Lecture 2, InfoVis MiniCourse

Space/Order, Depth/Occlusion, High Dimensionality, Interaction

LaBRI, University of Bordeaux
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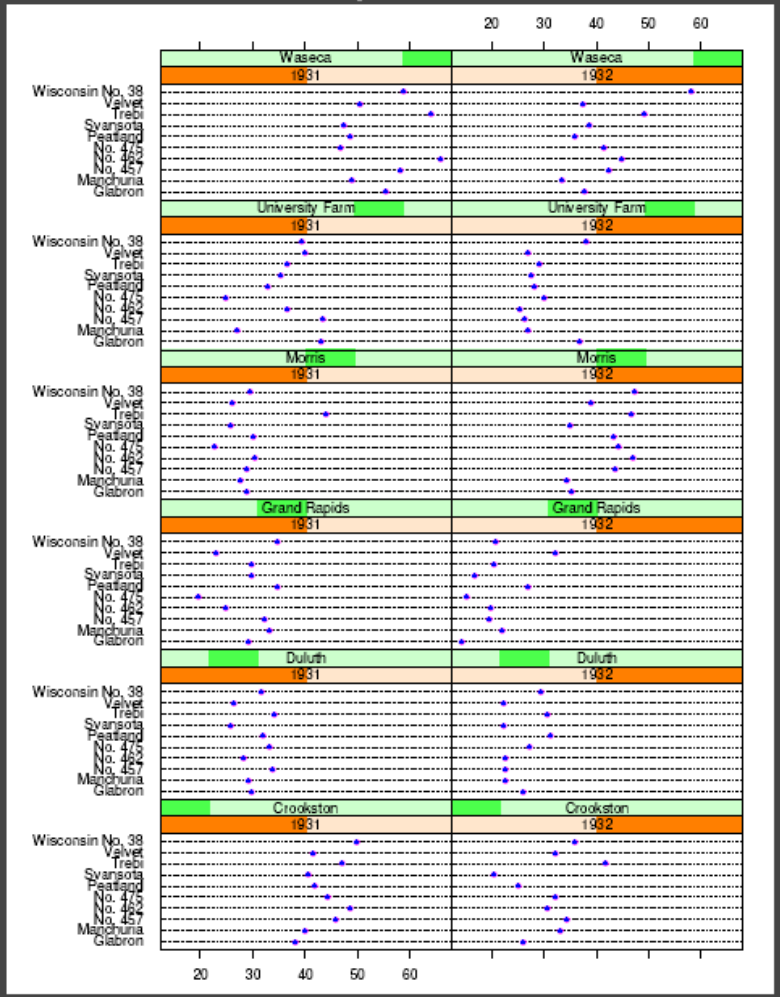
Mini-Course Outline

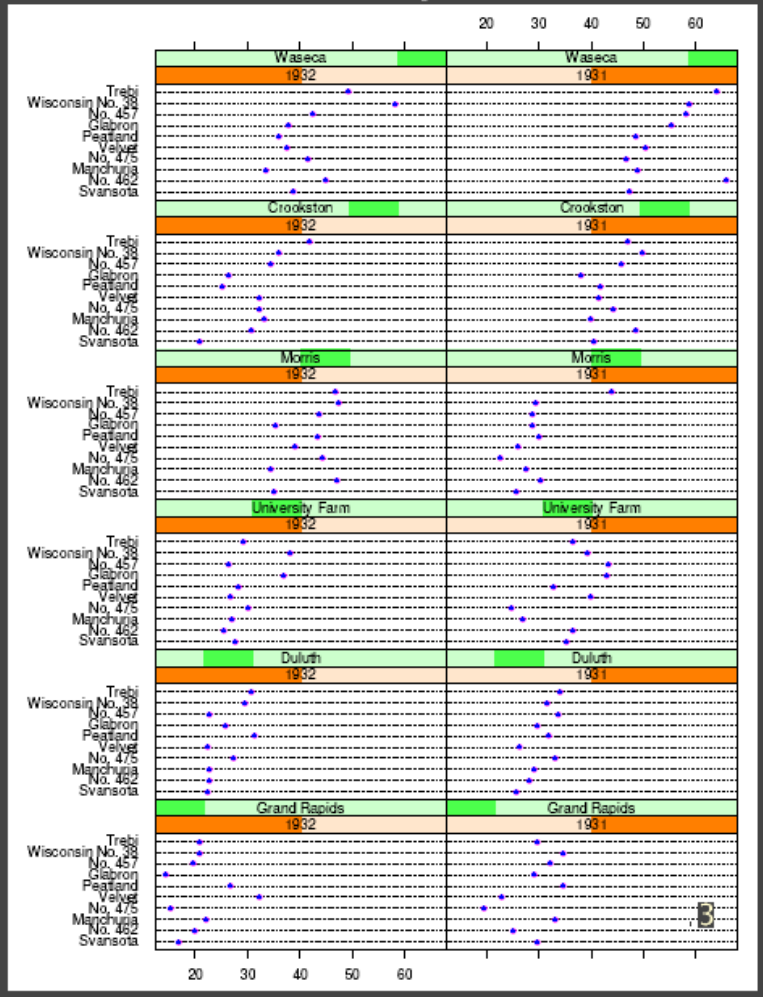
Perception
Frameworks
Color
Space/Order
Depth/Occlusion
High Dimensionality
Interaction
Navigation/Zooming
Focus+Context
Graphs/Trees
Scalability
Task-Centered Design

Finding the Right Order: Trellis

alphabetical

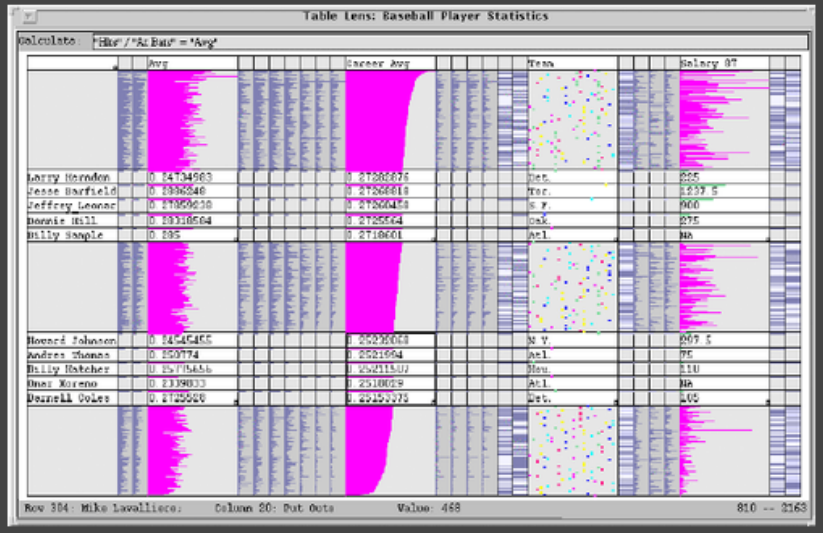


main-effects: sort by median value



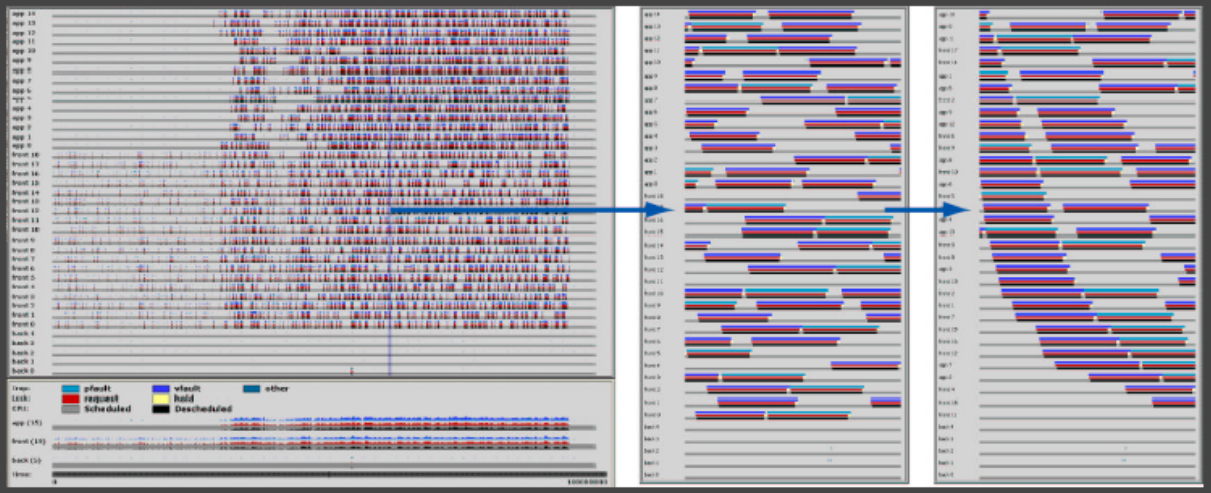
Finding the Right Order: Table Lens

- select column to sort
- user explores



[demo: www.tablelens.com]

Finding the Right Order: Rivet



[Bosch, Performance Analysis and Visualization of Parallel Systems Using SimOS and Rivet: A Case Study, HPCA6, 2000. graphics.stanford.edu/papers/rivet_argus]

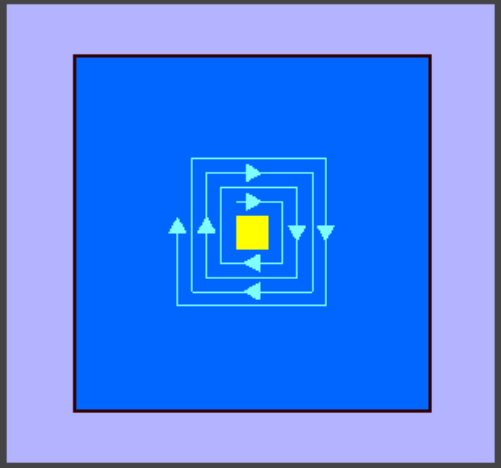
Finding the Right Order: VisDB

each pixel represents database entry

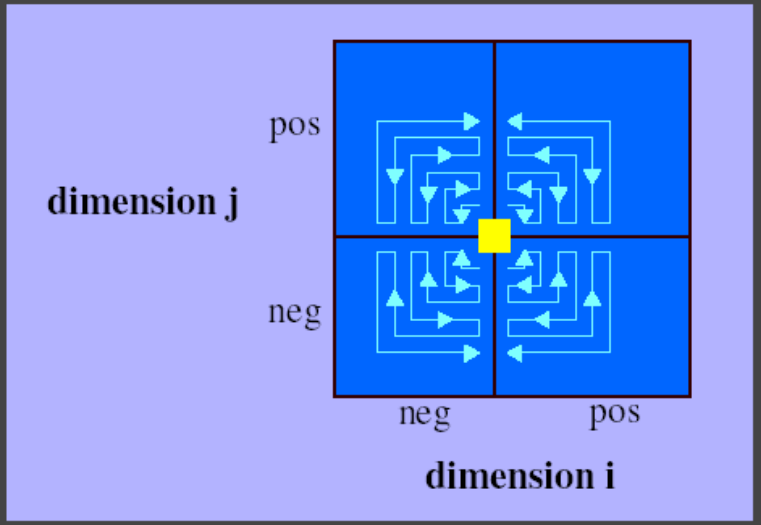
- color by query relevance

what order to sort?

