
number of visits,
dollar amount >


Solar-Radiation
Humidity

Comparison of Techniques

Comparison of Techniques

- ParCood: <1000 items, <20 attrs
  - » Relate between adjacent attr pairs
- StarCoord: <1,000,000 items, <20 attrs
  - » Interaction intensive
- TableLens: similar to par-coords
  - » more items with aggregation
  - » Relate 1:m attrs (sorting), short learn time
- Visdb: 100,000 items with 10 attrs
  - » Items*attrs = screenspace, long learn time, must query
- Spotfire : <1,000,000 items, <10 attrs (DQ many)
  - » Filtering, short learn time

Scaling up further

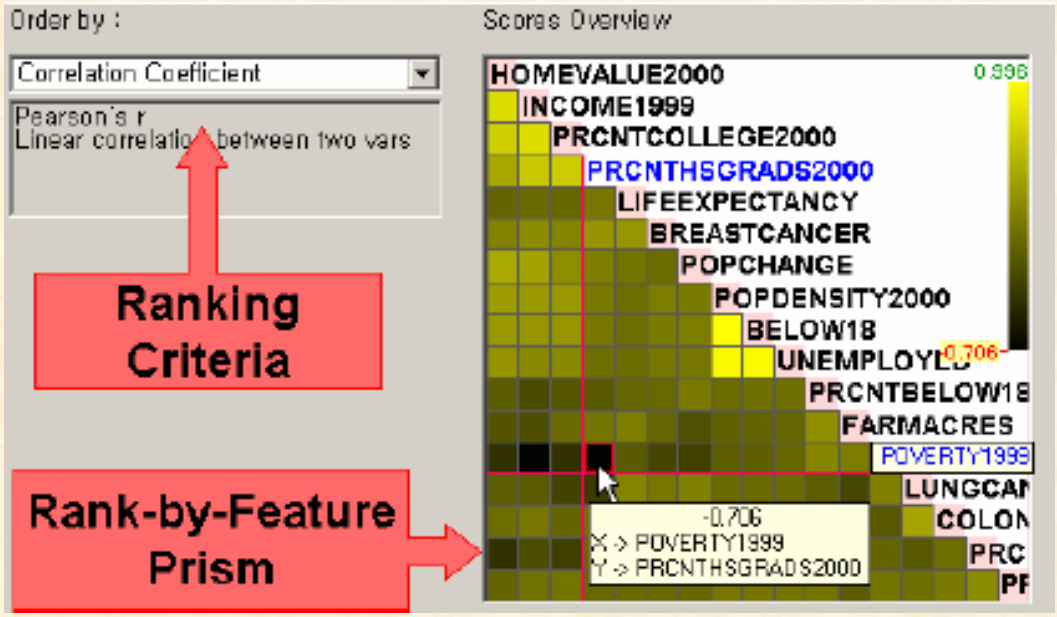
- Beyond 20 dimensions?

1. Interaction
   - E.g. Offload some dims to Dynamic Query sliders, …
2. Reduce dimensionality of the data
   - E.g. Multi-dimensional scaling (MDS) …later
3. Visualize features of the dimensions, instead of the data
   - E.g. rank-by-feature

- Tableau

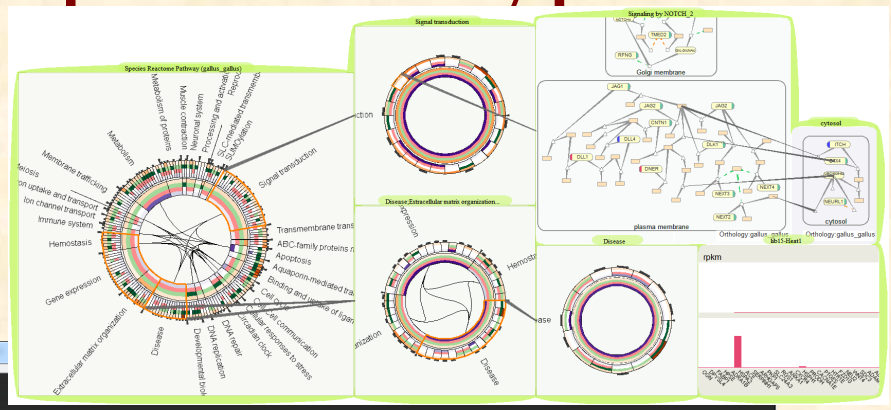
Rank-by-Feature

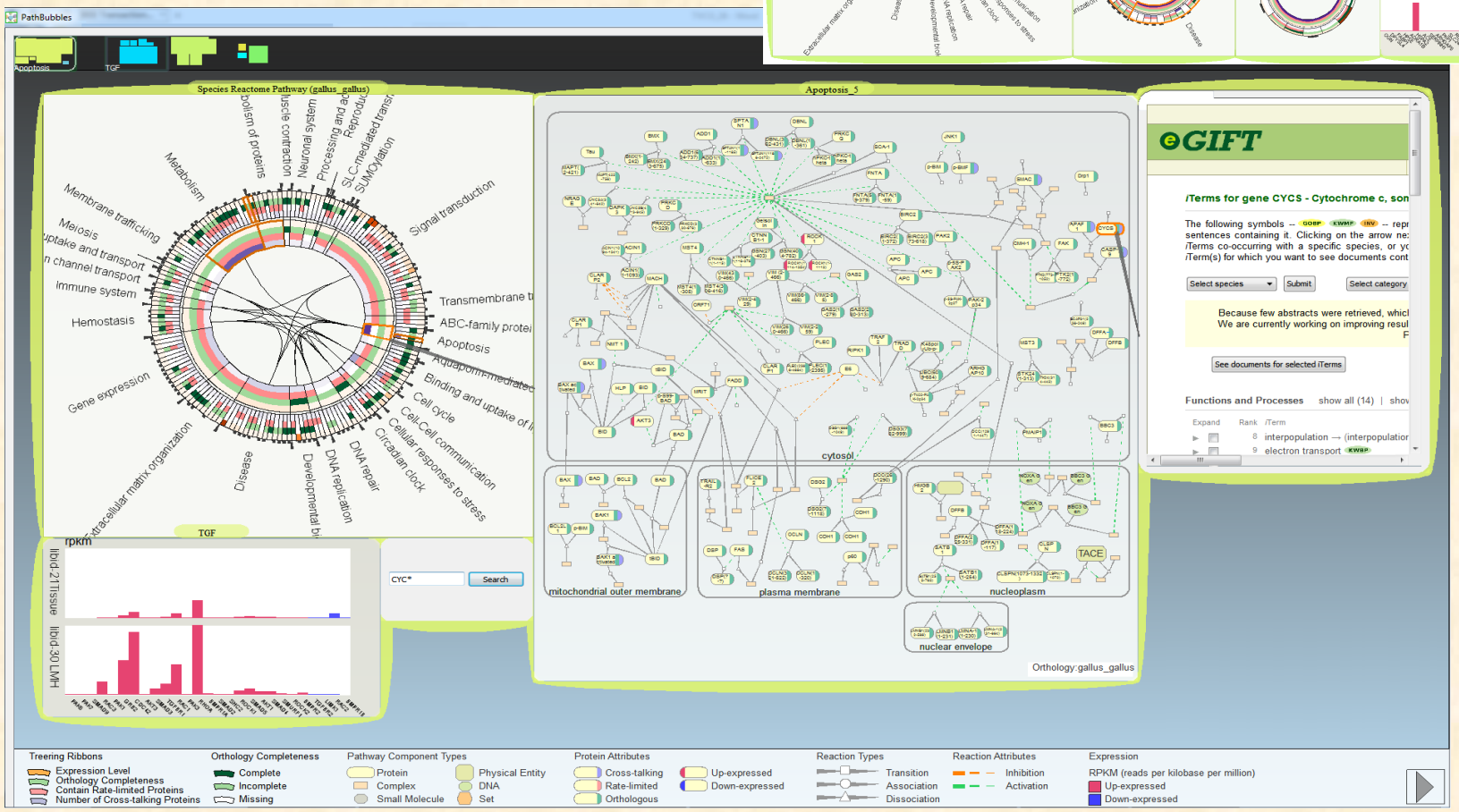
- Seo, et al.



Combining multiple data types

- Multi-Dimensional:
- PathBubbles: UMBC





- D
- S n
(1 spatial)
- D

Table - StateData ()

Load | Snap

State	College Degree %	Per Capita Income
Alabama	20.6%	11486
Alaska	30.3%	17610
Arizona	27.1%	13461
Arkansas	17.0%	10520
California	31.3%	16409
Colorado	33.9%	14821
Connecticut	33.8%	20189
Delaware	27.9%	15854
District of Columbia	36.4%	18881
Florida	24.9%	14698
Georgia	24.3%	13631
Hawaii	31.2%	15770
Idaho	25.2%	11457
Illinois	26.8%	15201
Indiana	20.9%	13149
Iowa	24.5%	12422
Kansas	26.5%	13300
Kentucky	17.7%	11153
Louisiana	19.4%	10635
Maine	25.7%	12957
Maryland	31.7%	17730
Massachusetts	34.5%	17224
Michigan	24.1%	14154
Minnesota	30.4%	14389

Your solutions

1. Small Multiples

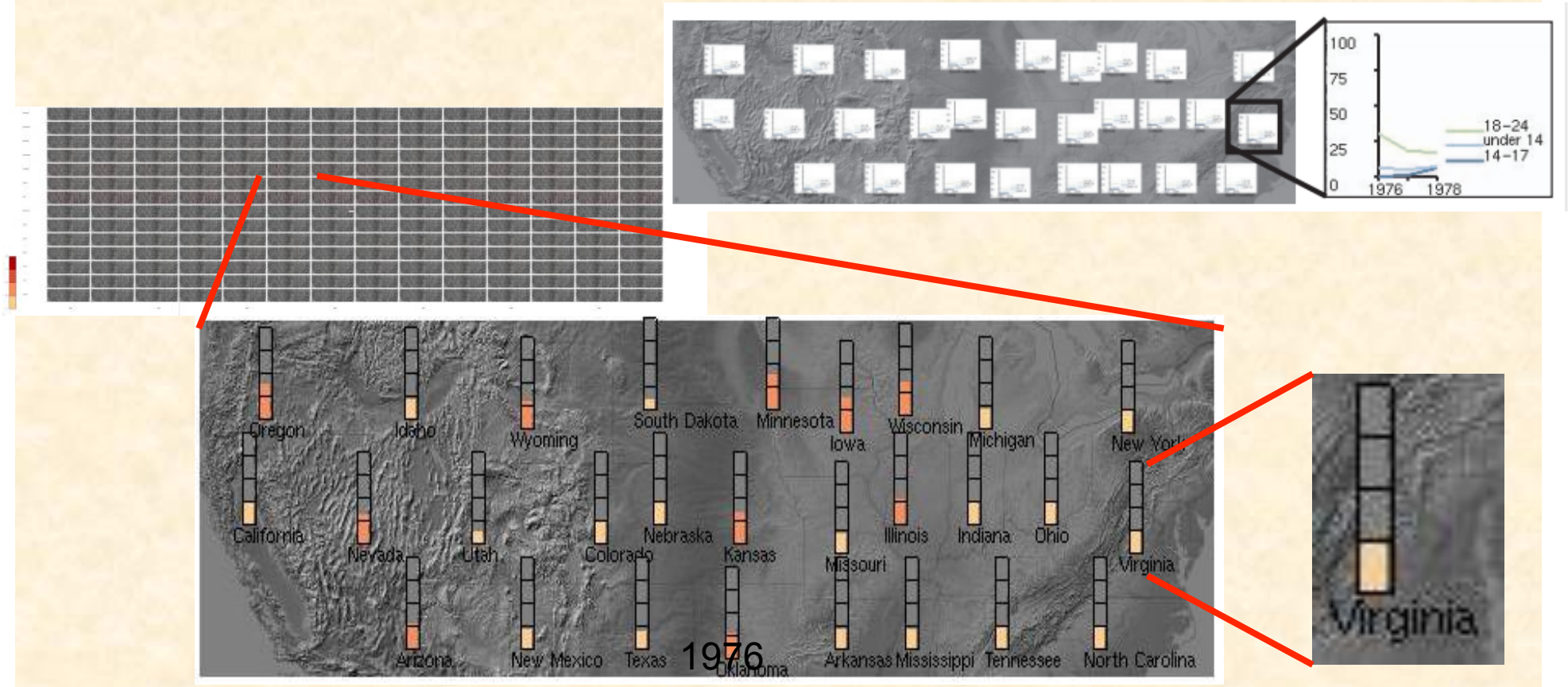
Multiple views: 1 or more attribute / map

Scalability issues: perception | display

ONS ON VISUALIZATION AND COMPUTER GRAPHICS, VOL. 12, NO. 5, SEPTEMBER/OCTOBER 2006

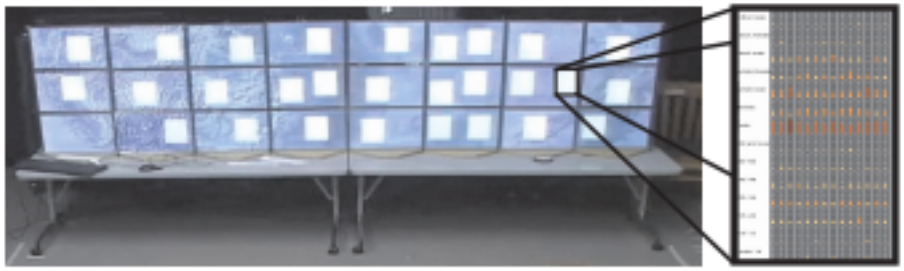
The Perceptual Scalability of Visualization

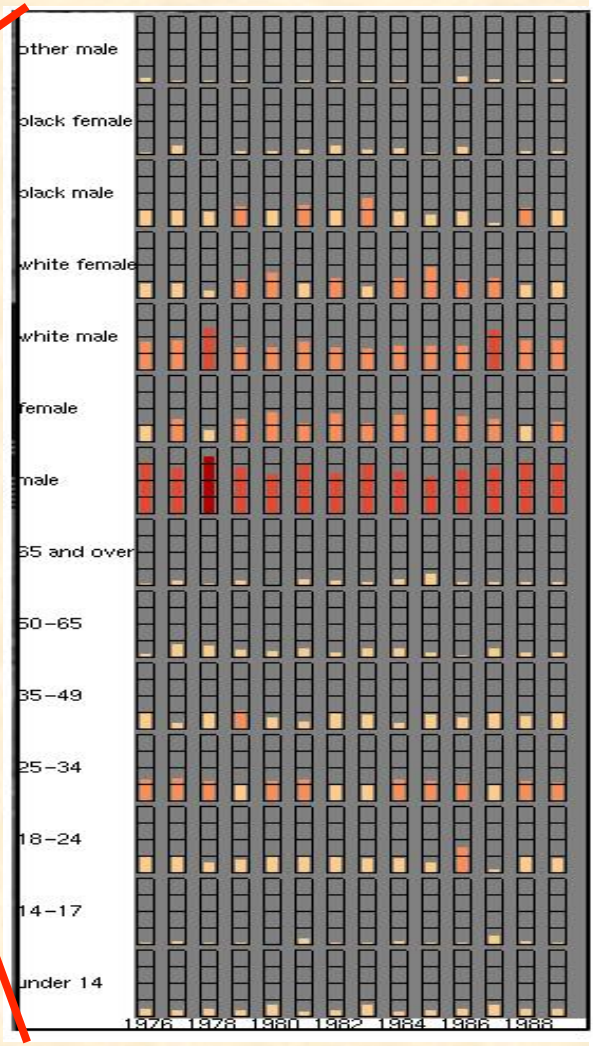
Beth Yost. *Student Member. IEEE* and Chris North



2. Embedded Visualizations

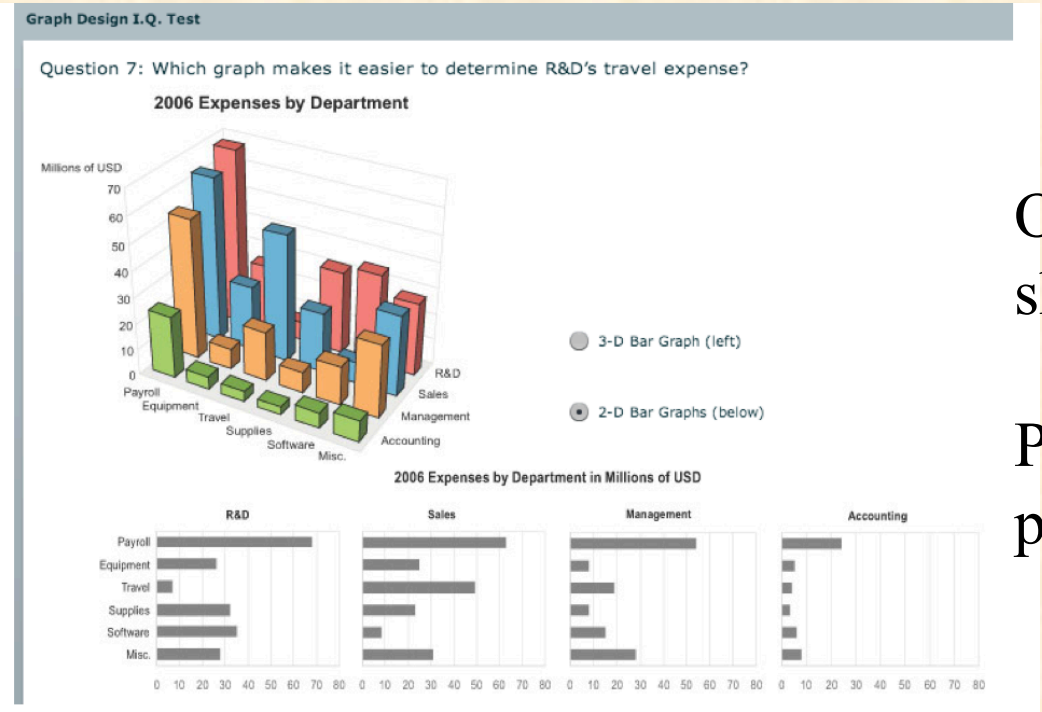
Complex glyphs: For each location, show vis of all attributes





2D vs. 3D

3. 2D vs. 3D



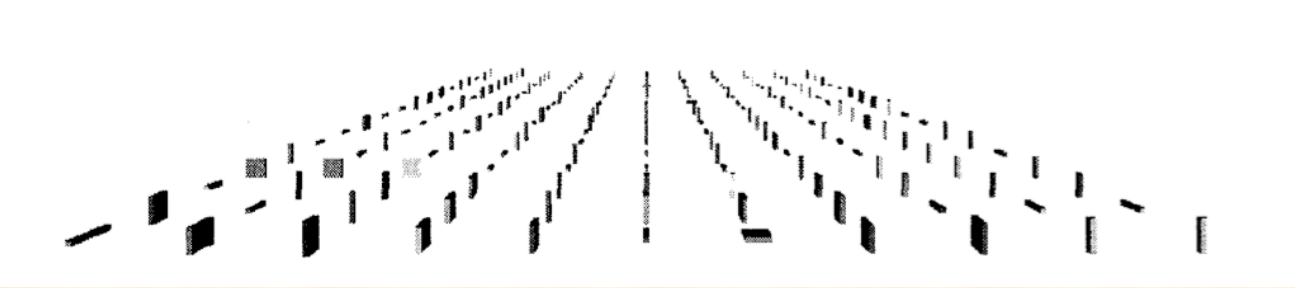
Occlusion

shadow changes the colors?

Chart junk

Patterns -> area;

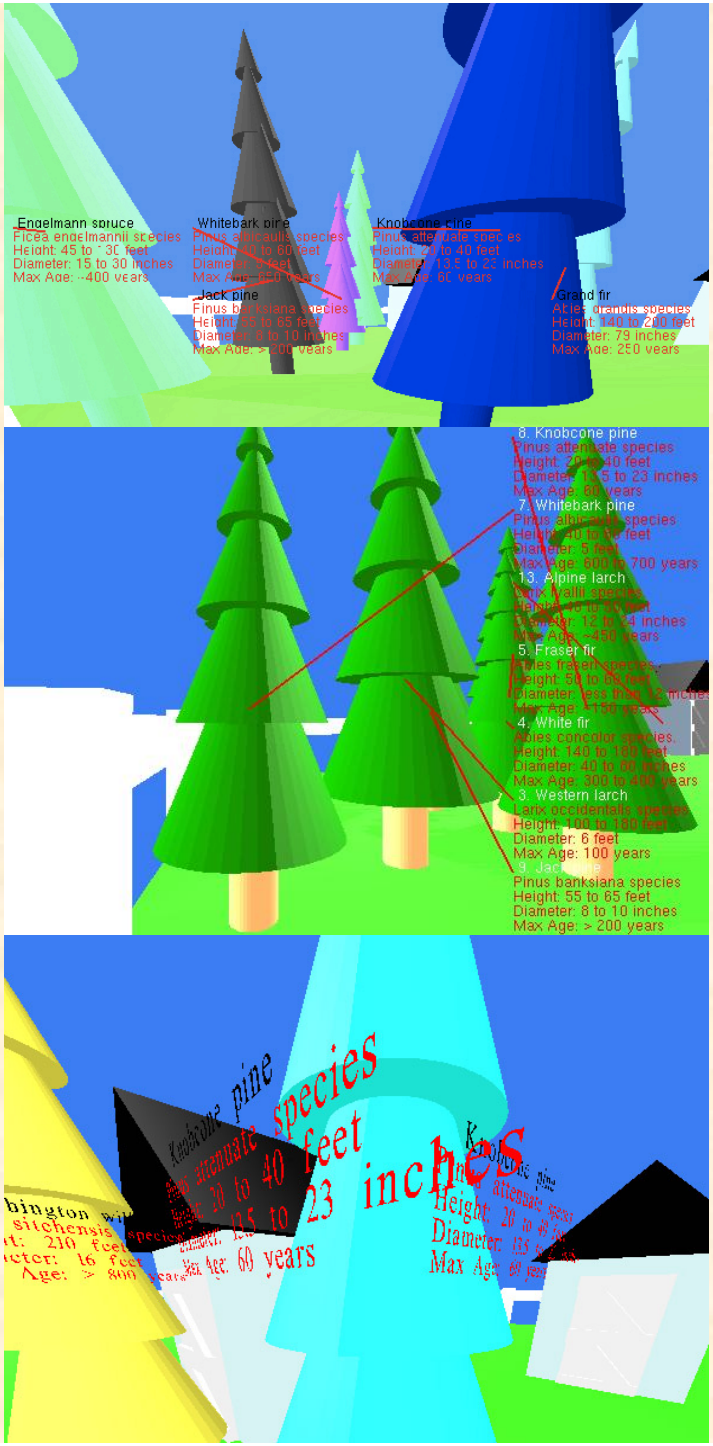
perspectives



2D vs. 3D: text?

- Texts?

- Feiner, Augmented reality



Mental modal vs. Features

VIS externalization media

Foundations of Science (2005) 10: 89–106

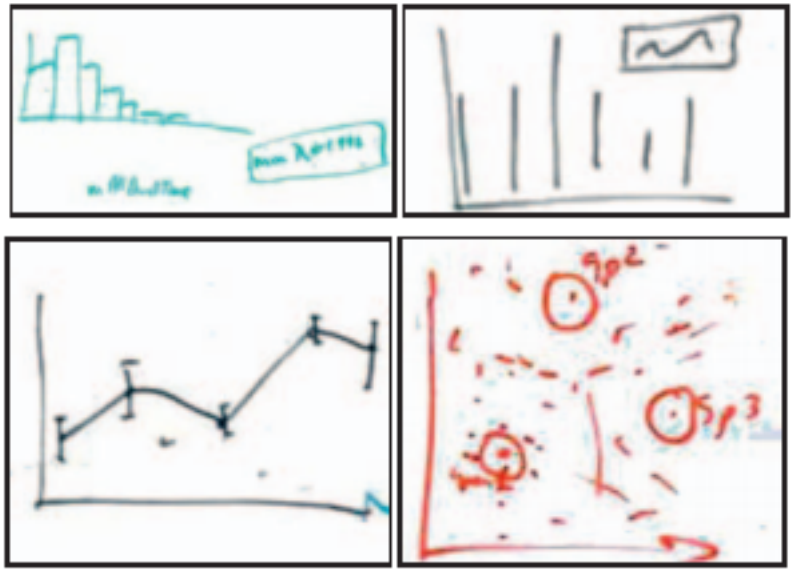
J. GREGORY TRAFTON, SUSAN B. TRICKETT and FARILEE E. MINTZ

CONNECTING INTERNAL AND EXTERNAL REPRESENTATIONS: SPATIAL TRANSFORMATIONS OF SCIENTIFIC VISUALIZATIONS

2508 IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS, VOL. 17, NO. 12, DECEMBER 2011

Visual Thinking In Action: Visualizations As Used On Whiteboards

Jagoda Walny, Sheelagh Carpendale, Nathalie Henry Riche, Gina Venolia, and Philip Fawcett



Stereo, tracking, larger FOV?

http://www.youtube.com/watch?v=I1x4-g6wbtU#t=29

Linsen group, the effect of stereoscopic immersive environment on projection-based multi-dimensional data visualization. IV 2013.

Tasks: 1. count the cluster; 2/3. find closest cluster to a specific point/cluster; 4. detect the densest cluster; 5. find the most distant cluster pair; 6. count the outliers; 7. find the closest cluster to select group of points; 8. name all of the pairs of overlapping clusters

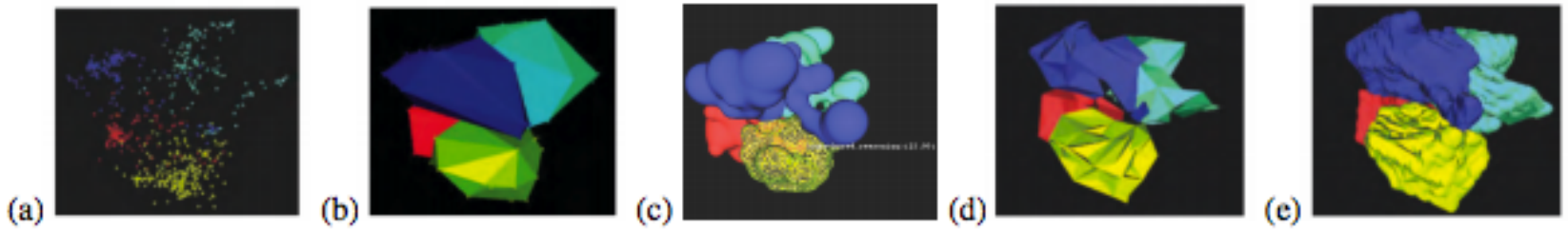
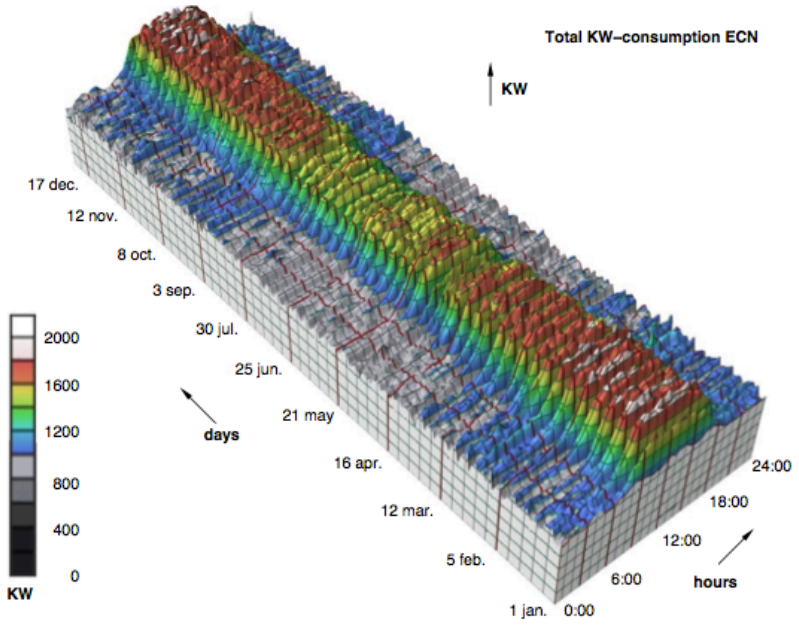


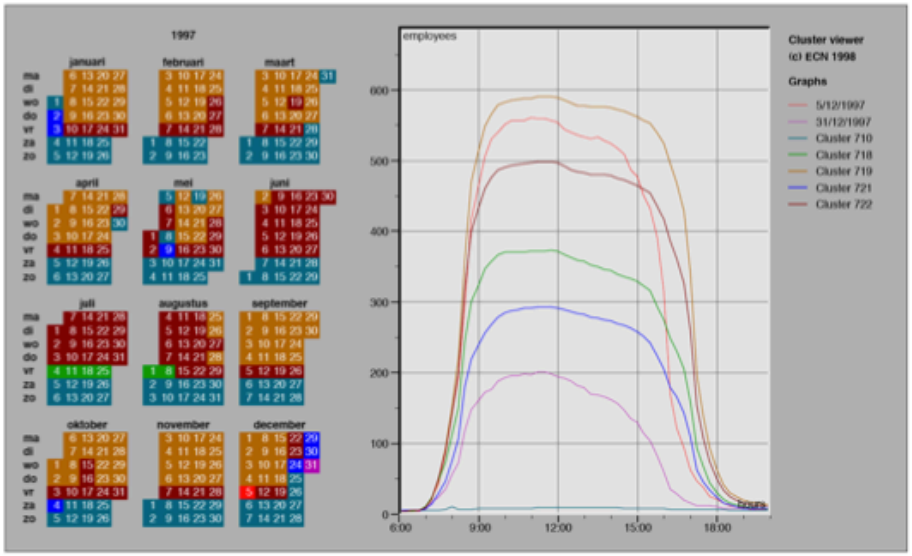
Fig. 1. Visual encoding of the clusters in 3D visual space using (a) Points, a 3D scatterplot with clusters encoded by color., (b) ConvHull, (c) PointsEncSurf, (d) NonconvHull, and (e) HullEncSurf.