spiral



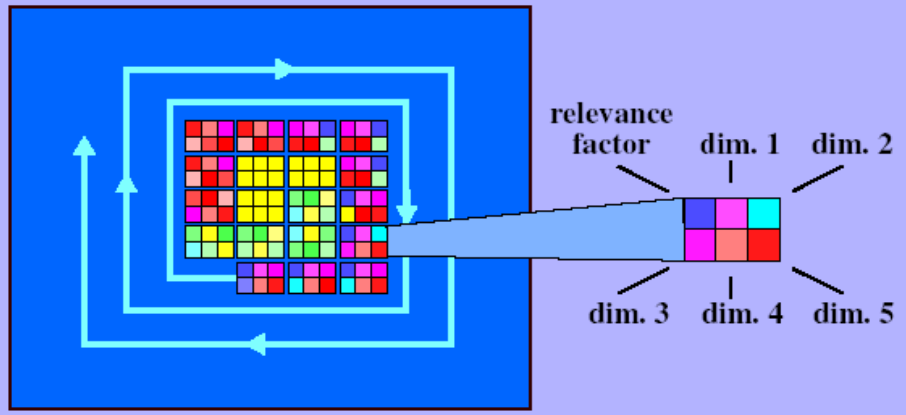
2D



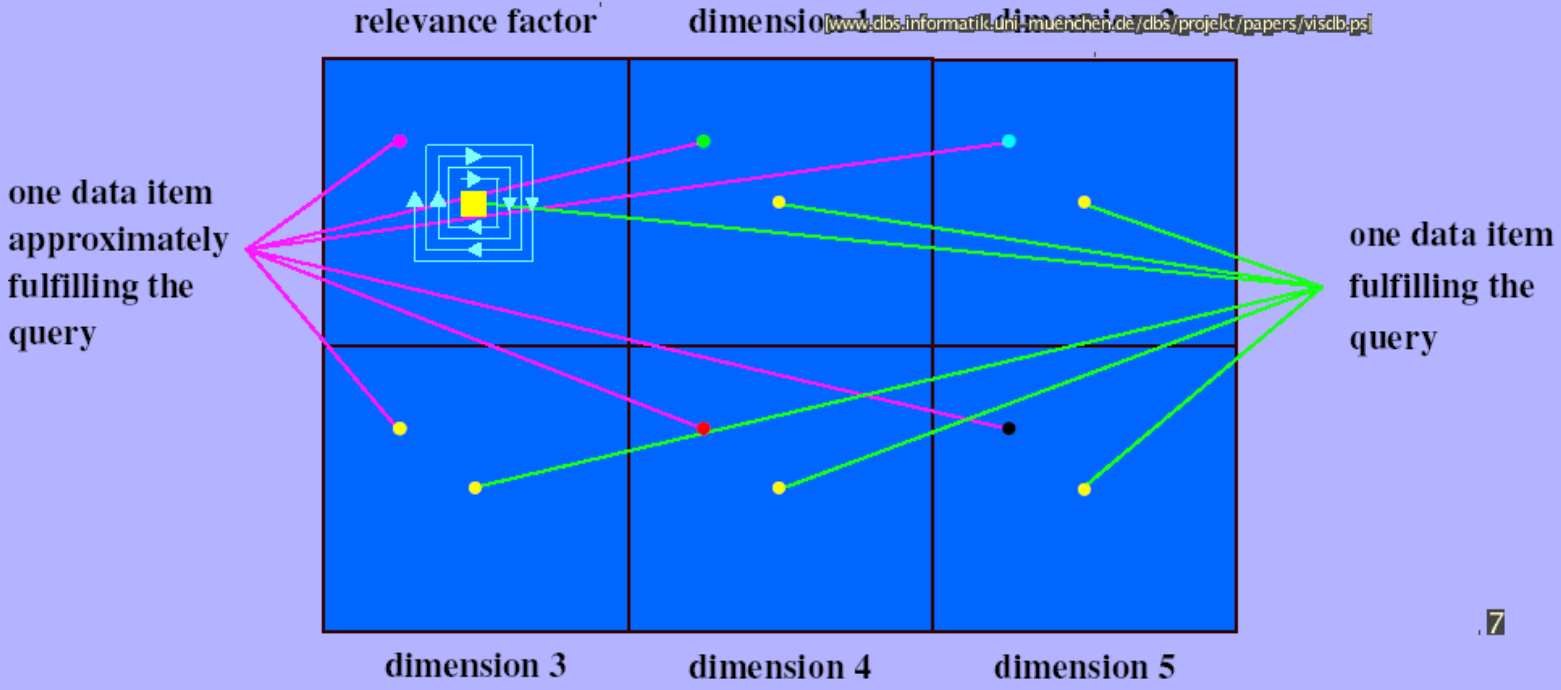
[www.dbs.informatik.uni-muenchen.de/dbs/projekt/papers/visdb.ps]

VisDB Windows

group dimensions



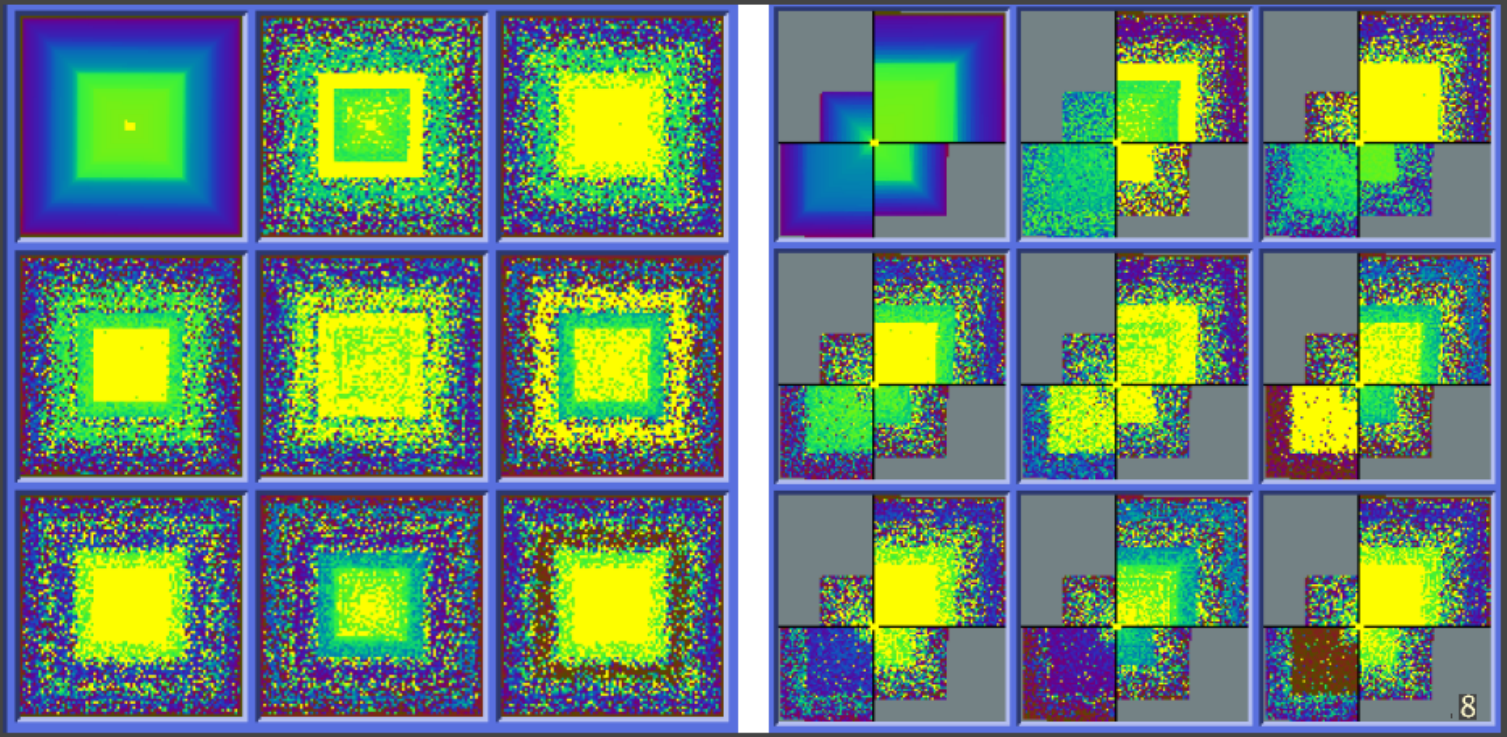
separate dimensions



VisDB Results: Separate Dimensions

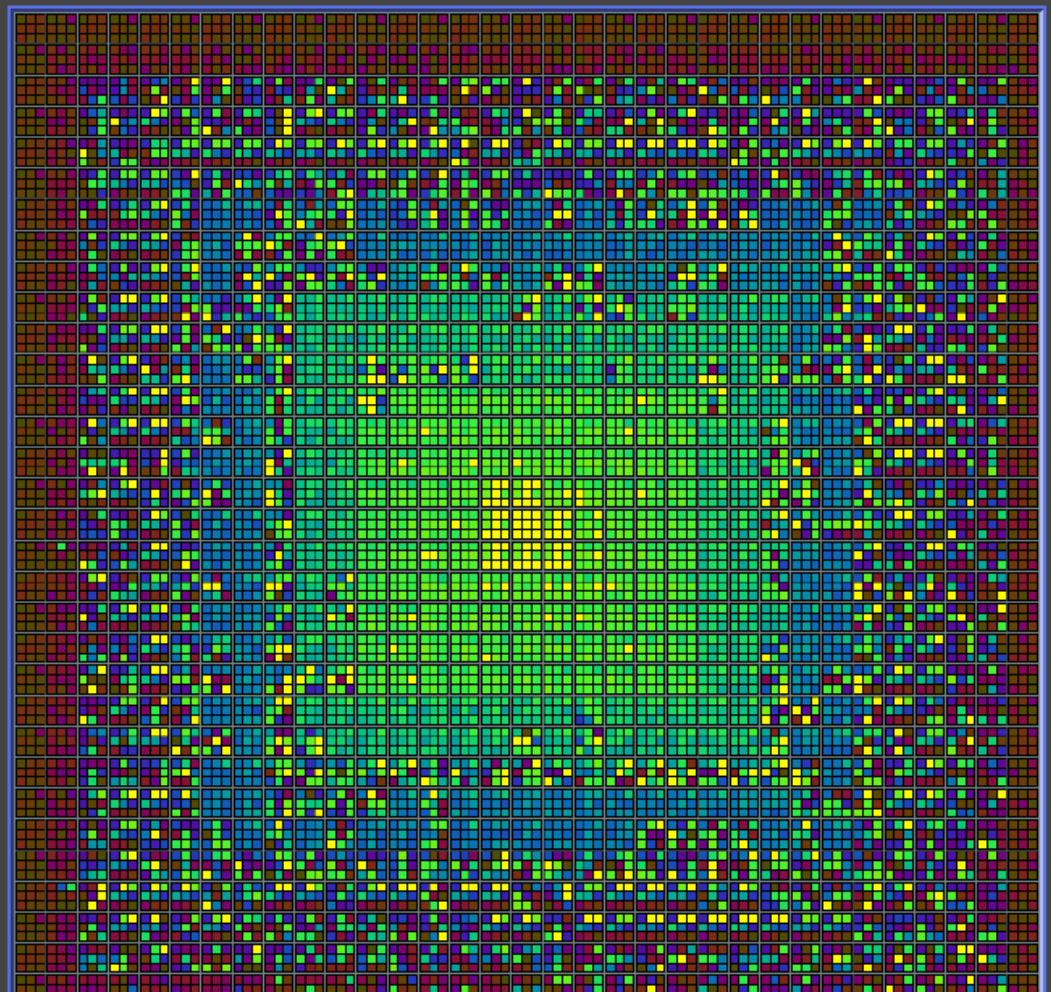
spiral

2D



[www.dbs.informatik.uni-muenchen.de/dbs/projekt/papers/visdb.ps]

VisDB Results: Grouped Dimensions

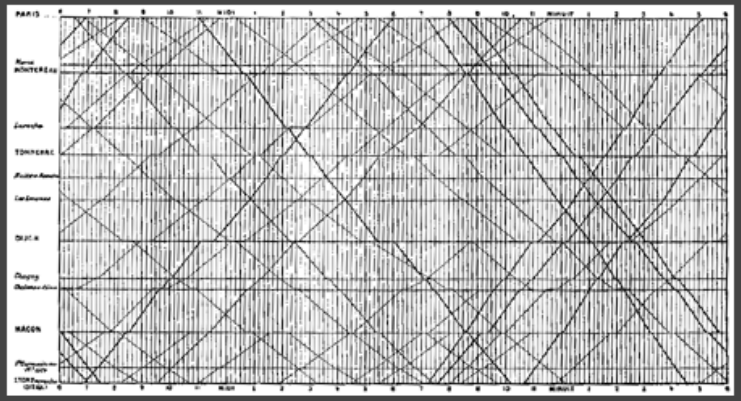


Derived Spaces: Slope

narrative of space and time

Marey train schedule, 1885

- horizontal line length: stop length
- slope: speed
- intersection: time/place of crossing