Time series

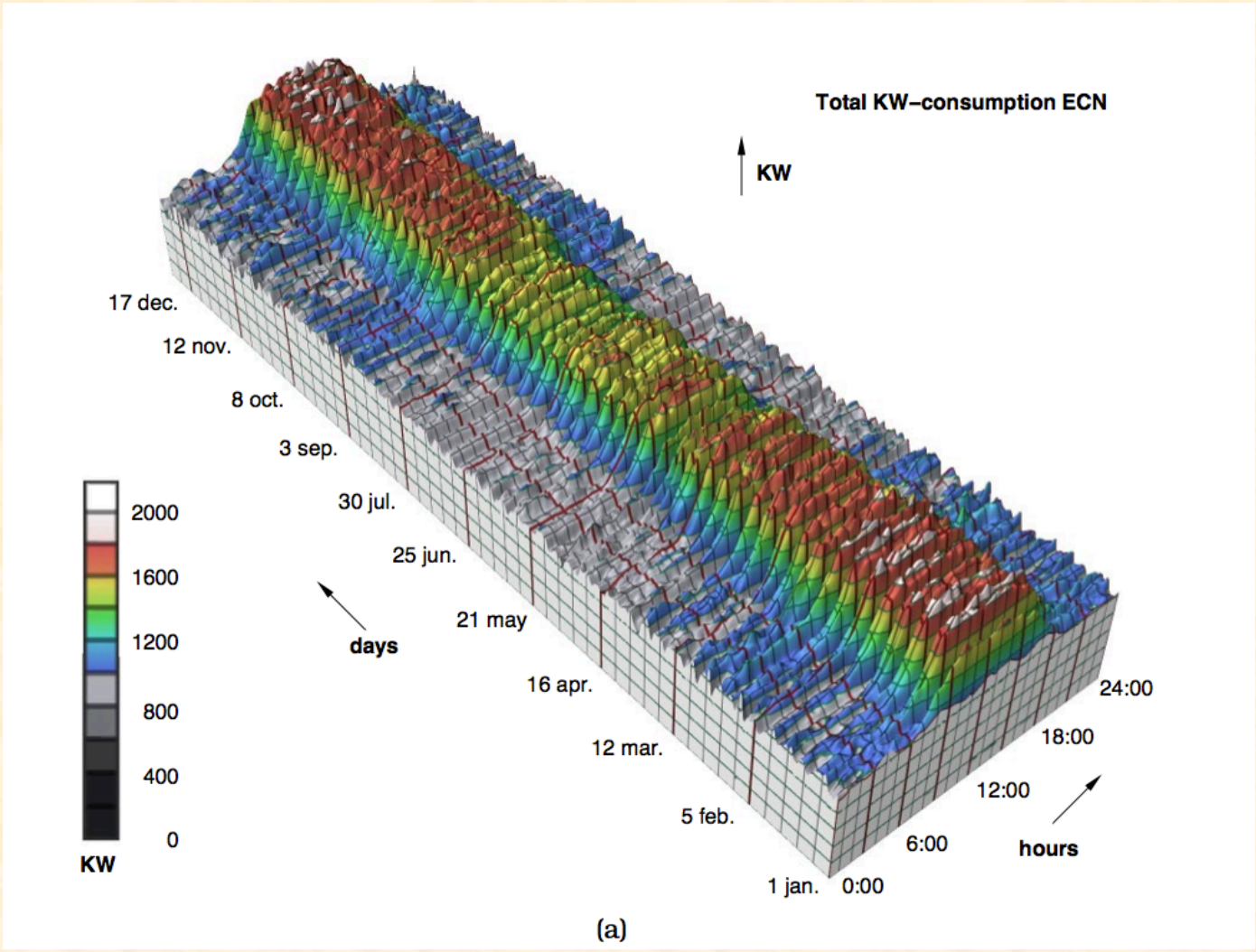
- Van wijk and van Selow 99,
  - # of people inside and amount of power used over the course of each day for one full year.



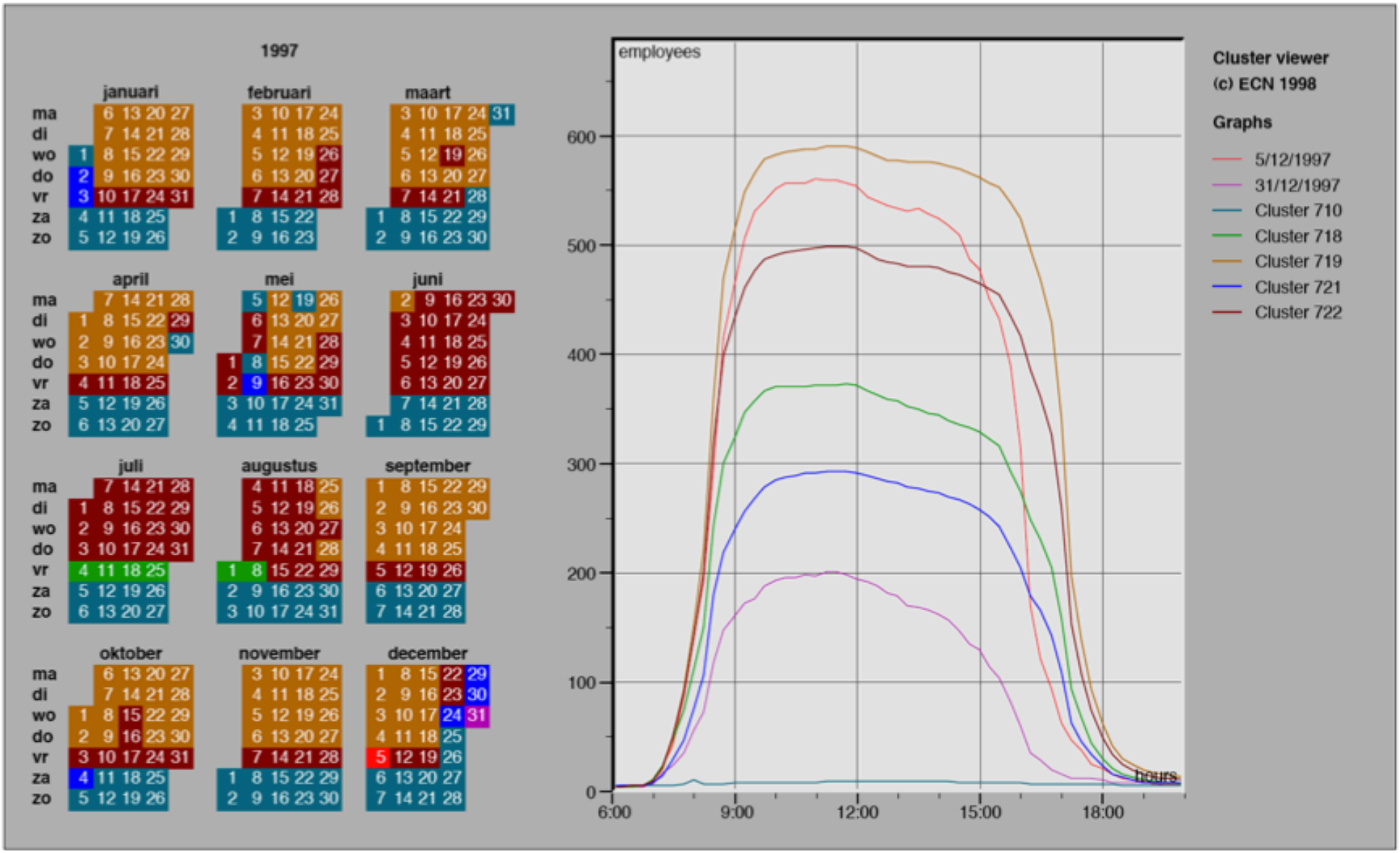
(a)



(b)

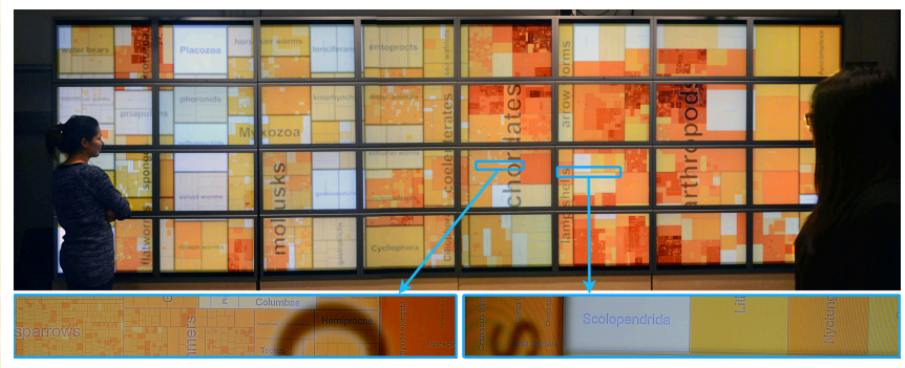

Total KW–consumption ECN
KW
17 dec.
12 nov.
8 oct.
3 sep.
30 jul.
25 jun.
21 may
16 apr.
12 mar.
5 feb.
1 jan.
days
2000
1600
1200
800
400
0
KW
0:00
6:00
12:00
18:00
24:00
hours

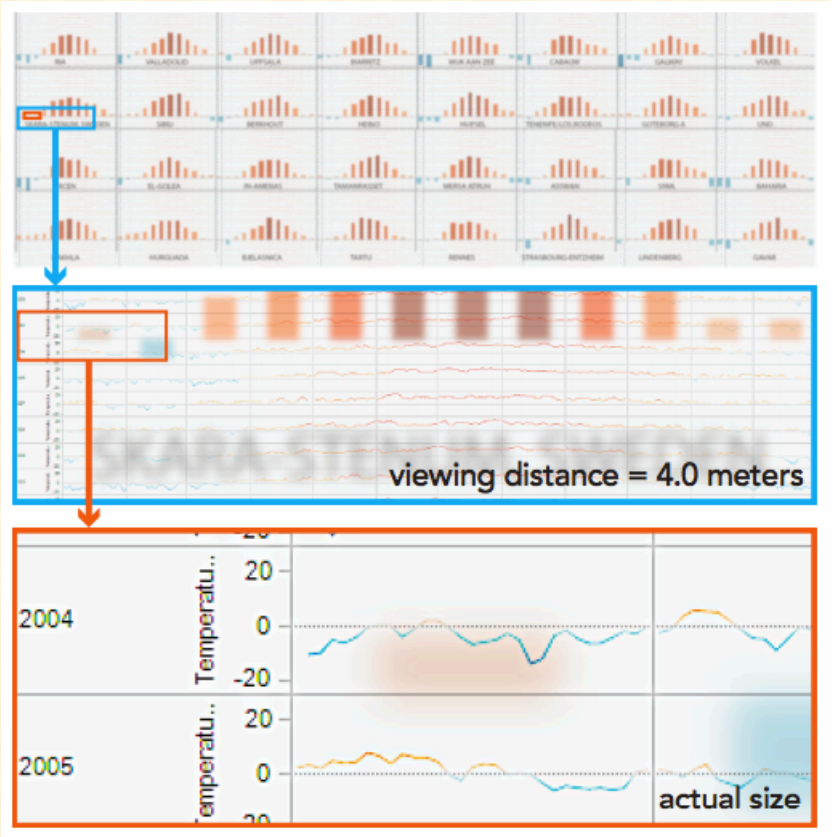
(a)