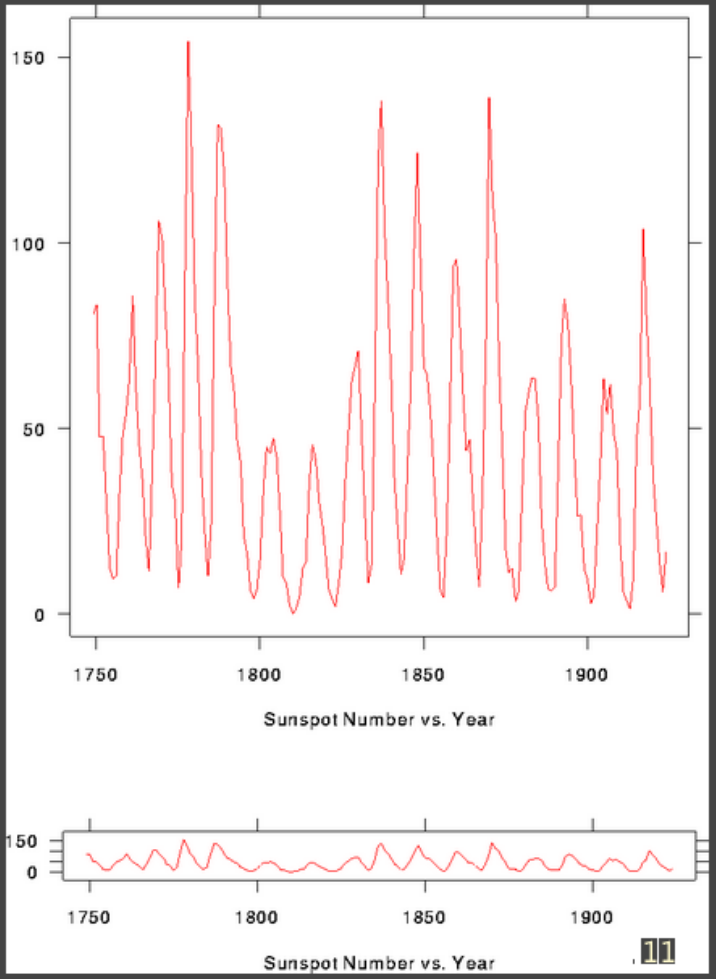
[Tufte I p 31, www.nap.edu/html/hs_math/images/tl_f8.gif]

Slope: Banking to 45 Degrees

what size should a line graph be?

perceptual principle: most accurate slope judgement near 45 degrees

pick aspect ratio (height/width) to maximize amount of 45 degree slope



[Trellis, www.research.att.com/~rab/trellis/sunspot.html]

Space vs. Time: Showing Change

literal — abstract

<----------->

time for time — space for time

animation: show time using temporal change

good

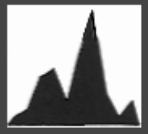
- show process
- compare two things by blinking

bad

- directly compare between many things
  intermediate frames "overload mental buffer"



[www.geom.uiuc.edu/docs/outreach/oi/evert.mpg] [www.astroshow.com/ccdpho/pluto.gif]



Space vs. Time: Showing Change

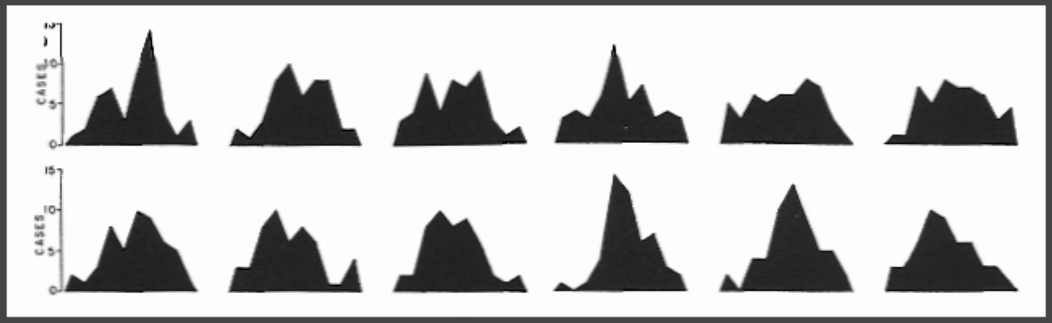
literal — abstract

<----------->

time for time — space for time

small multiples: show time using space

- overview: show each time step in array
- compare: side-by-side easier than temporal
  external cognition instead of internal memory
- general technique, not just for temporal changes



[Edward Tufte. The Visual Display of Quantitative Information, p 172]

More Reading

The Visual Design and Control of Trellis Display
R. A. Becker, W. S. Cleveland, and M. J. Shyu
Journal of Computational and Statistical Graphics, 5:123-155. (1996).
http://cm.bell-labs.com/stat/doc/trellis.jcgs.col.ps

Envisioning Information. Edward Tufte. Graphics Press, 1990.
Chapter 4: Small Multiples, Chapter 6: Narratives of Space and Time

The Elements of Graphing Data, William S. Cleveland, Hobart Press 1994.

VisDB: Database Exploration using Multidimensional Visualization,
Daniel A. Keim and Hans-Peter Kriegel, IEEE CG&A, 1994
http://www.dbs.informatik.uni-muenchen.de/dbs/projekt/papers/visdb.ps

The Table Lens: Merging Graphical and Symbolic Representations in an Interactive Focus + Context Visualization for Tabular Information
Ramana Rao and Stuart K. Card, SIGCHI '94, pp. 318-322.
http://citeseer.ist.psu.edu/545353.html

Performance Analysis and Visualization of Parallel Systems Using SimOS and Rivet: A Case Study. Robert Bosch, Chris Stolte, Gordon Stoll, Mendel Rosenblum, and Pat Hanrahan. In Proc. Sixth IEEE International Symposium on High-Performance Computer Architecture, January 2000. http://graphics.stanford.edu/papers/rivet_argus/

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Scalability
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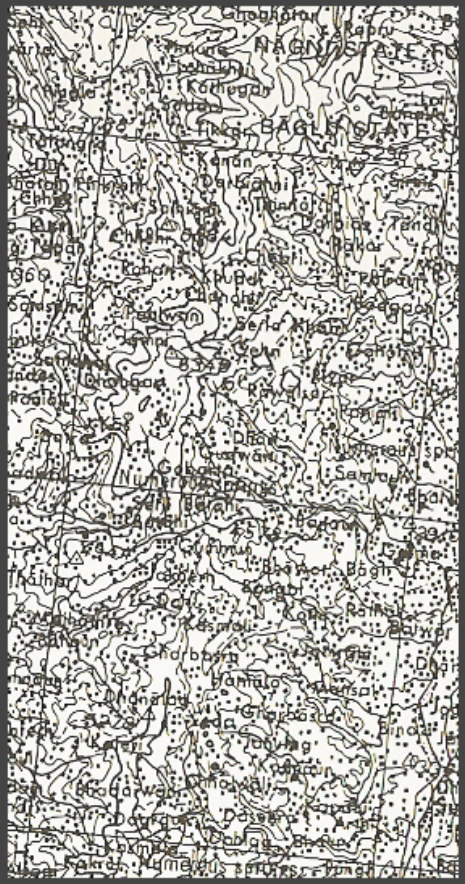
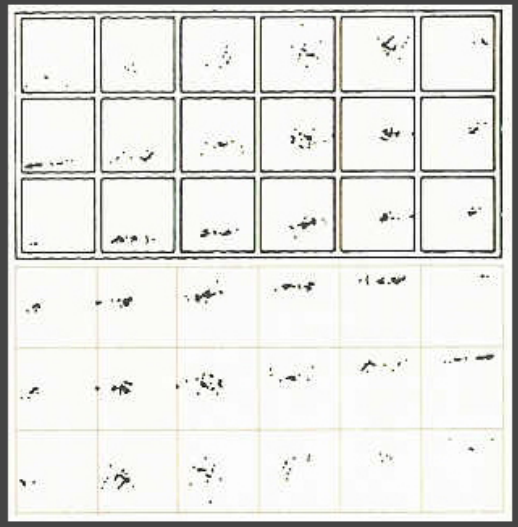
Layering And Separation



Visual Clutter

subtler background than foreground



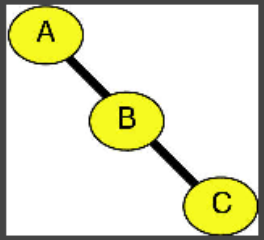
[Tufte, Envisioning Information, Chap 3]

Visual Layering For Graphs

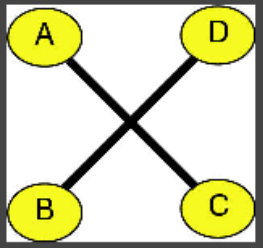
edge crossing problem
- false attachments

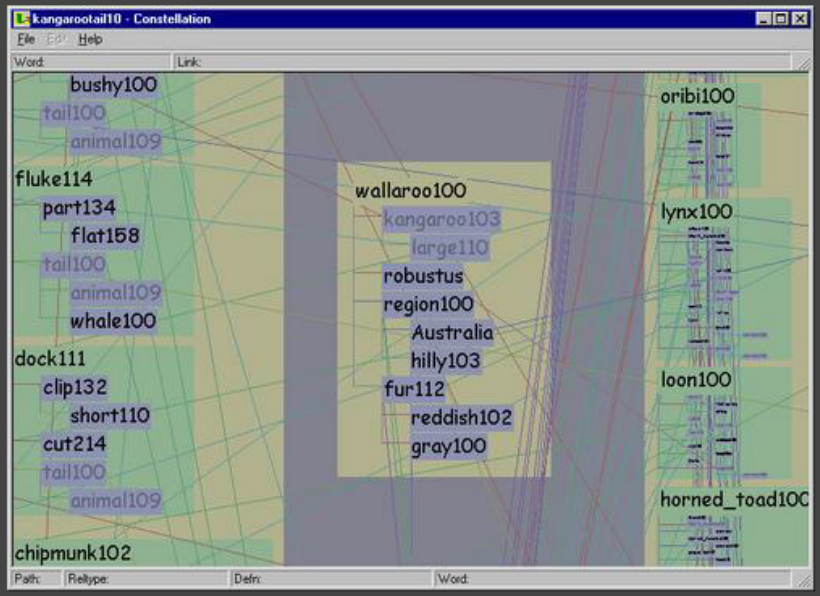
layers to avoid perception
- vs. spatial position

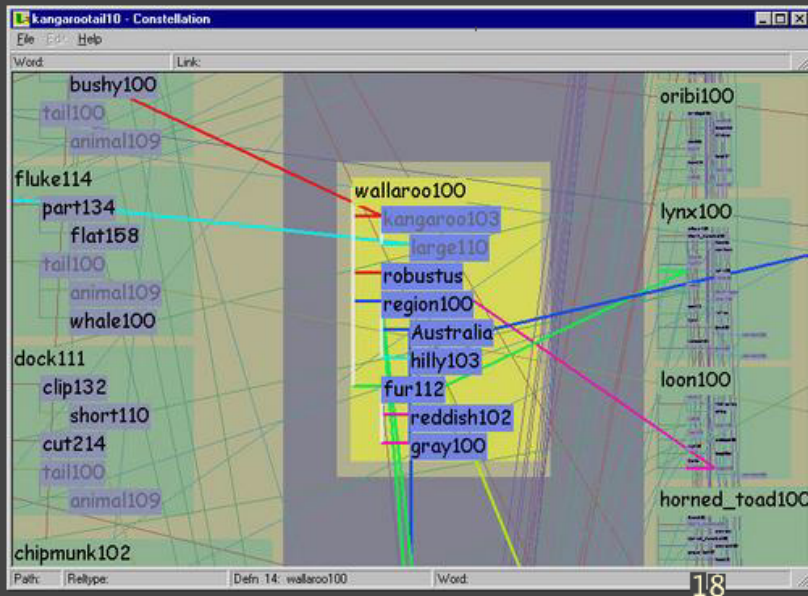
ambiguity



artifact salience





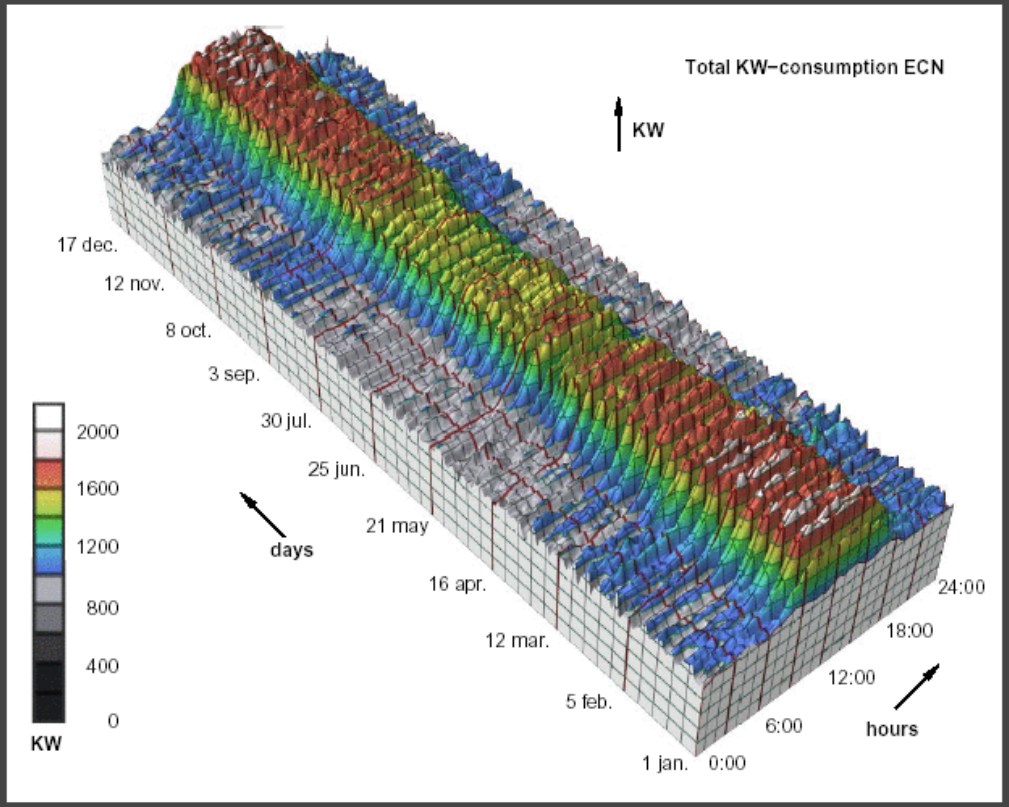


[Munzner et al, Constellation, graphics.stanford.edu/papers/const]