1997
januari
ma 6 13 20 27
di 7 14 21 28
wo 1 8 15 22 29
do 2 9 16 23 30
vr 3 10 17 24 31
za 4 11 18 25
zo 5 12 19 26
februari
ma 3 10 17 24
di 4 11 18 25
wo 5 12 19 26
do 6 13 20 27
vr 7 14 21 28
za 1 8 15 22
zo 2 9 16 23
maart
ma 3 10 17 24 31
di 4 11 18 25
wo 5 12 19 26
do 6 13 20 27
vr 7 14 21 28
za 1 8 15 22 29
zo 2 9 16 23 30
april
ma 7 14 21 28
di 1 8 15 22 29
wo 2 9 16 23 30
do 3 10 17 24
vr 4 11 18 25
za 5 12 19 26
zo 6 13 20 27
mei
ma 5 12 19 26
di 6 13 20 27
wo 7 14 21 28
do 1 8 15 22 29
vr 2 9 16 23 30
za 3 10 17 24 31
zo 4 11 18 25
juni
ma 2 9 16 23 30
di 3 10 17 24
wo 4 11 18 25
do 5 12 19 26
vr 6 13 20 27
za 7 14 21 28
zo 1 8 15 22 29
juli
ma 7 14 21 28
di 1 8 15 22 29
wo 2 9 16 23 30
do 3 10 17 24 31
vr 4 11 18 25
za 5 12 19 26
zo 6 13 20 27
augustus
ma 4 11 18 25
di 5 12 19 26
wo 6 13 20 27
do 7 14 21 28
vr 1 8 15 22 29
za 2 9 16 23 30
zo 3 10 17 24 31
september
ma 1 8 15 22 29
di 2 9 16 23 30
wo 3 10 17 24
do 4 11 18 25
vr 5 12 19 26
za 6 13 20 27
zo 7 14 21 28
oktober
ma 6 13 20 27
di 7 14 21 28
wo 1 8 15 22 29
do 2 9 16 23 30
vr 3 10 17 24 31
za 4 11 18 25
zo 5 12 19 26
november
ma 3 10 17 24
di 4 11 18 25
wo 5 12 19 26
do 6 13 20 27
vr 7 14 21 28
za 1 8 15 22 29
zo 2 9 16 23 30
december
ma 1 8 15 22 29
di 2 9 16 23 30
wo 3 10 17 24 31
do 4 11 18 25
vr 5 12 19 26
za 6 13 20 27
zo 7 14 21 28
employees
600
500
400
300
200
100
0
6:00
9:00
12:00
15:00
18:00
hours
Cluster viewer
(c) ECN 1998
Graphs
5/12/1997
31/12/1997
Cluster 710
Cluster 718
Cluster 719
Cluster 721
Cluster 722

2.5D

- Petra Isenberg, Hybrid-image vis (2013)

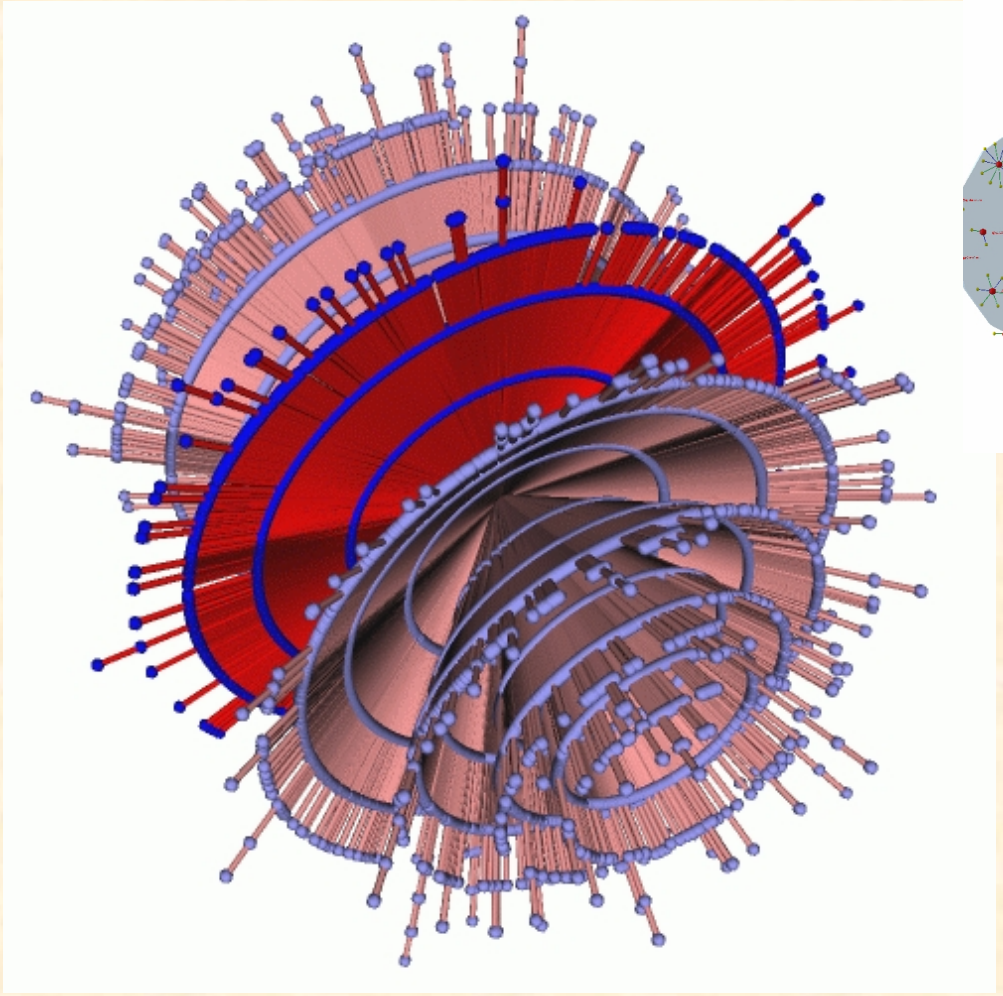


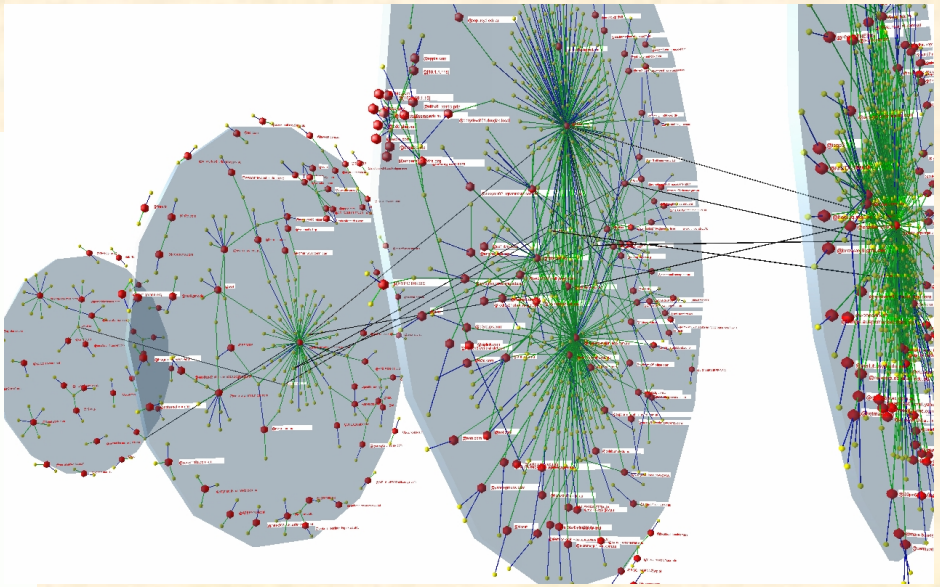


- Today: Alex Garbarino (pathway analysis)

2.5D

- Seokhee Hong





Multi-Dimensional Functions

Multi-Dimensional Functions

- $y = f(x_1, x_2, x_3, \ldots, x_n)$
- Continuous:
  - E.g. $y = x_1^3 + 2x_2^2 - 9x_3$
- Discrete:
  - x_i are uniformly sampled in a bounded region
  - E.g. $x_i = [0,1,2,\ldots,100]$
  - E.g. measured density in a 3D material under range of pressures and room temperatures.

Variables

- Independent variables
- Dependent variables

Table - StateData ()

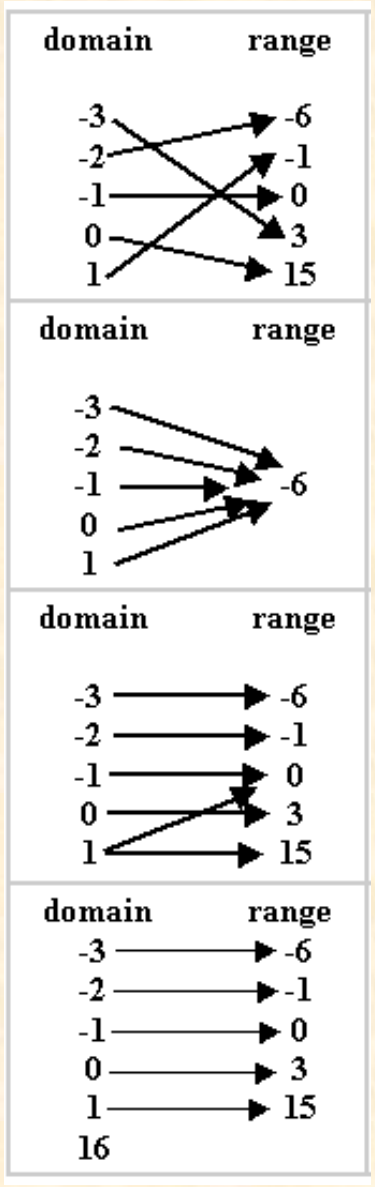
Load Snap

State	College Degree %	Per Capita Income
Alabama	20.6%	11486
Alaska	30.3%	17610
Arizona	27.1%	13461
Arkansas	17.0%	10520
California	31.3%	16409
Colorado	33.9%	14821
Connecticut	33.8%	20189
Delaware	27.9%	15854
District of Columbia	36.4%	18881
Florida	24.9%	14698
Georgia	24.3%	13631
Hawaii	31.2%	15770
Idaho	25.2%	11457
Illinois	26.8%	15201
Indiana	20.9%	13149
Iowa	24.5%	12422
Kansas	26.5%	13300
Kentucky	17.7%	11153
Louisiana	19.4%	10635
Maine	25.7%	12957
Maryland	31.7%	17730
Massachusetts	34.5%	17224
Michigan	24.1%	14154
Minnesota	30.4%	14389

Relations vs. Functions

- Relations:
  - R(A, B, C, D, E, F)
  - All dependent variables (1 ind.var.?)
  - Sparse points in multi-d dep.var. space
- Functions: well behaved relations
  - R(A, B, C, D, E, F, Y) : Y=f(A, B, C, D, E, F)
  - Many independent variables
  - Defined at every point in multi-d ind.var. space (“onto”)
  - Huge scale: 6D with 10 samples/D = 1,000,000 data points

Relation or function?



Function

Function

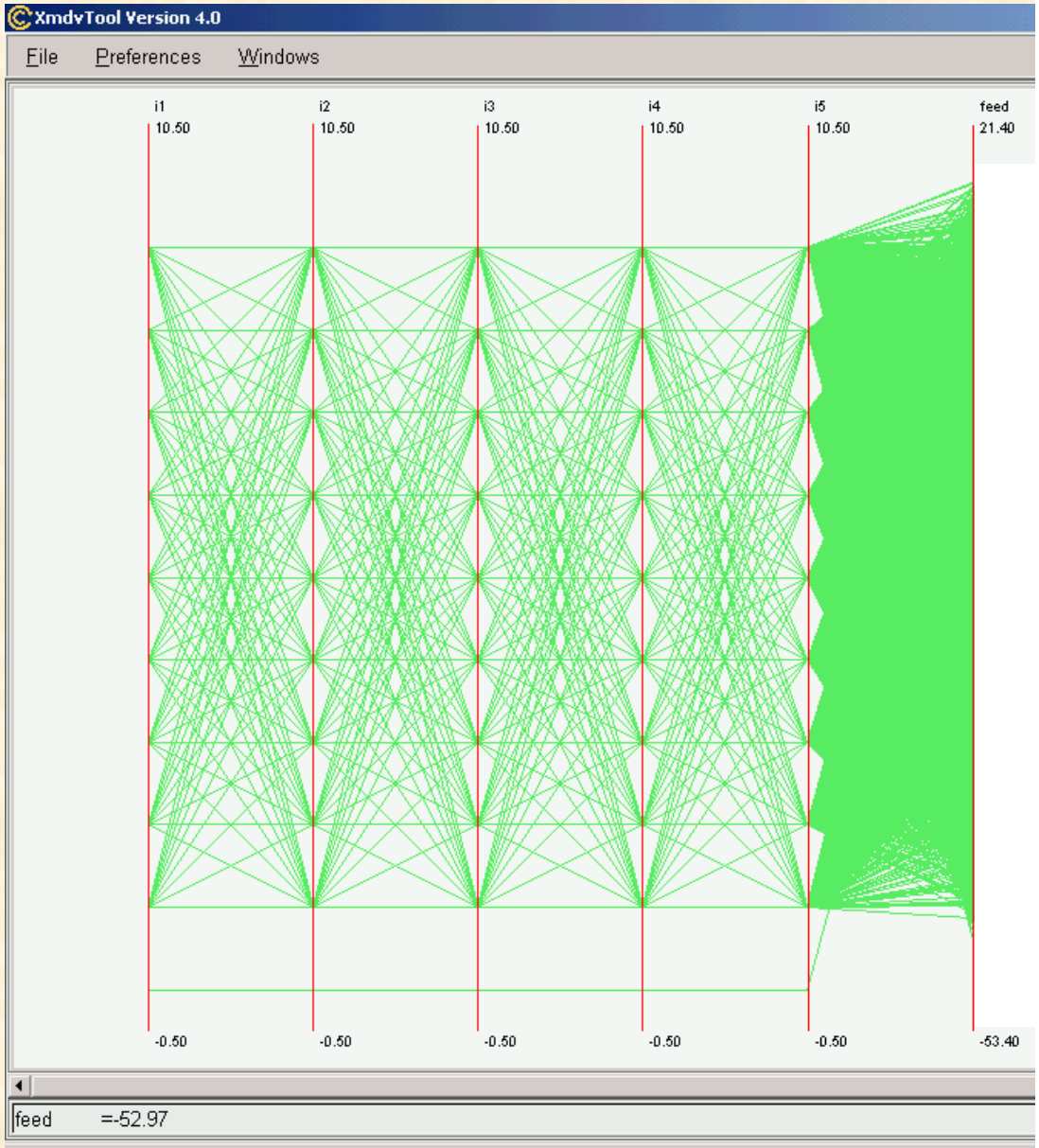
Relation

Neither Function nor Relation?

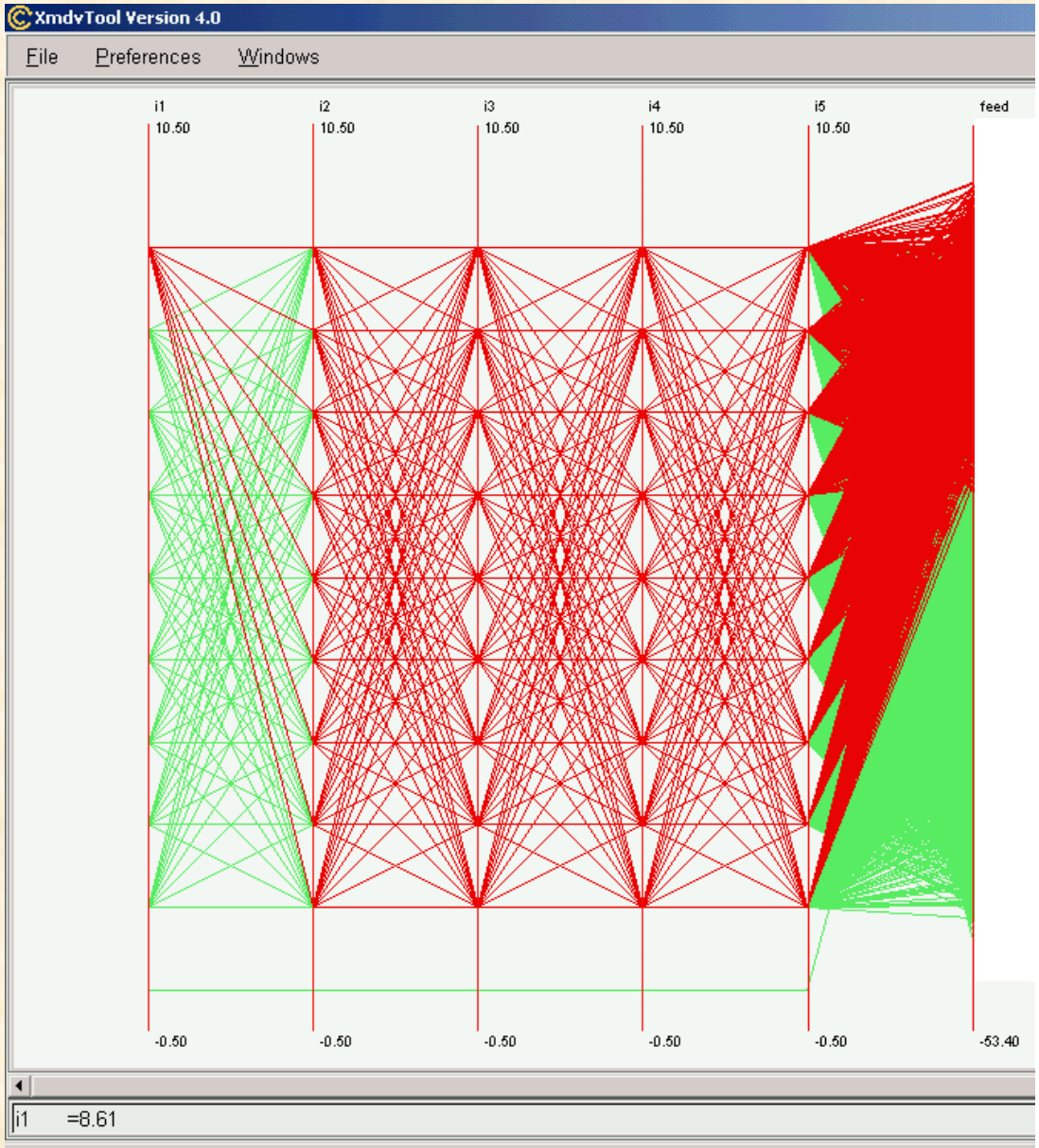
Multi-D Relation Visualizations…

- Don’t work well for multi-D functions

- Example:
  - Parallel coords
  - 5D func sampled on 1-9 for all ind.vars.



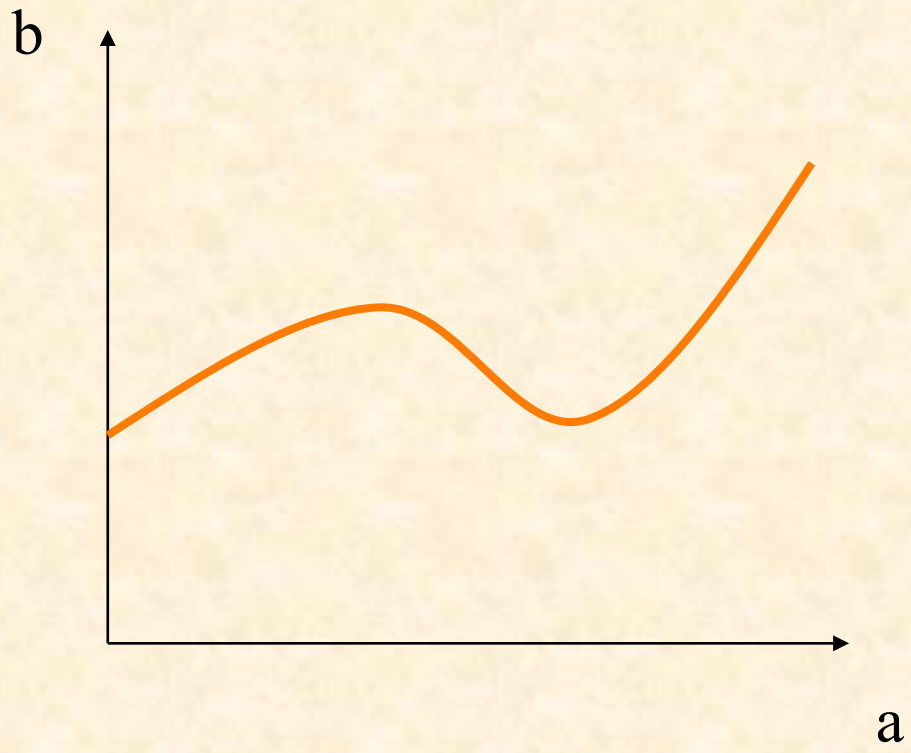
- Typically want to encode ind.vars. as spatial attrs



1-D: Easy

- b = f(a)

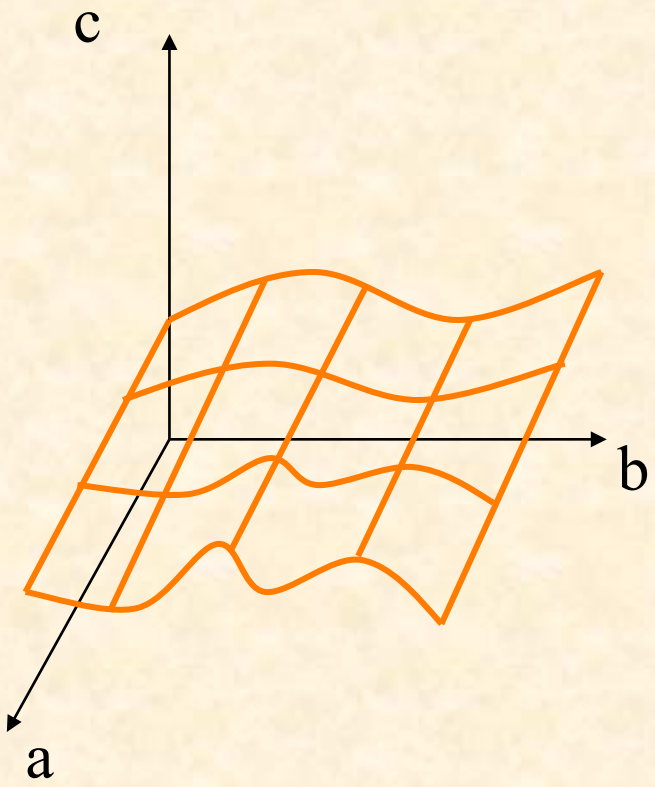
- a → x
- b → y



2-D: Easy

- c = f(a, b)

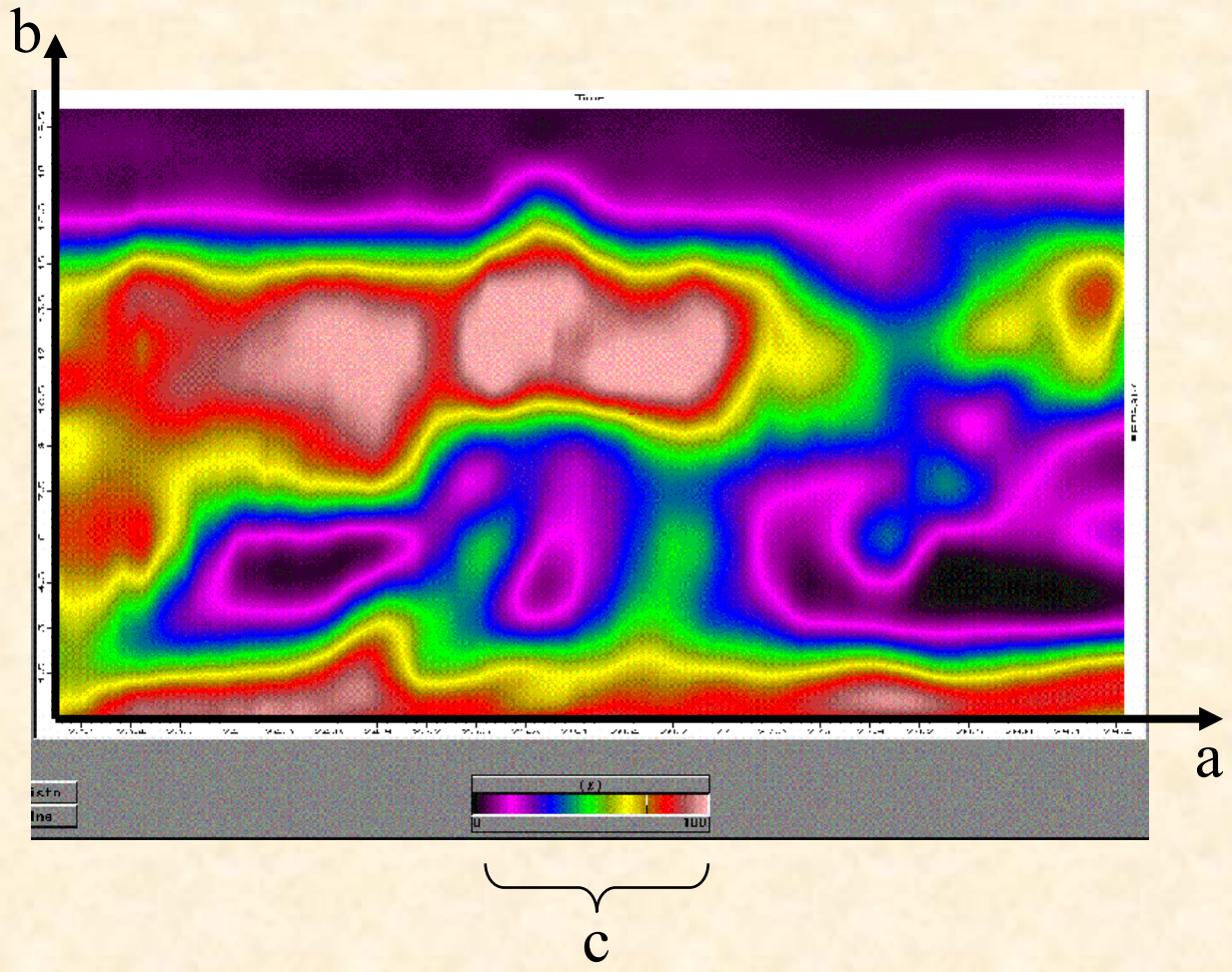
- Height field:
- a → x
- b → y
- c → z



2-D: Easy

- c = f(a, b)

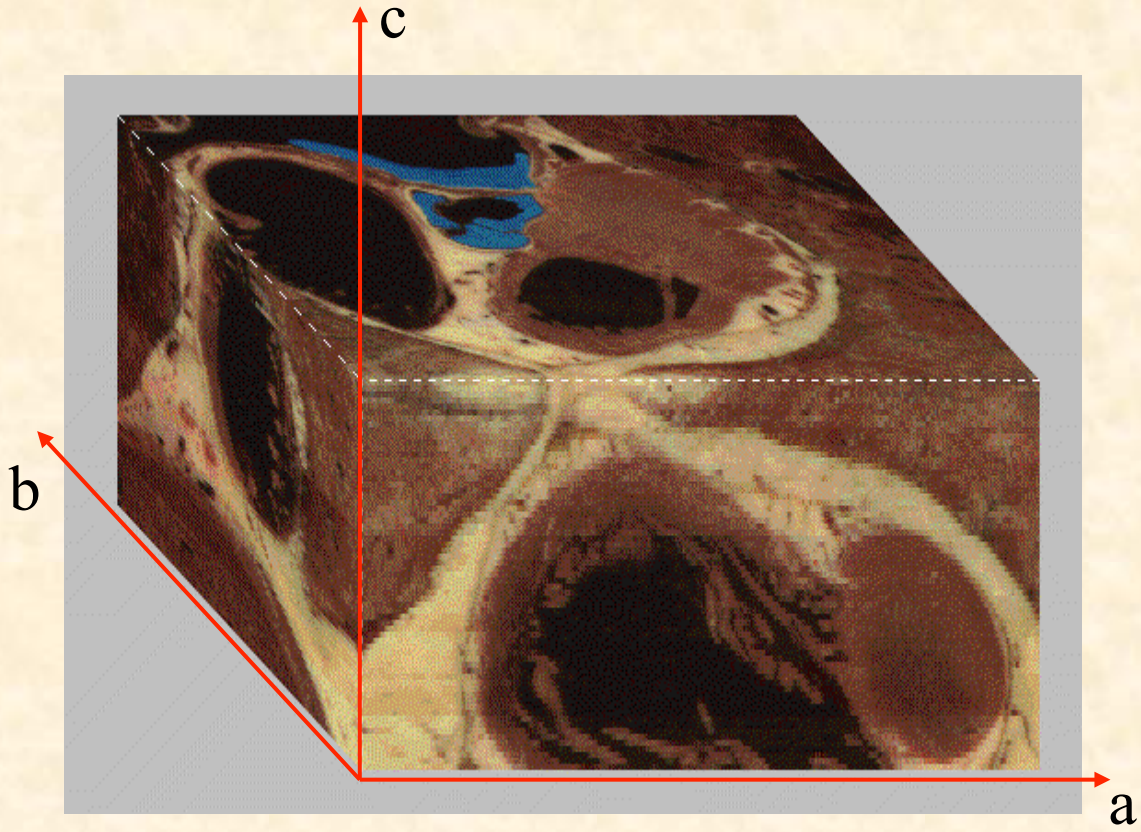
- Heat map:
- a → x
- b → y
- c → color



3-D: Hard

- d = f(a, b, c)

- Color volume:
- a → x
- b → y
- c → z
- d → color



- What's inside?