3D Time-series Data

3D extrusion pretty but not useful

- daily, weekly patterns hard to see
- occlusion hides, perspective interferes



Time-series Data Analysis

data: N pairs of (value, time)

- N large: 50K

tasks

- find standard day patterns
- find how patterns distributed over year, week, season
- find outliers from standard daily patterns
- want overview first, then detail on demand

possibilities

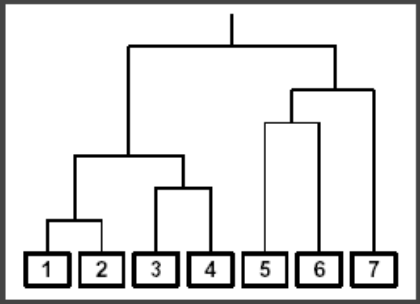
- predictive mathematical models
  details lost, multiscale not addressed
- scale-space approaches (wavelet, fourier, fractal)
  hard to interpret, known scales lost
- 3D mountain: x hours, y value, z days
  occlusion hides, perspective interferes

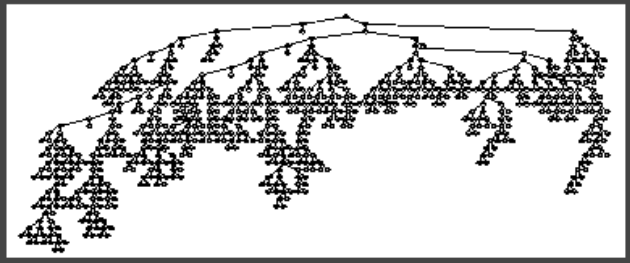
Hierarchical Clustering

start with all M day patterns
- compute mutual differences, merge most similar
- continue up to 1 root cluster

result: binary hierarchy of clusters
- choice of distance metrics

dendrogram display common
- shows structure of hierarchy
- does not solve pattern finding problem!

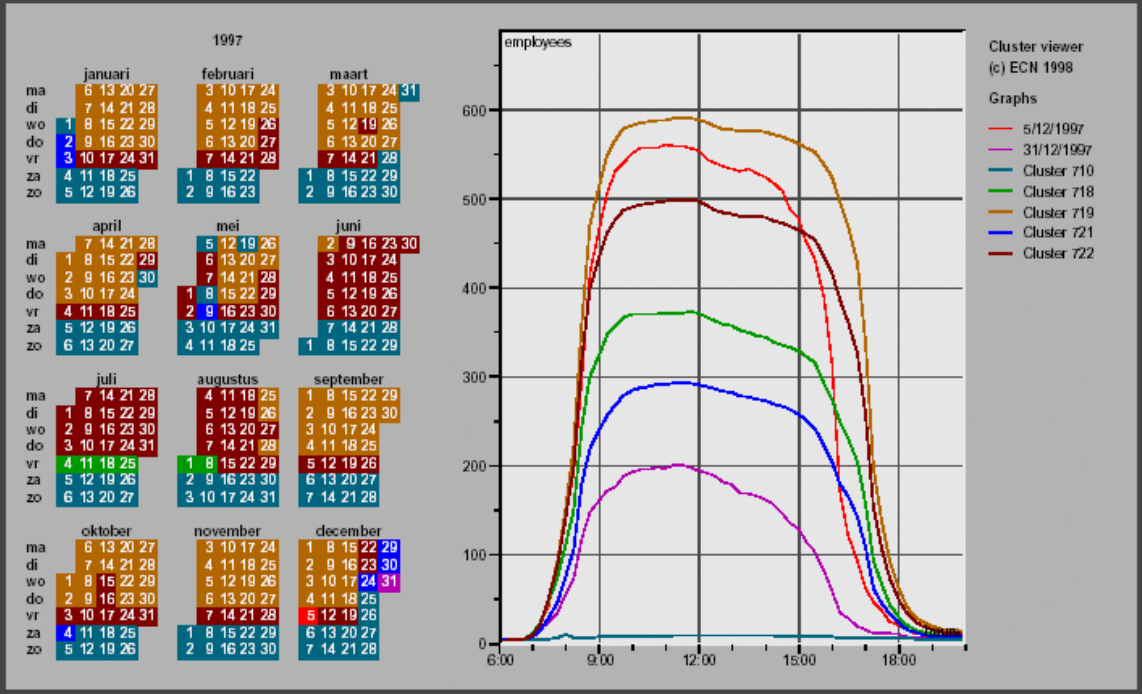




Link Clusters and Calendar

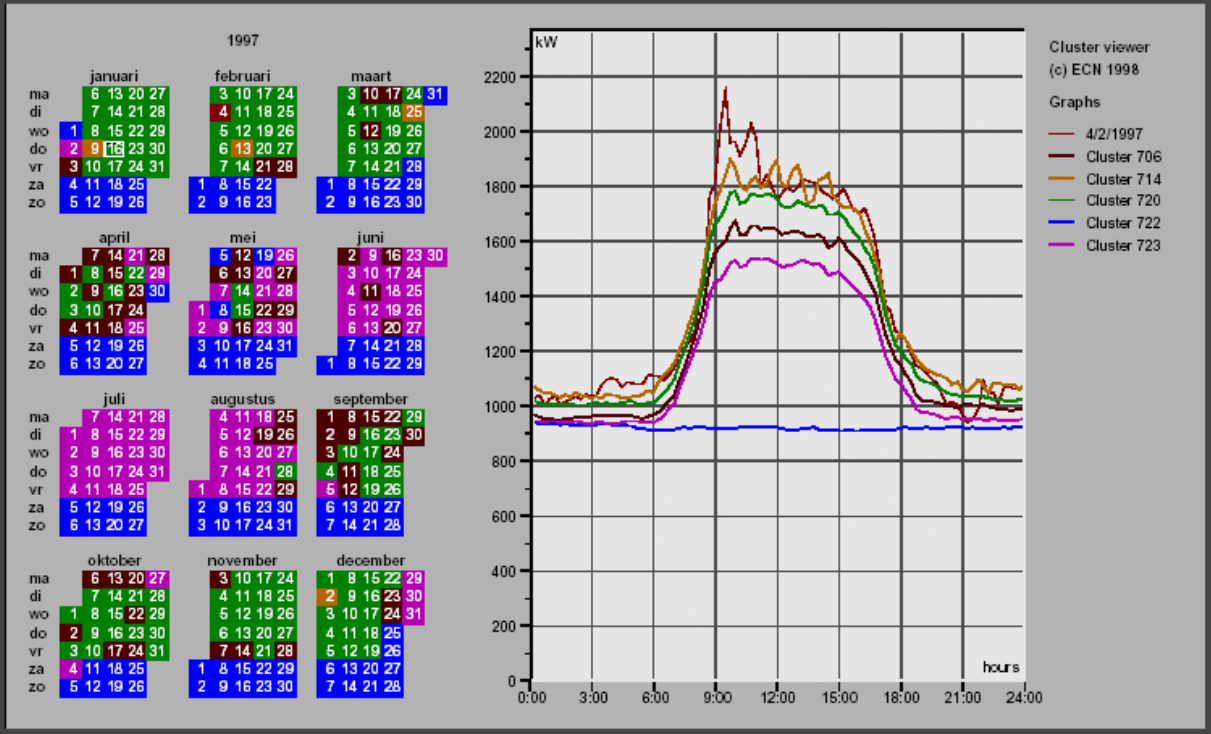
2D linked clusters-calendars shows patterns

- number of employees:
- office hours, fridays in/and summer, school break
- weekend/holidays, post-holiday, santa claus



[van Wijk and van Selow, Cluster and Calender based Visualization of Time Series Data, InfoVis99, Figure 4, citeseer.nj.nec.com/vanwijk99cluster.html]

Power Consumption



[van Wijk and van Selow, Cluster and Calender based Visualization of Time Series Data, InfoVis99, Figure 5, citeseer.nj.nec.com/vanwijk99cluster.html]

van Wijk Lessons

derived space: clusters

visual representation of time: calendar

- linked display
- interactive exploration

clear task analysis guided choices

- reject standard 3D extrusion
- reject standard dendrogram

critique

- pro: great design study, problem solved!
- con: some chosen colors not discriminable

3DPS

1: 2D displace+magnify

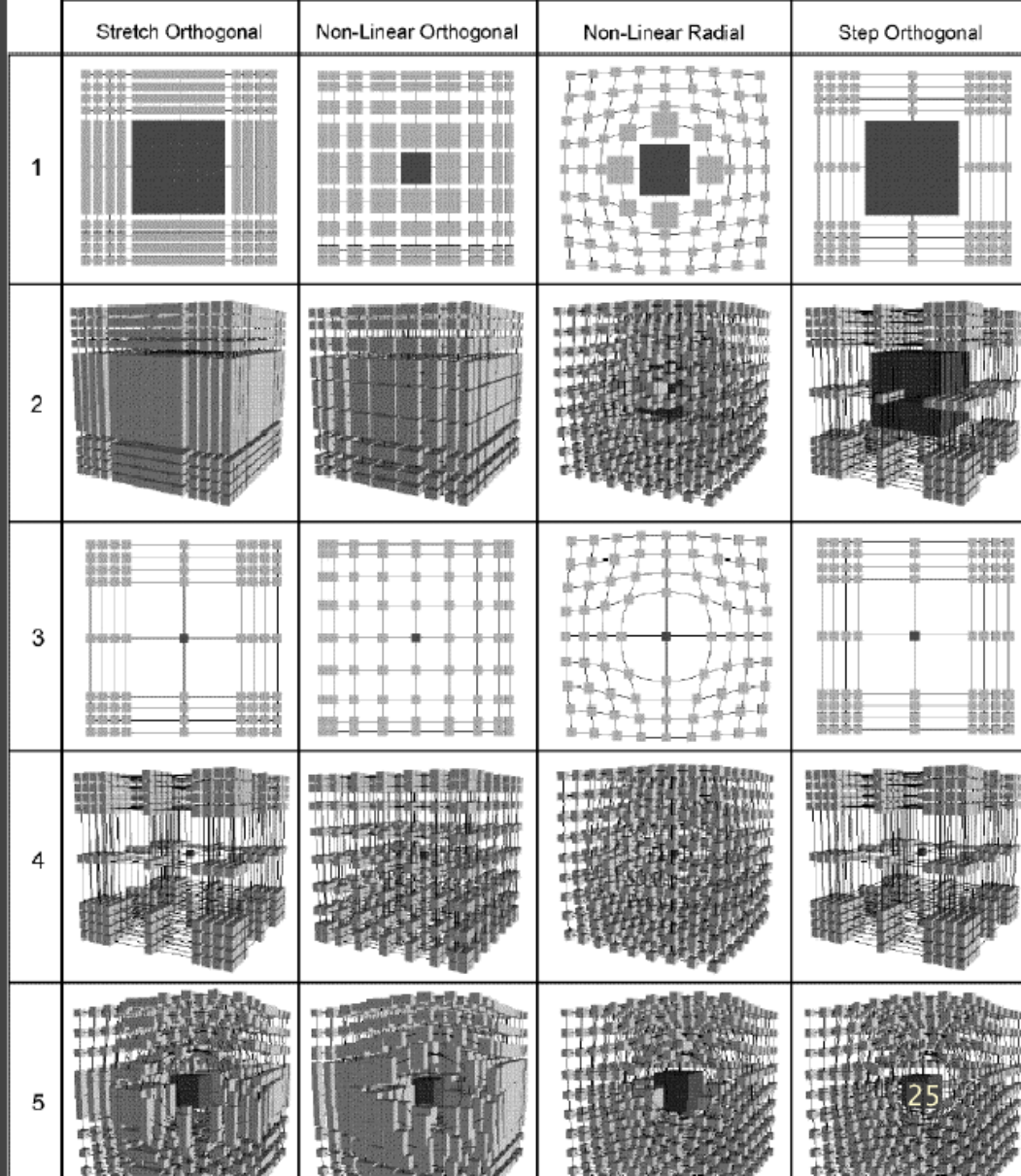
2: 3D displace+magnify

3: 2D displace only

4: 3D displace only

5: visual access distortion

Extending Distortion Viewing Techniques from 2D to 3D Data
Carpendale et al 1997



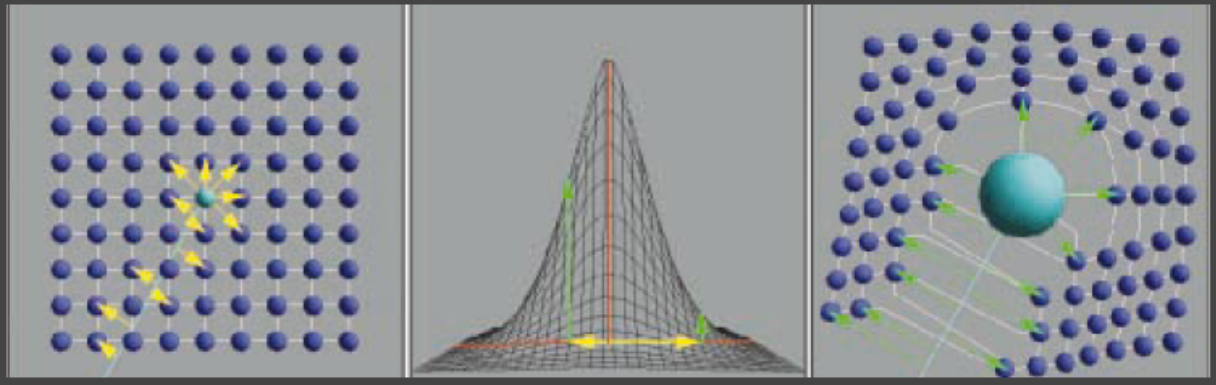
Visual Access Distortion

naive 2D -> 3D extension yields occlusion

- same problem as van Wijk

graph-based solution

- move geometry according to viewpoint
- magnify focus only
- introduce curves into formerly straight lines

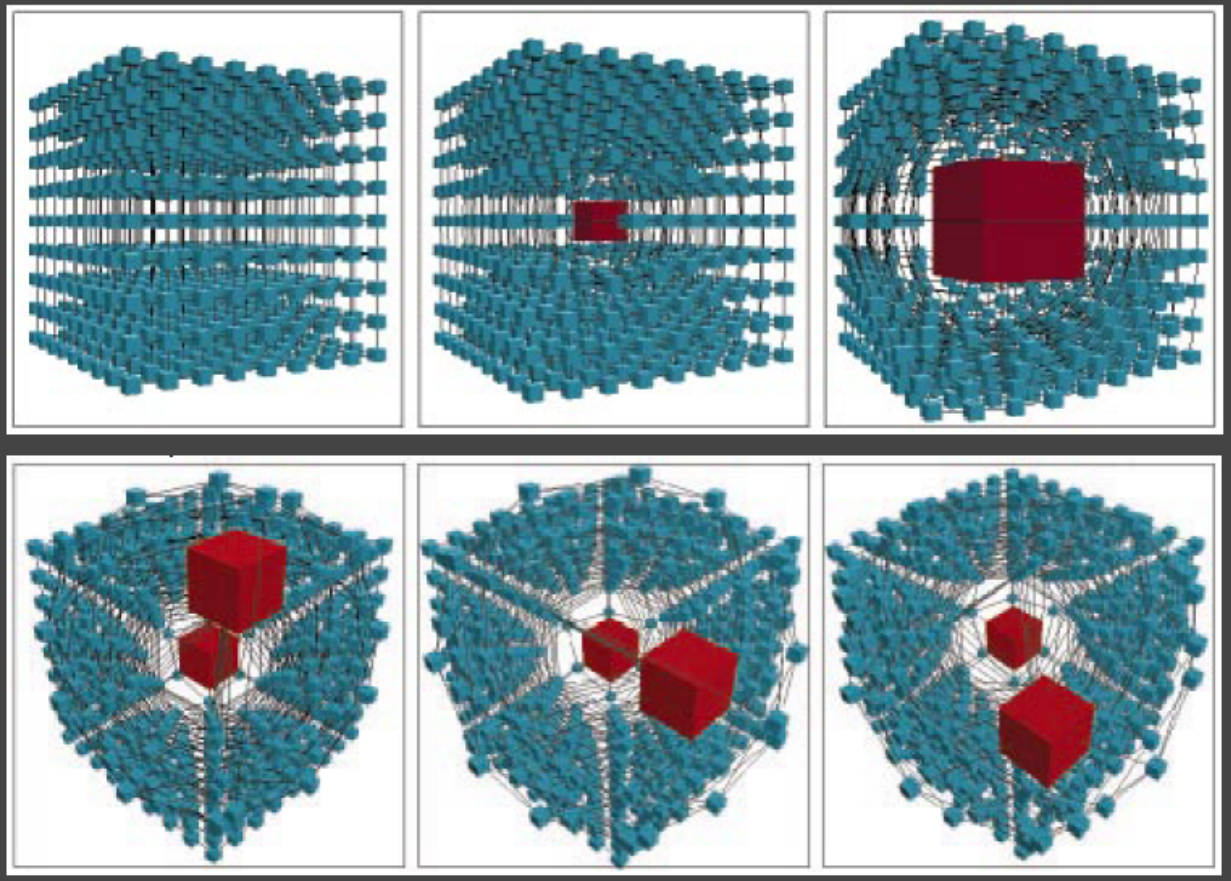


focus+context issues discussed later

[pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/cga97.pdf]

Results

single, multiple foci

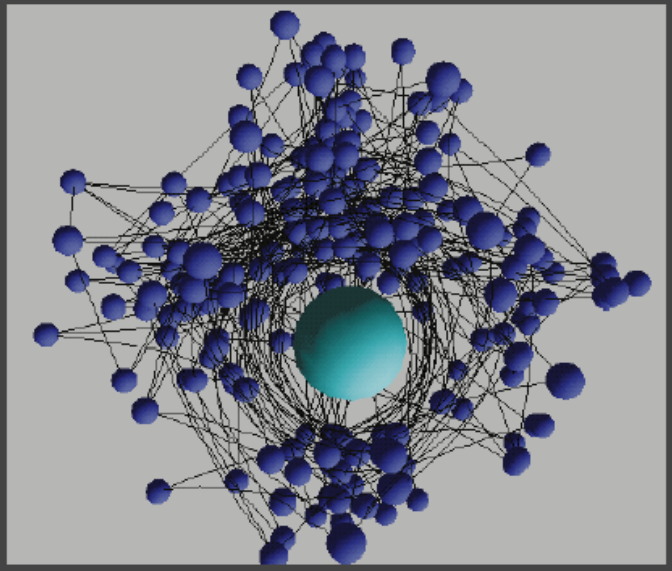


[pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/cga97.pdf]

Results

randomly positioned nodes instead of grid

- closer to real dataset



[pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/cga97.pdf]

Critique

sophisticated way to navigate 3D graphs

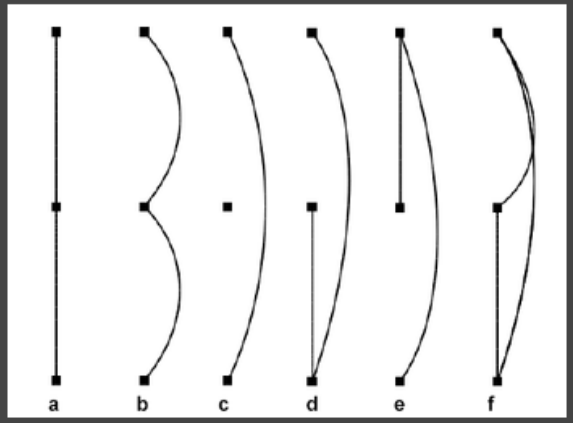
nice technique paper
- not a design study

interesting discussion I'd like to see
- more analysis of why 3D necessary
  - cites Ware 3x improvement
- occlusion workaround vs. occlusion avoidance

never shown on real data
- hard to draw conclusions from toy datasets

EdgeLens

interactive control over edge occlusion



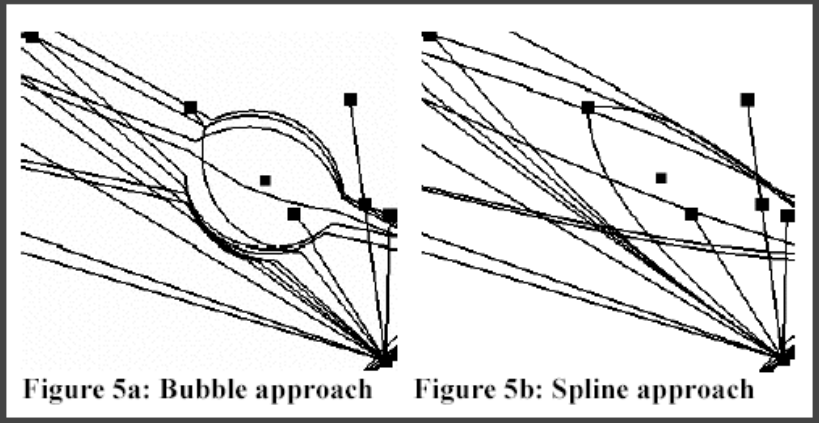


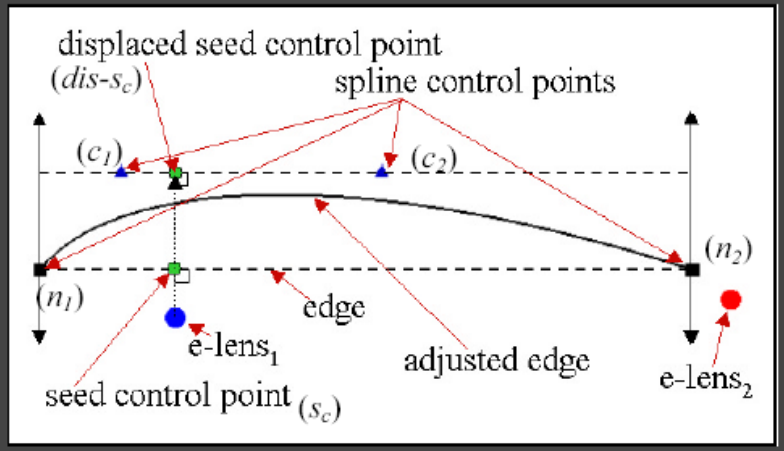
Figure 5a: Bubble approach

Figure 5b: Spline approach

user study: spline better than bubble

[EdgeLens: An Interactive Method for Managing Edge Congestion in Graphs
Nelson Wong, M. Sheelagh T. Carpendale, Saul Greenberg, Proc. InfoVis03, pp 51–58.
pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/2003/wong-carp-infovis03-submit.pdf]

EdgeLens Final Algorithm

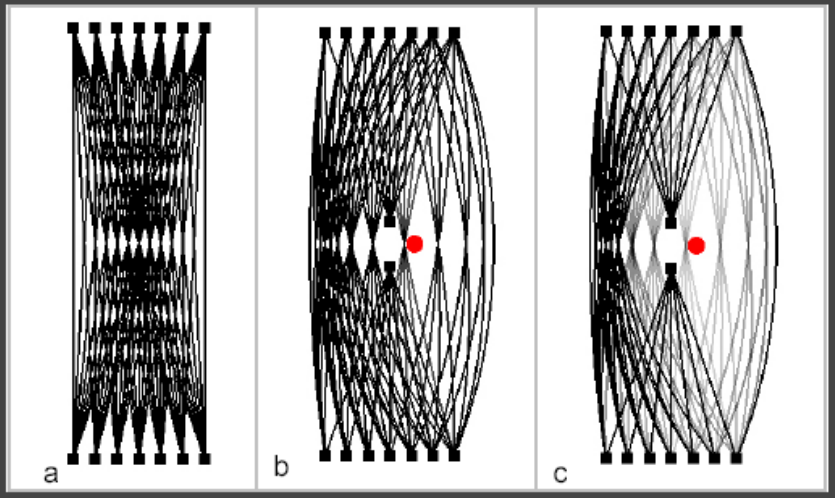


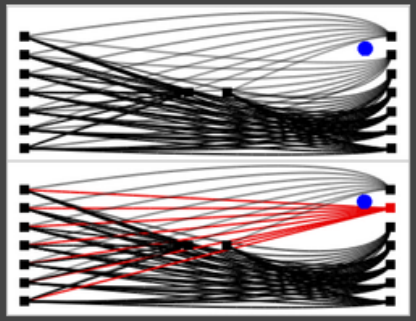
decide which edges affected
calculate displacements
calculate spline control points
draw curves