≥4D: Really Hard

- $y = f(x_1, x_2, x_3, x_4, \ldots, x_n)$
- What does a 5D space look like?

- Approaches:
  - Positioning: Recursive pattern (Keim)
  - Scalable aggregation: imMens (Liu)
  - Nested coordinate frames (Worlds within Worlds)
  - Slicing (HyperSlice)
  - Radial Focus+Context (PolarEyez, Sanjini)
  - What we talked about before: filtering | overview

Position on paper

- Keim, Recursive pattern: a technique for visualization very large amounts of data

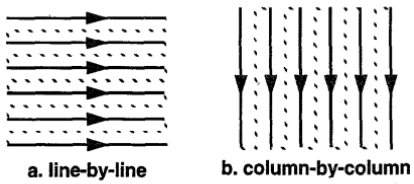


Figure 1: Simple Data Arrangements

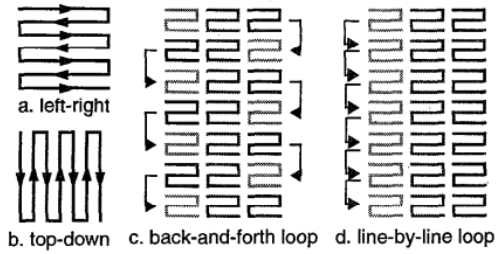


Figure 3: Examples of Possible Arrangements

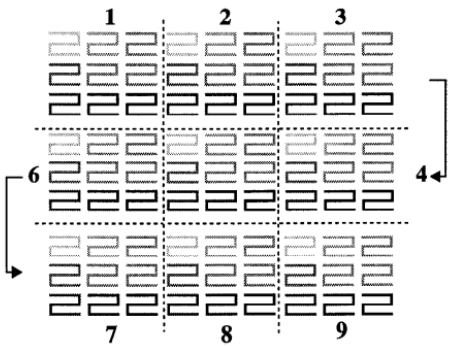


Figure 4: Fully Recursive Arrangement

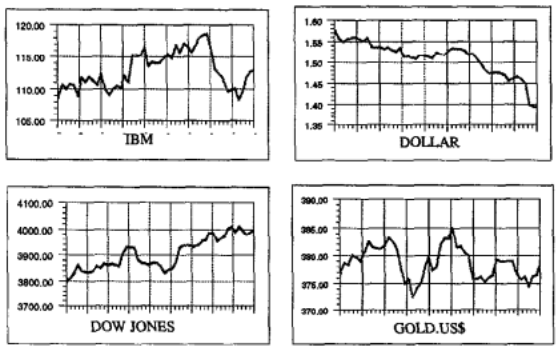


Figure 5: X-Y Diagrams

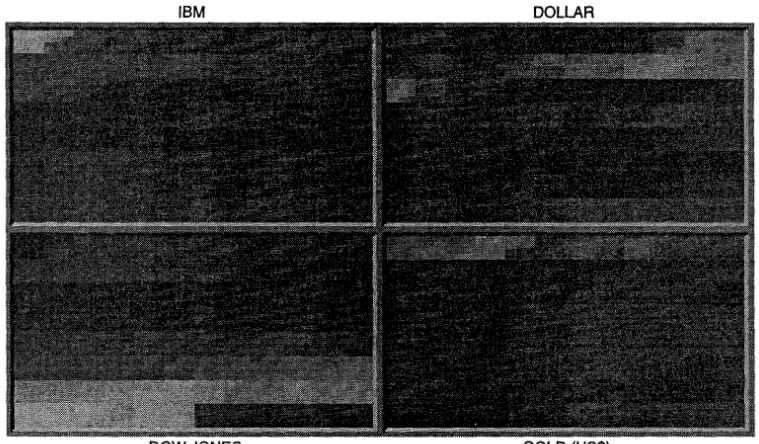
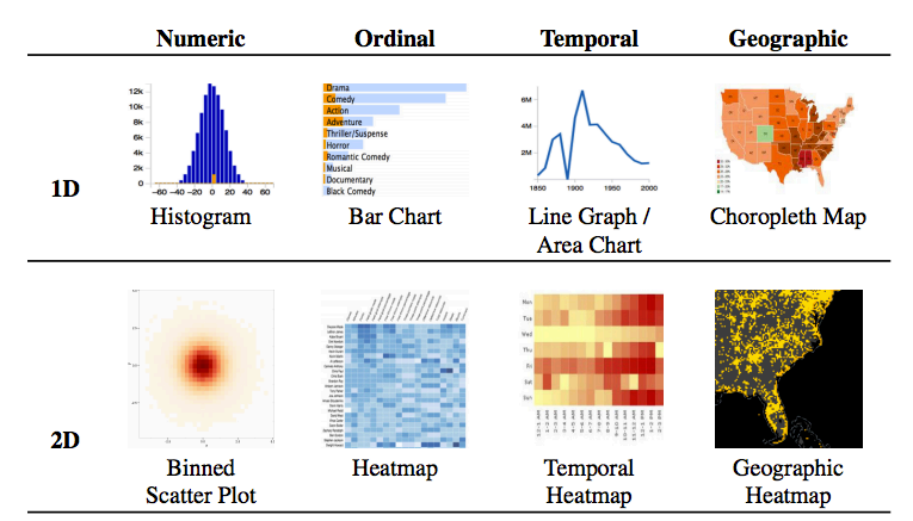


Figure 6: Five Level Recursive Arrangement (Sep. '87 - Feb. '95)

Aggregation: Binned plots

- Liu, Jiang and Heer, imMens: Real-time visual querying of big data
  - ‘big’: one million or more data cases
  - Bin: adjacent intervals over a continuous range
  - Scalability issues: perception | interaction.
  - Novelty: scalability should be limited by the chosen resolution of the visualized data, not the number of records.



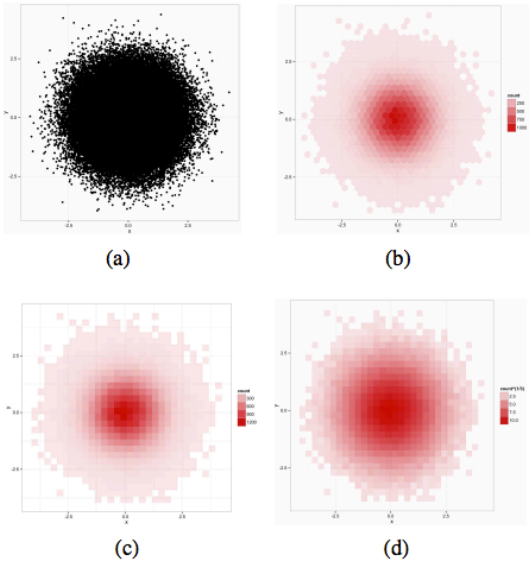


Figure 2: *Scatter plots with 100,000 data points: (a) traditional, (b) hexagonal bins, (c) rectangular bins and (d) rectangular bins with perceptual (cube root) color adjustment.*

Interactive Visualization of Streaming Data with Kernel Density Estimation

Ove Daae Lampe*
University of Bergen, Norway and
Chr. Michelsen Research AS

Helwig Hauser†
University of Bergen, Norway
www.ii.UiB.no/vis

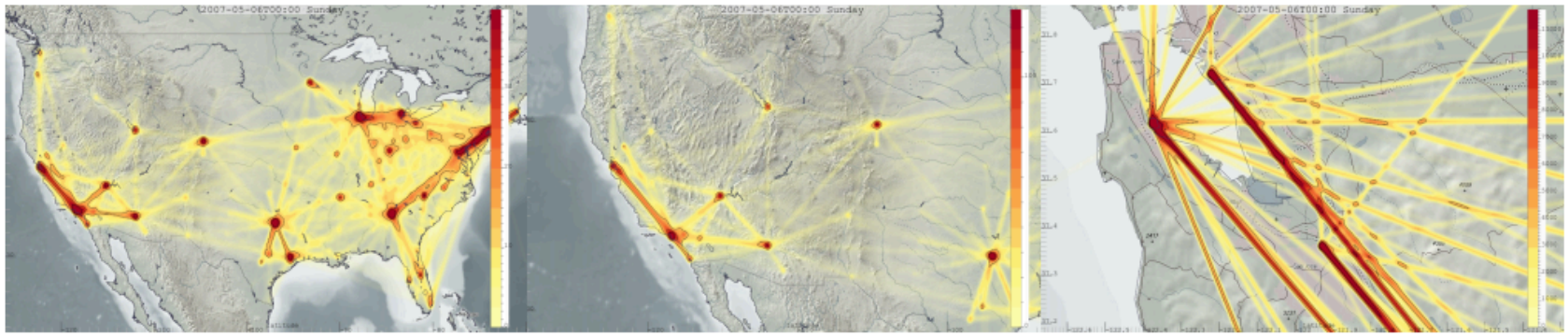
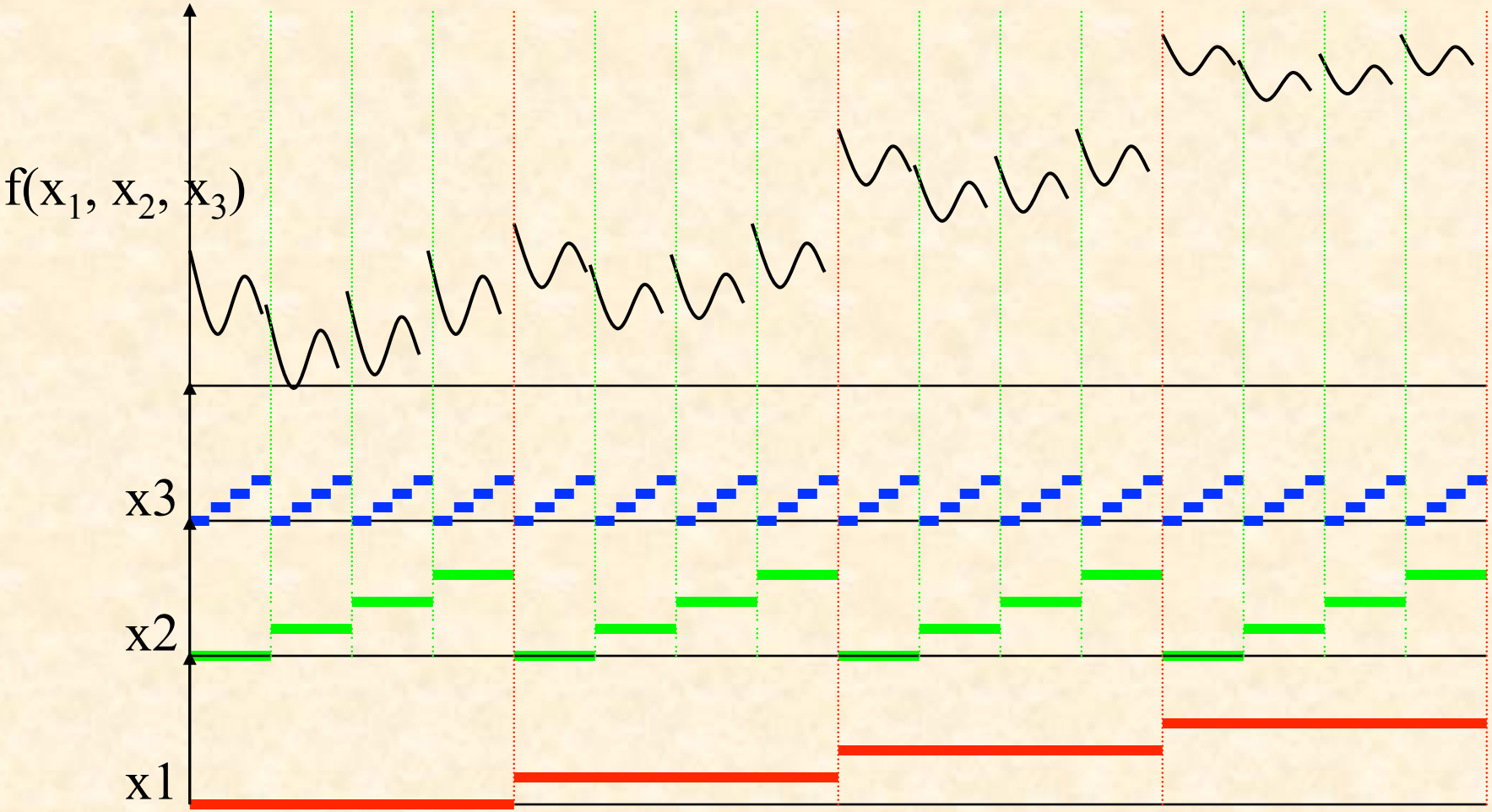


Figure 1: Interactive zooming towards SF Bay, where at first all the traffic from the Bay Area is aggregated, to a view where we can separate traffic from the three major airports, and even the distribution of traffic in each airports' cardinal direction. This interaction is enabled by automatically updating the bandwidth of the KDE when the viewport changes.

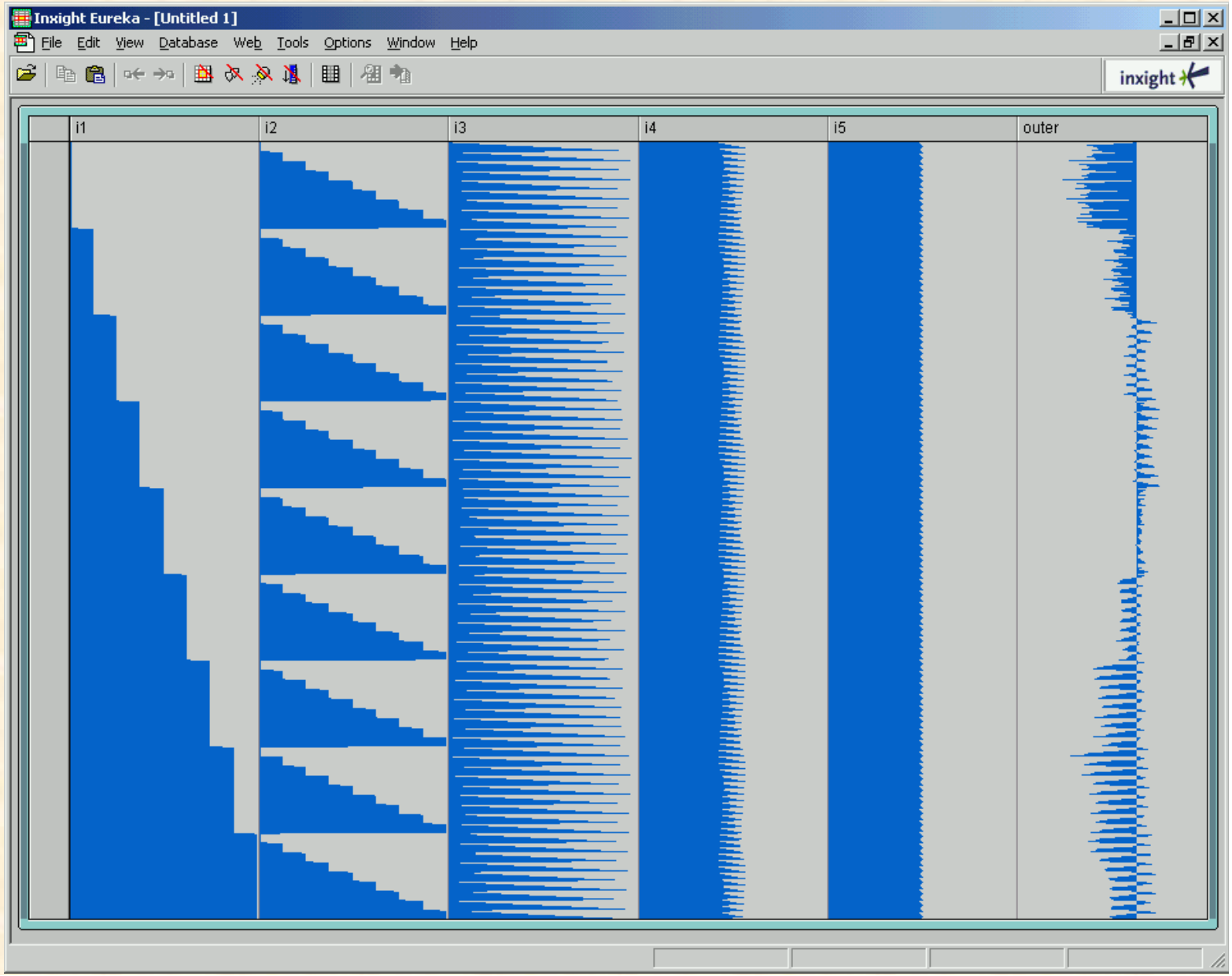
Hierarchical Axes

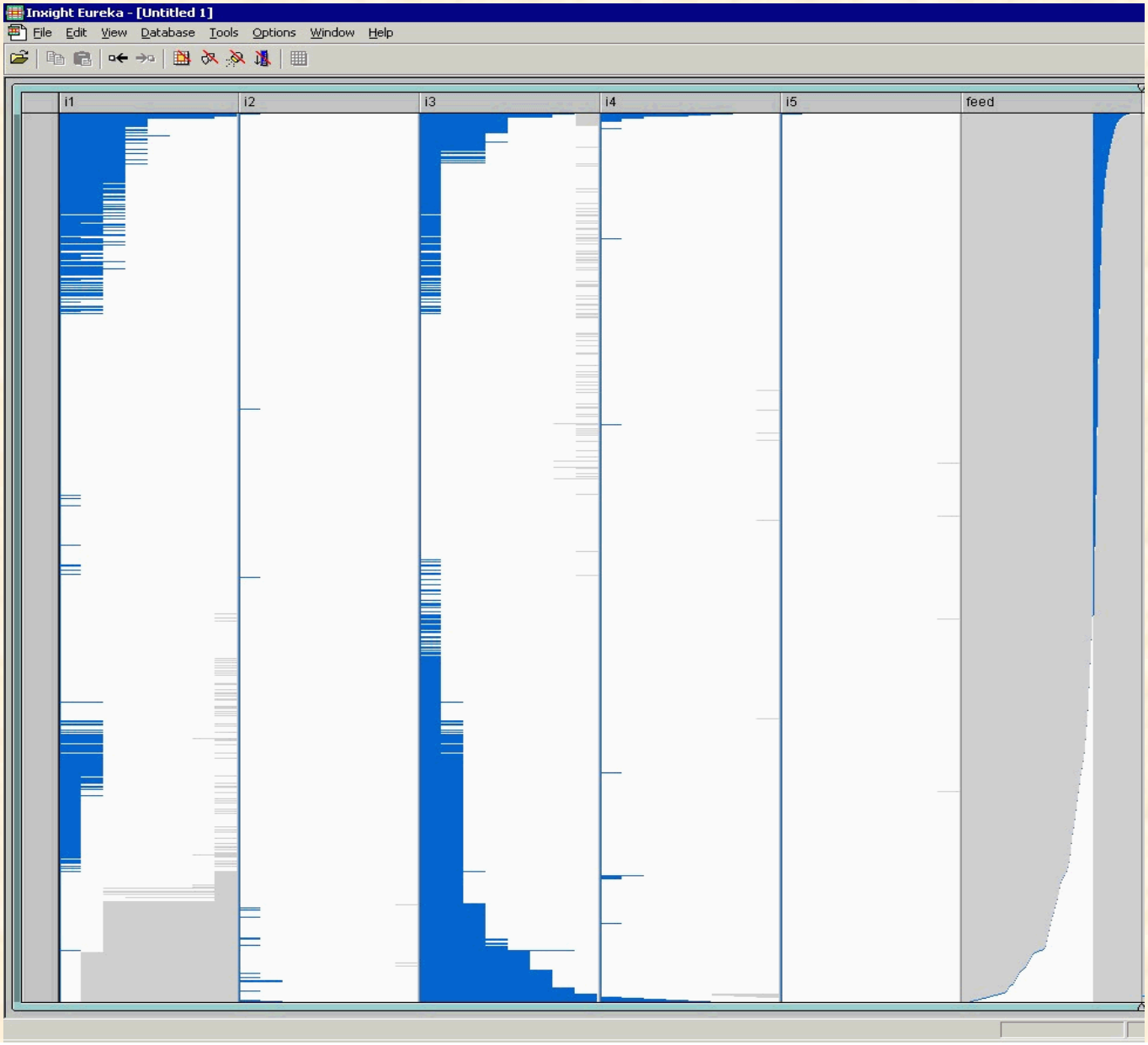
- 1D view of 3D function: (Mihalisin *et al.*)



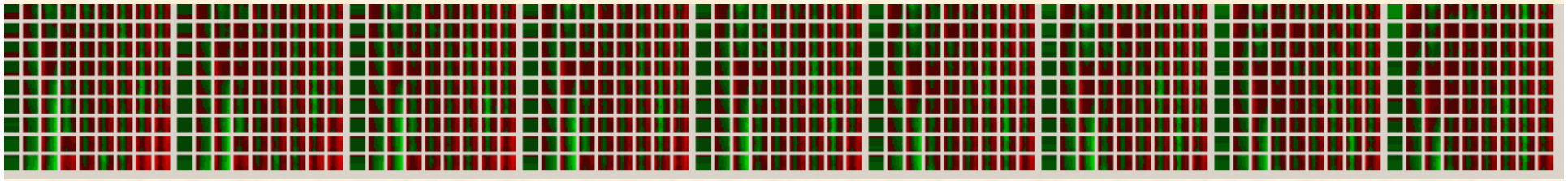
as in TableLens

5D
9 samp/D



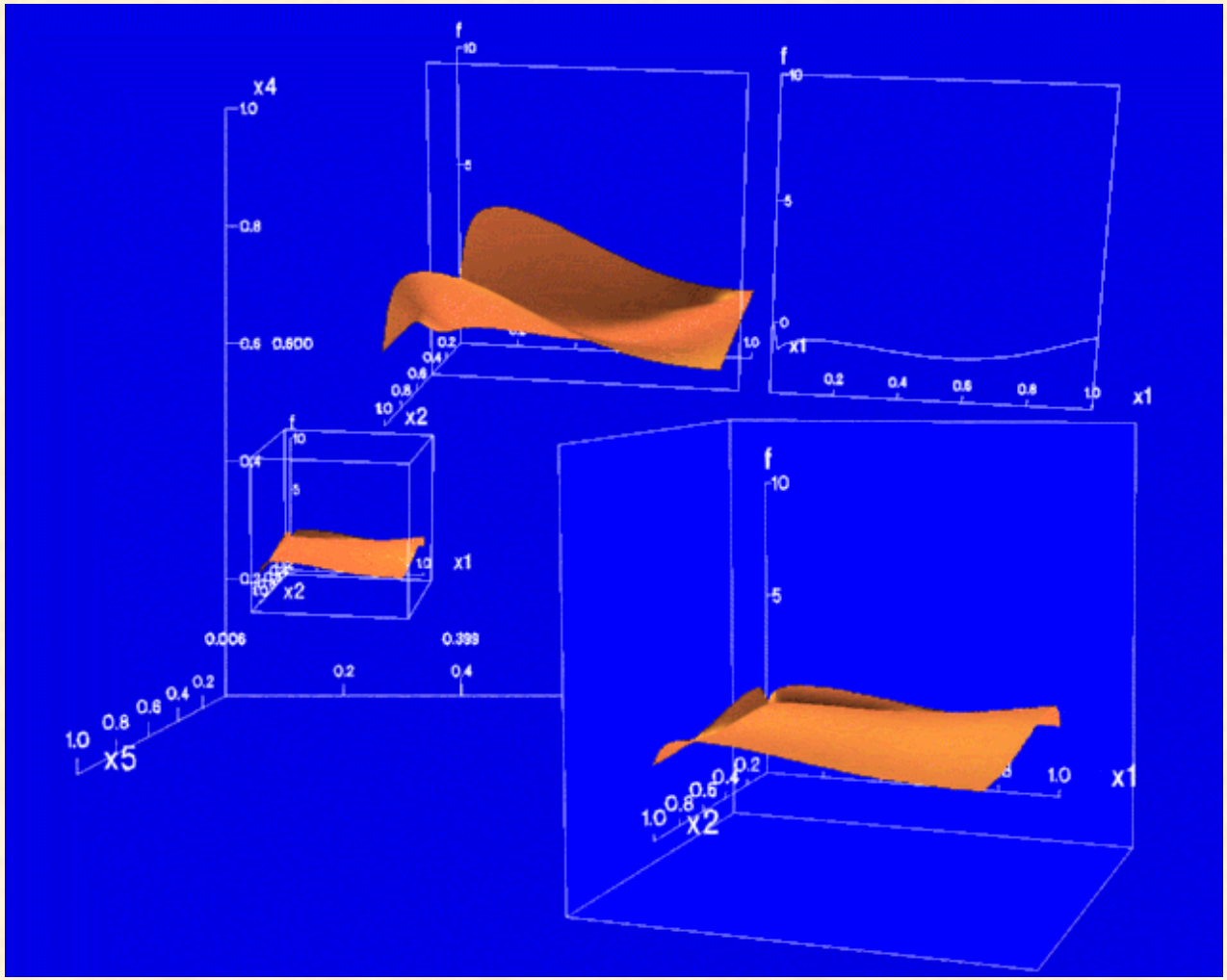

Inxight Eureka - [Untitled 1]
File Edit View Database Tools Options Window Help
i1
i2
i3
i4
i5
feed