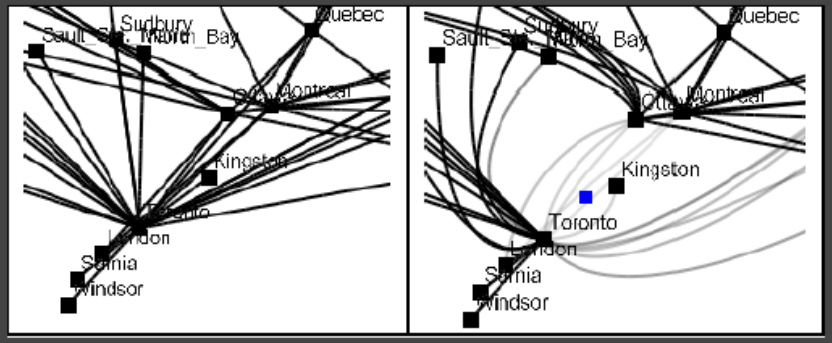
[pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/2003/wong-carp-infovis03-submit.pdf]

EdgeLens Techniques

transparency, color

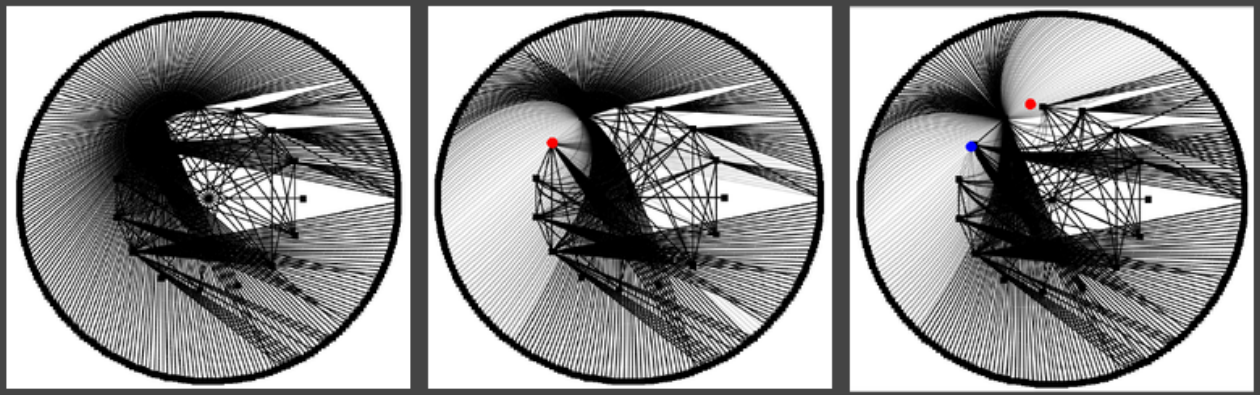






[pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/2003/wong-carp-infovis03-submit.pdf]

EdgeLens Results



[pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/2003/wong-carp-infovis03-submit.pdf]

critique

- very nice technique
  compelling need
- shown on real data

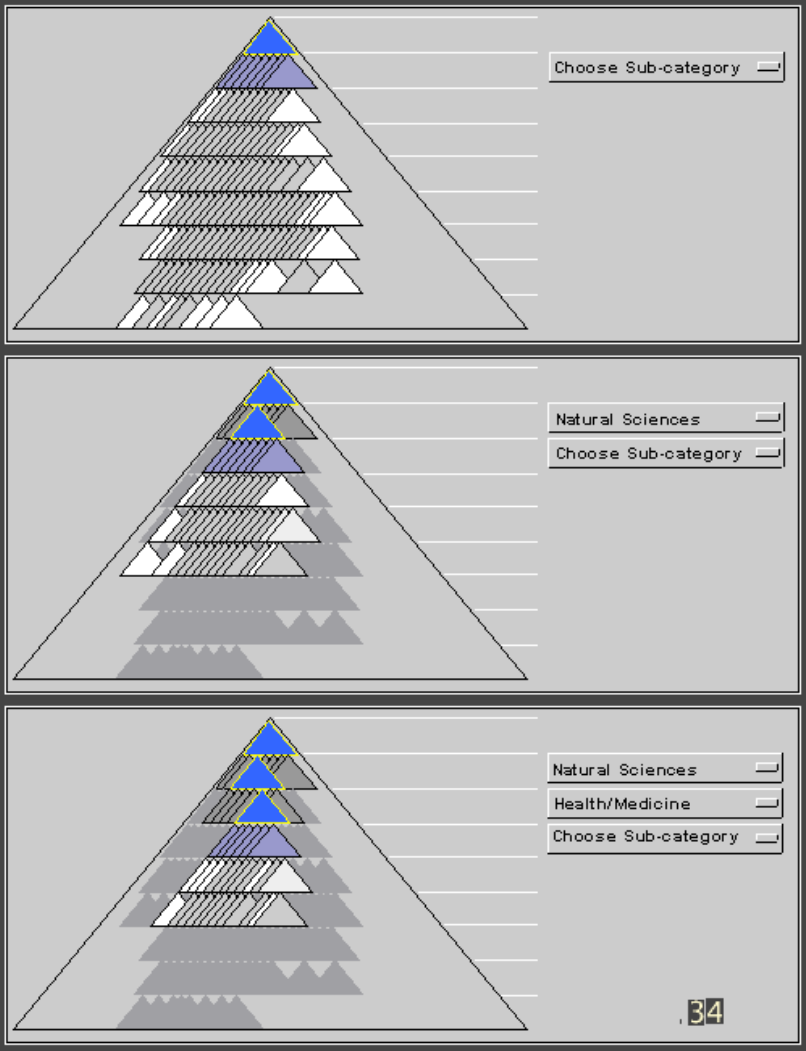
Cheops

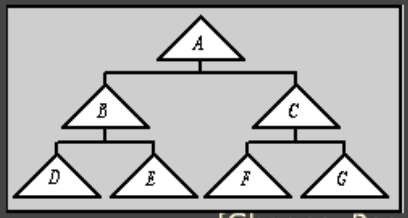
compact

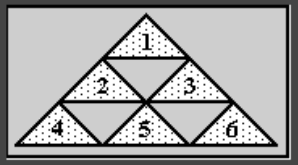
show paths through tree

extreme occlusion deliberately

browsing/exploration, not topological analysis







[Cheops, Beaudoin/Parent/Vroomen, www.istop.com/~maparent/paper.html]

Cheops Critique

pro

- tiny footprint
  suitable when main user focus is other task

- interaction techniques investigated
  informal usability

con

- relatively hard to understand

- singular nodes very salient, but not so important

More Reading

Envisioning Information. Edward Tufte. Graphics Press, 1990.
Chapter 3: Layering and Separation

Tamara Munzner, Interactive Visualization of Large Graphs and Networks
Chapter 5, Constellation: Linguistic Semantic Networks
PhD thesis, Stanford University, 2000, pp 87–122
http://graphics.stanford.edu/papers/munzner_thesis/html/node10.html

Cluster and Calendar based Visualization of Time Series Data
Jarke J. van Wijk Edward R. van Selow, Proc InfoVis 99.
http://citeseer.nj.nec.com/vanwijk99cluster.html

Extending Distortion Viewing Techniques from 2D to 3D Data
M.S.T. Carpendale, David J. Cowperthwaite, and F. David Fracchia, IEEE CG&A, 17(4), pp 42 – 51, July 1997.
http://pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/cga97.pdf

EdgeLens: An Interactive Method for Managing Edge Congestion in Graphs
Nelson Wong, M. Sheelagh T. Carpendale, Saul Greenberg, Proc. InfoVis03, pp 51–58.
http://pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/2003/wong-carp-infovis03-submit.pdf

Cheops: A Compact Explorer For Complex Hierarchies
Luc Beaudoin, Marc-Antoine Parent, Louis C. Vroomen, Proc. Visualization 1996, pp 87–92. http://www.istop.com/~maparent/paper.html

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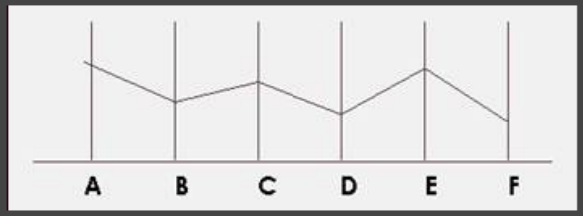
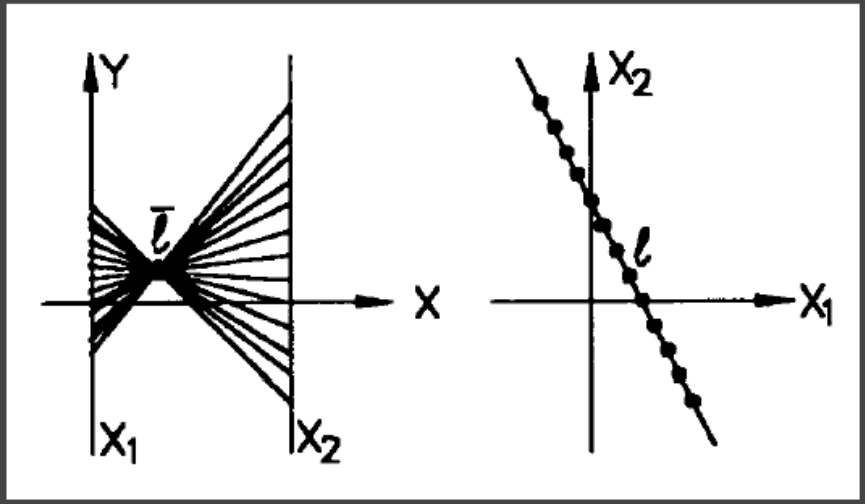
Parallel Coordinates

only 2 orthogonal axes in the plane
instead, use parallel axes!



point–line duality



[Parallel Coordinates: A Tool for Visualizing Multi-Dimensional Geometry.