- 5D
  9 sample/D



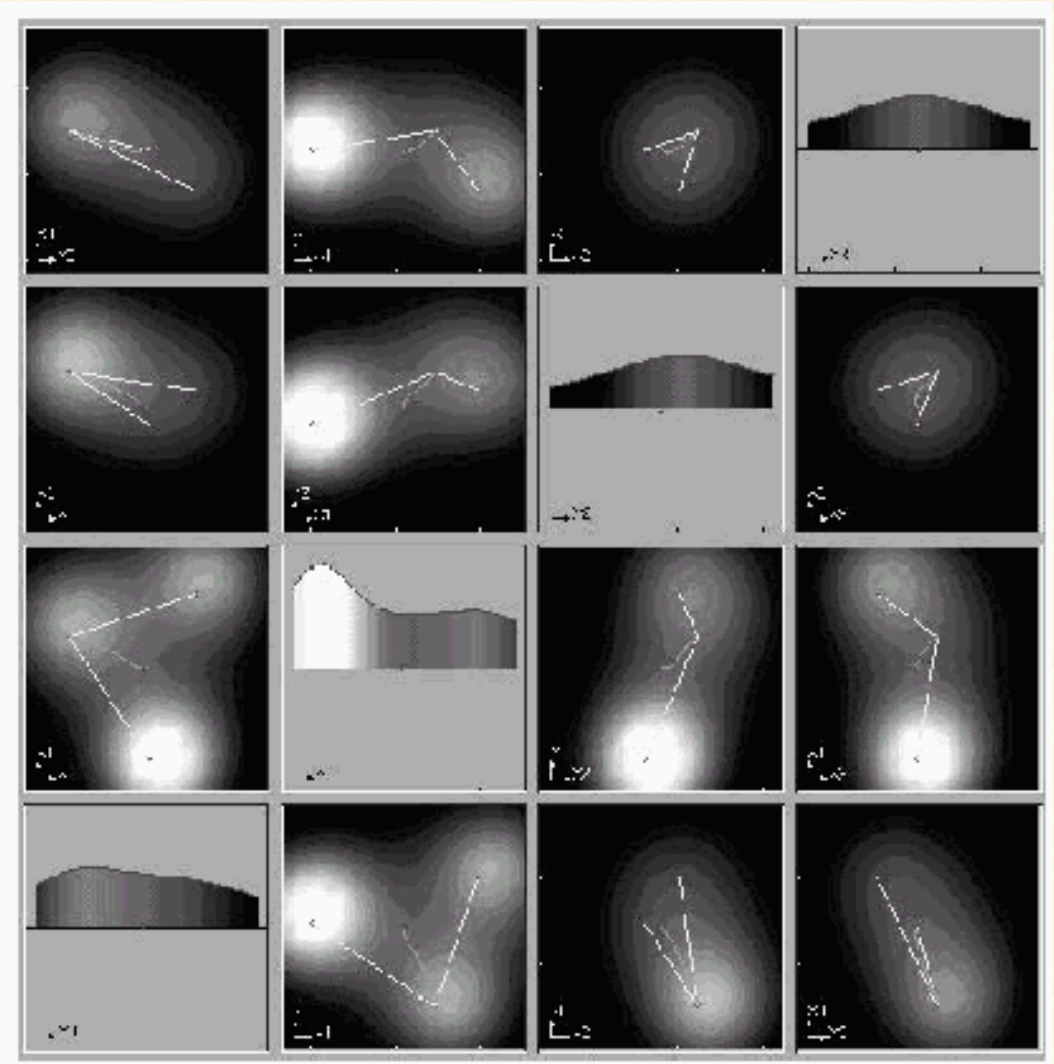
Nested Coordinate Frames

- Feiner, “Worlds within Worlds”
  -

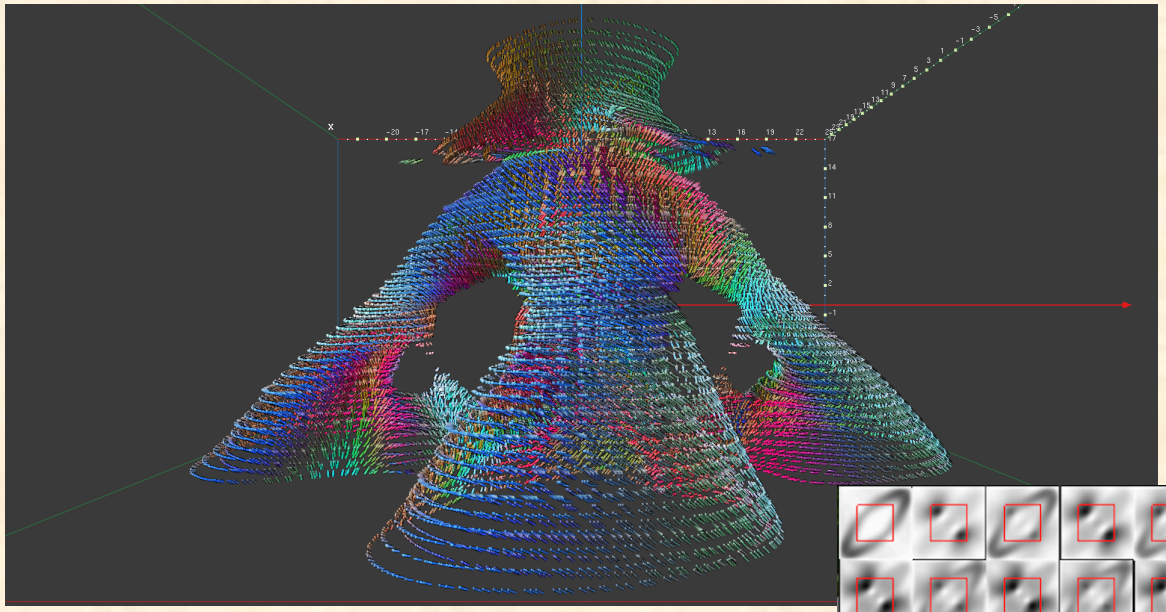


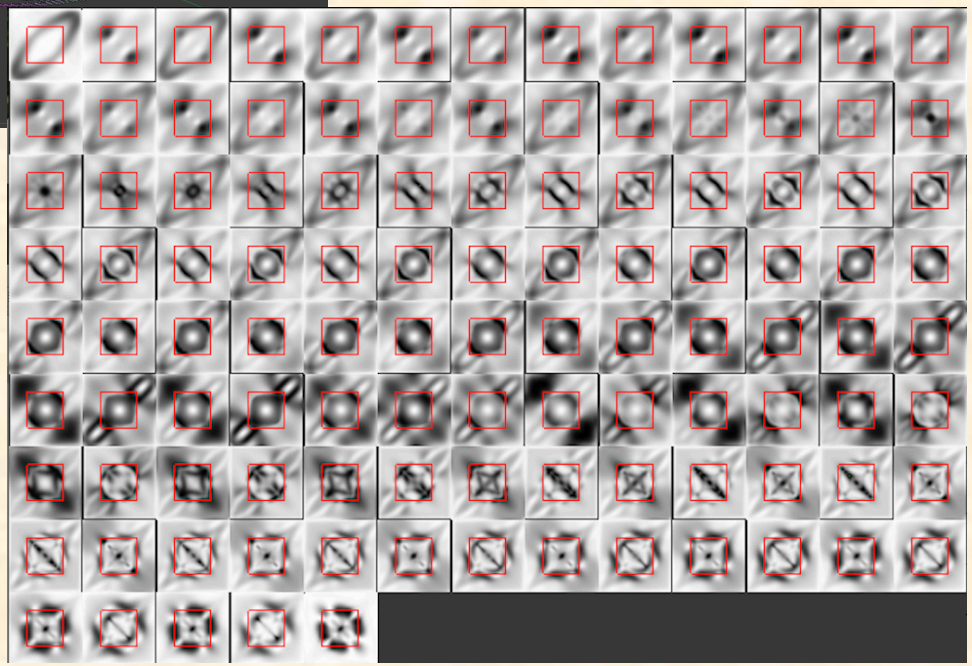
Slicing

- Van Wijk, “HyperSlice”
  -



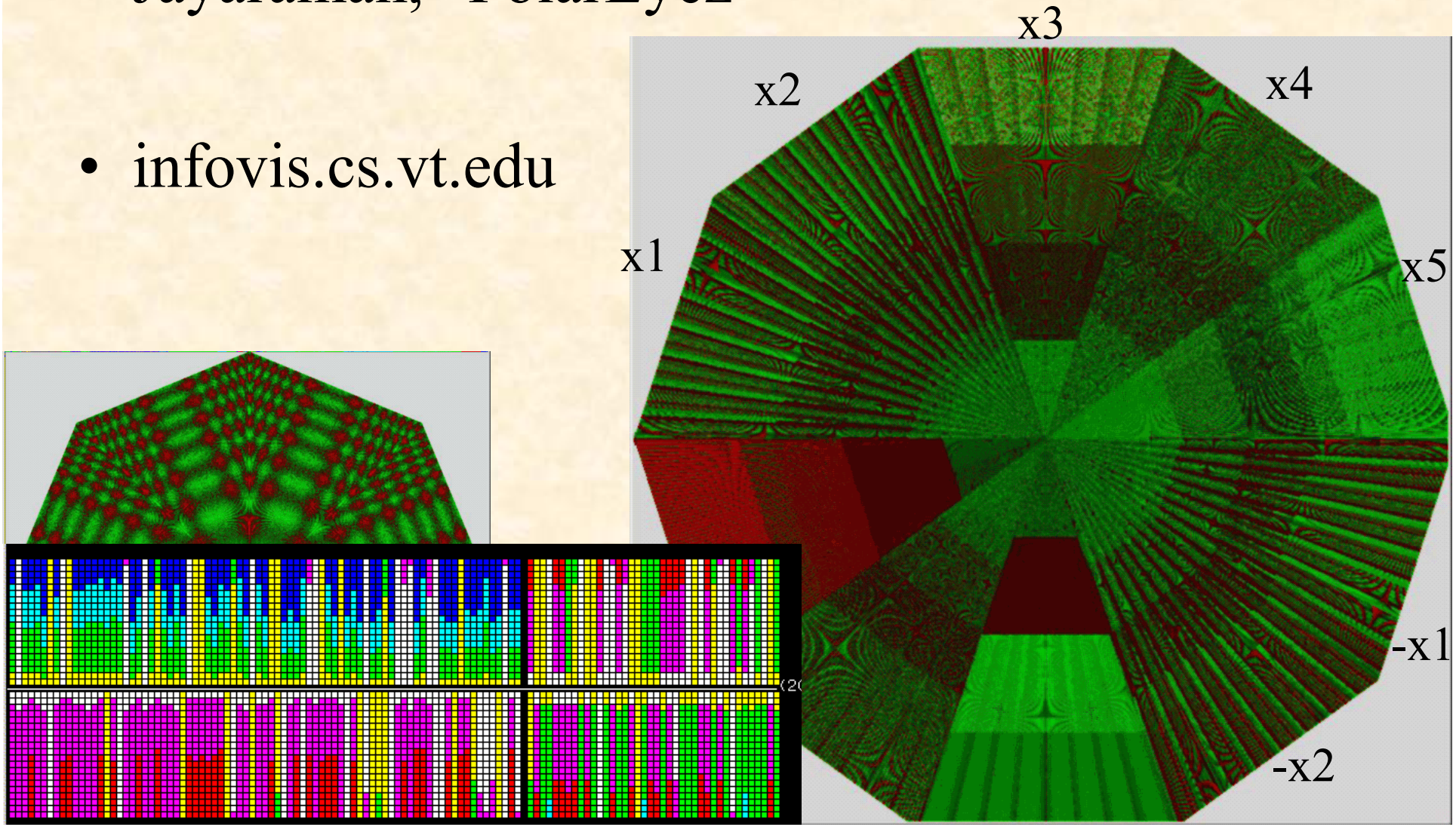
Slicing





Radial Focus+Context

- Jayaraman, “PolarEyez”
- infovis.cs.vt.edu



Comparison

- Hierarchical axes (Mihalisin):
  -
- Nested coordinate frames (Worlds in Worlds)
  -
- Slicing (HyperSlice):
  -
- Radial Focus+Context (PolarEyez)
  -

Comparison

- Hierarchical axes (Mihalisin):
  - < 6d by 10 samples, ALL slices, view 2d at a time
- Nested coordinate frames (Worlds in Worlds)
  - < 5-8d, continuous, no overview, 3d hardware
- Slicing (HyperSlice):
  - < 10d by 100 samples, 2d slices
- Radial Focus+Context (PolarEyez)
  - < 10d by 1000 samples, overview, all D uniform, rays

Review (9/17)

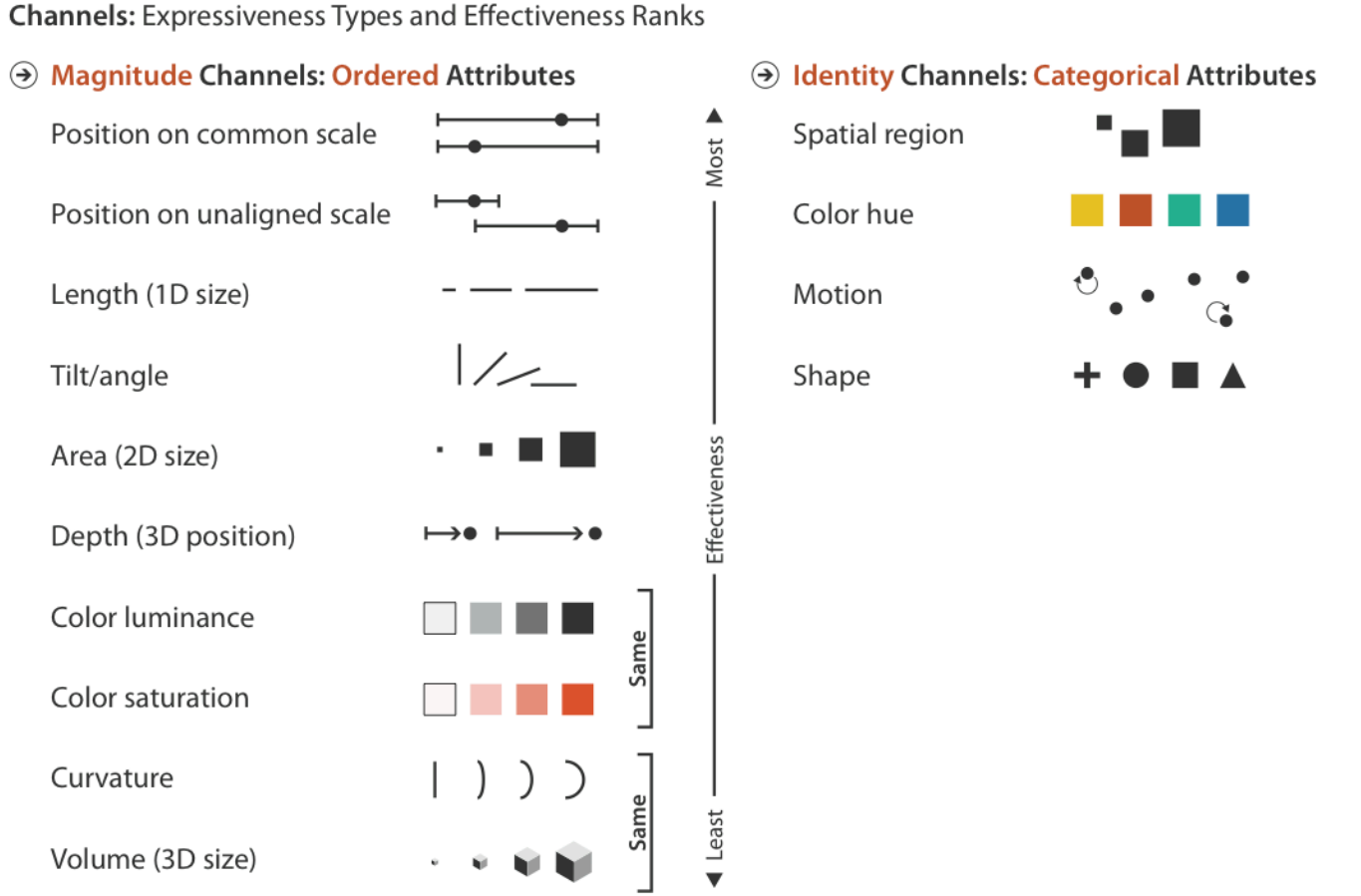


Figure 5.6. Channels ranked by effectiveness according to data and channel type. Ordered data should be shown with the magnitude channels, and categorical data with the identity channels.

Review (9/17)

- Many ways to look at tables; multi-D data; what are they?
  - Glyph (face; star glyphs;)
  - Coordinates (star coordinates; parallel coordinates)
  - Table lens

Upcoming (9/17)

- Homework 2 (out tonight, due 9/29)
- Proposal due (10/20)
  - Title of your final report (begin with the title of the project first)
  - Meeting with the client / advisors
  - Data abstraction
  - Task abstraction
  - Initial design

  Mandatory: talk to Jian about your project topic next Monday / Wednesday after class 2:30-3:30pm. You MUST have a client.