Parallel Coords: Axis Ordering

geometric interpretations

- hyperplane, hypersphere: points have intrinsic order

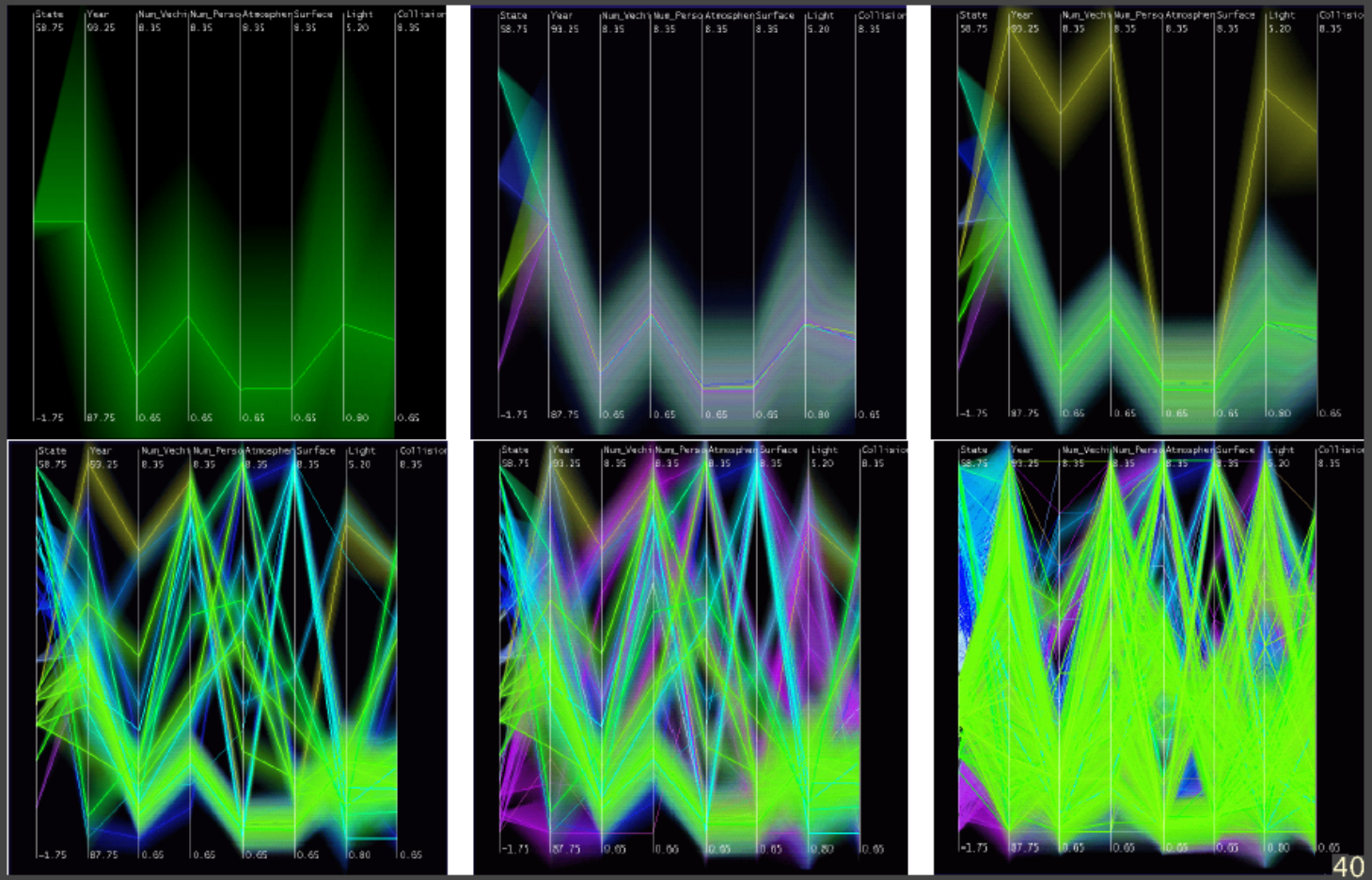
infovis

- no intrinsic order, what to do?
- indeterminate/arbitrary order
  - weakness of many techniques
  - downside: human-powered search
  - upside: powerful interaction technique
- most implementations
  - user can interactively swap axes

Automated Multidimensional Detective

- [Inselberg 99]
- machine learning approach

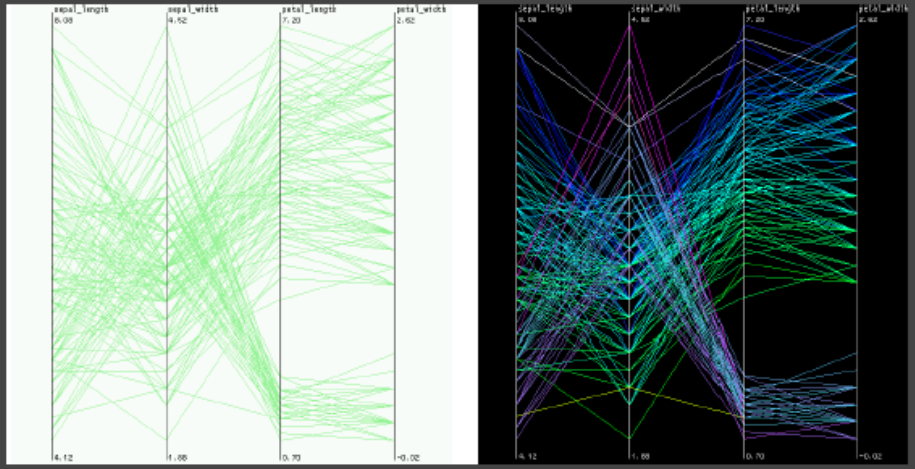
Hierarchical Parallel Coords: LOD



[Hierarchical Parallel Coordinates for Visualizing Large Multivariate Data Sets
Fua, Ward, and Rundensteiner, IEEE Vis '99, davis.wpi.edu/~xmdv/docs/vis99_HPC.pdf]

Hierarchical Clustering

proximity-based coloring



[Hierarchical Parallel Coordinates for Visualizing Large Multivariate Data Sets
Fua, Ward, and Rundensteiner. IEEE Vis '99, davis.wpi.edu/~xmdv/docs/vis99_HPC.pdf]

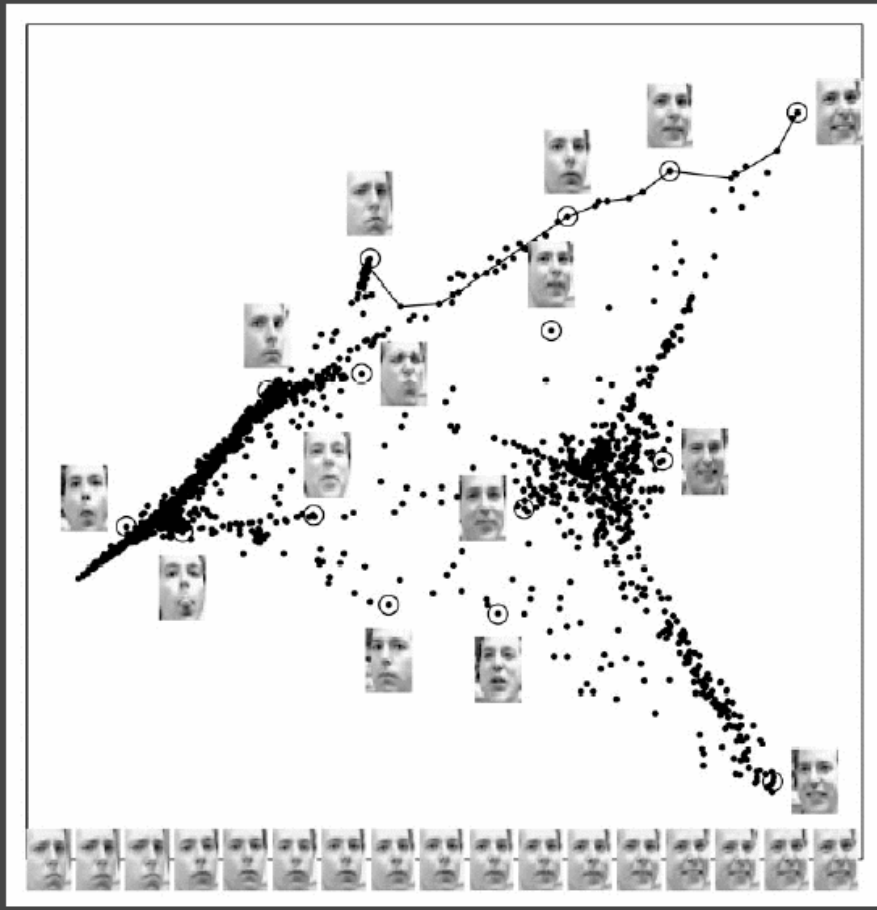
Dimensionality Reduction

mapping
- Q high dims
- P low dims (2 or 3)
- n points
- map Q->P
- minimize error of low-dim distances wrt high-dim dist

distance measures
- pairwise distance matrix between points
- metric between points in space

methods
- MDS (multidimensional scaling)
- LLE (locally linear embedding)
- IsoMap, charting
- PCA, SOM

complexity
- naive O(n^3), many O(n^2),
- best O(n sqrt n)



[LLE, Roweis and Saul, www.cs.toronto.edu/~roweis/papers/2323.pdf]

True Dimensionality: Linear

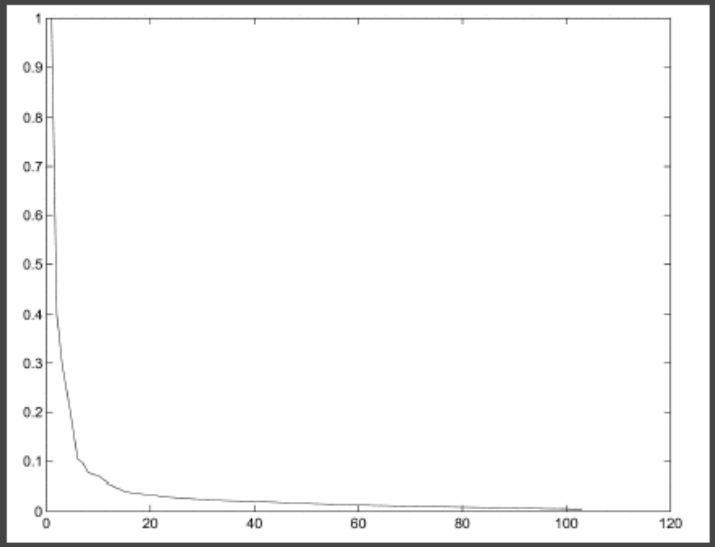
how many dimensions is enough? > 2 or 3?

- knee in error curve

example: measured materials from graphics

linear PCA: 25

- can get physically impossible intermediate points



[A Data-Driven Reflectance Model, SIGGRAPH 2003, W Matusik, H. Pfister M. Brand and L. McMillan, graphics.lcs.mit.edu/~wojciech/pubs/sig2003.pdf]

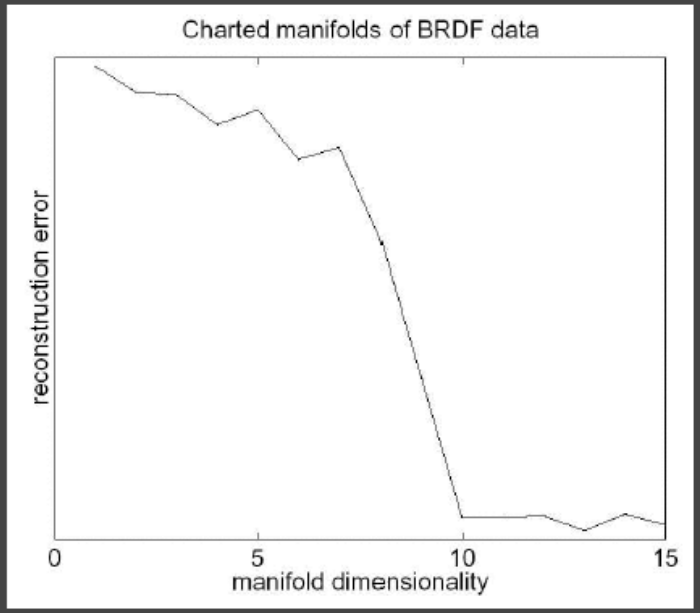
True Dimensionality: Nonlinear

nonlinear MDS: 10–15

- all intermediate points possible

categorizable by people

- red, green, blue, specular, diffuse, glossy, metallic,
- plastic-y, roughness, rubbery, greasiness, dustiness...

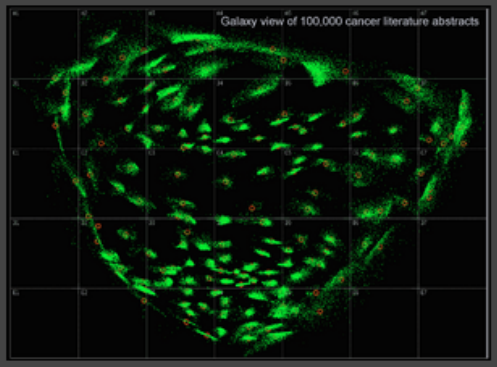


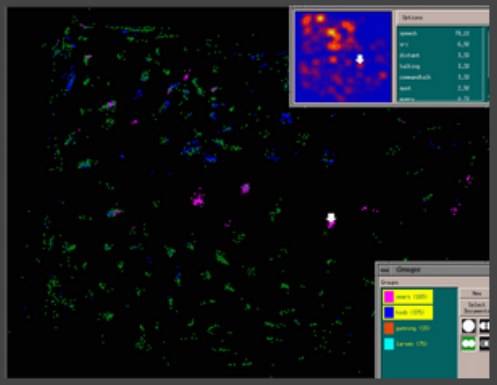
[A Data-Driven Reflectance Model, SIGGRAPH 2003, W Matusik, H. Pfister

Themescapes/Galaxies

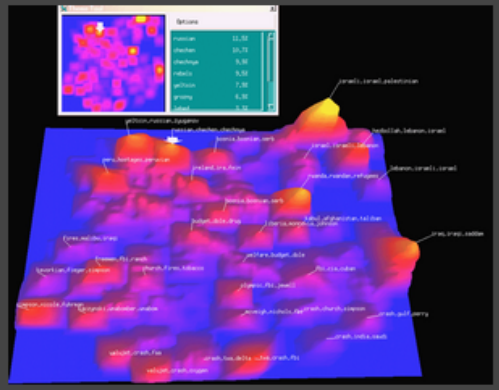
MDS output: beyond just drawing points

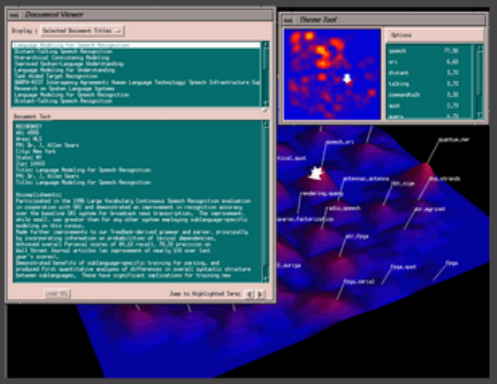
- galaxies: aggregation





- themescapes: terrain/landscapes





[www.pnl.gov/infoviz/graphics.html]

Cluster Stability

display

- also terrain metaphor

underlying computation

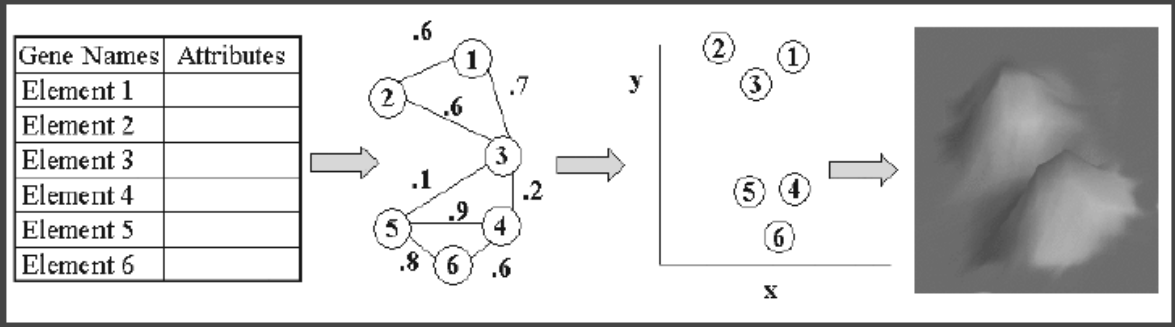
- energy minimization (springs) vs. MDS
- weighted edges

do same clusters form with different random start points?

"ordination"

- spatial layout of graph nodes

Approach



normalize within each column

similarity metric

- discussion: Pearson's correllation coefficient

threshold value for marking as similar

- discussion: finding critical value

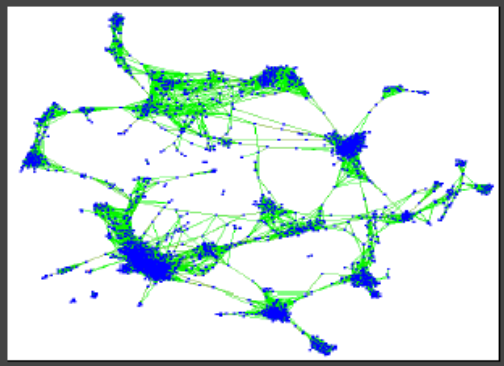
Graph Layout

criteria

- distance in layout matching graph-theoretic distance
  - vertices one hop away close
  - vertices many hops away far
- insensitive to random starting positions
  - major problem with previous work!
- tractable computation

force-directed placement

- discussion: energy minimization
- others: gradient descent, etc
- discussion: termination criteria

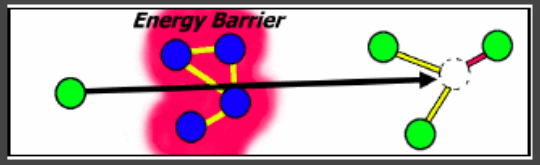


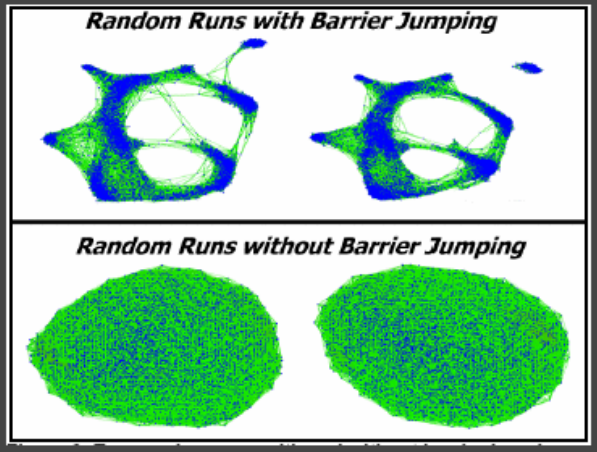
Barrier Jumping

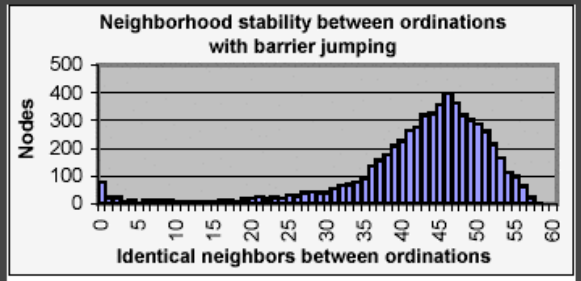
same idea as simulated annealing

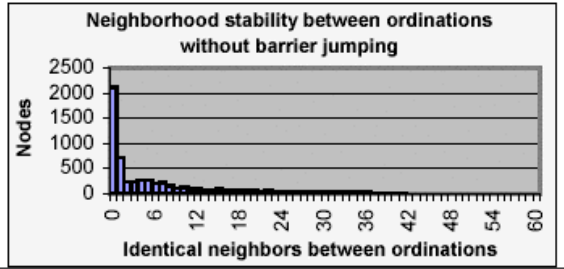
- but compute directly
- just ignore repulsion for fraction of vertices

solves start position sensitivity problem









Results

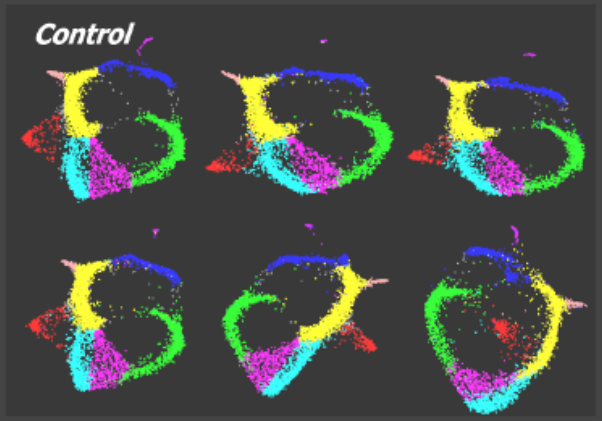
efficiency

- naive approach: O(V^2)
- approximate density field: O(V)

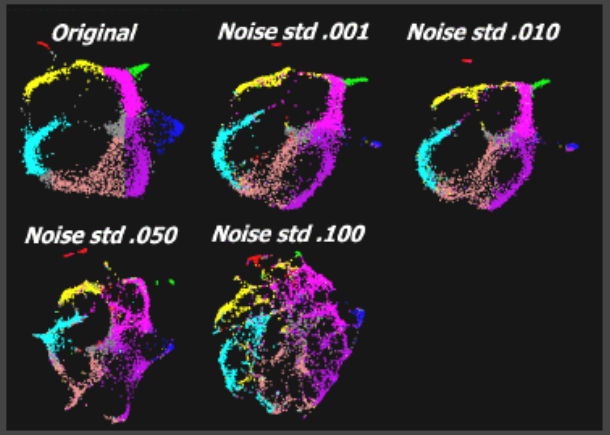
good stability

- rotation/reflection can occur

different random start



adding noise



Critique

real data

- suggest check against subsequent publication!

give criteria, then discuss why solution fits

visual + numerical results

- convincing images plus benchmark graphs

detailed discussion of alternatives at each stage

specific prescriptive advice in conclusion

More Reading

Parallel Coordinates: A Tool for Visualizing Multi-Dimensional Geometry.
Alfred Inselberg and Bernard Dimsdale, IEEE Visualization '90, 1990.

On Some Graphical Representations of Multivariate Data.
M. Bolorfoush and E. J. Wegman. Proc. of Interface '88, Amer. Stat. Assoc.

Hierarchical Parallel Coordinates for Visualizing Large Multivariate Data Sets
Fua, Ward, and Rundensteiner. IEEE Visualization '99,
http://davis.wpi.edu/~xmdv/docs/vis99_HPC.pdf

Nonlinear dimensionality reduction by locally linear embedding.
Sam Roweis & Lawrence Saul. Science v.290 no.5500, Dec.22, 2000. pp.2323--2326.
http://www.cs.toronto.edu/~roweis/papers/2323.pdf

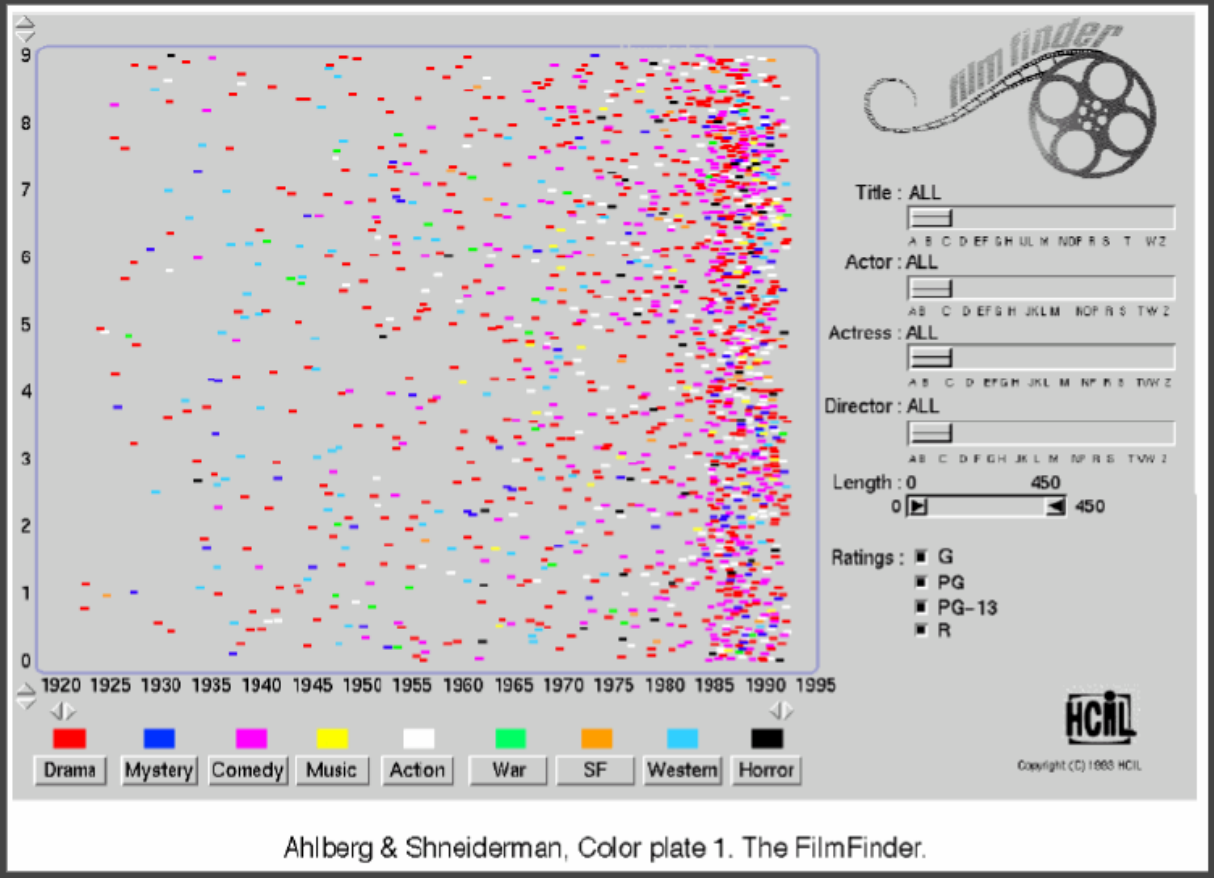
Fast Multidimensional Scaling through Sampling, Springs and Interpolation
Alistair Morrison, Greg Ross, Matthew Chalmers
Information Visualization 2(1) March 2003, pp. 68-77.
http://www.dcs.gla.ac.uk/~matthew/papers/JInfoVis.pdf

Cluster Stability and the Use of Noise in Interpretation of Clustering
George S. Davidson, Brian N. Wylie, Kevin W. Boyack, Proc InfoVis 2001.
http://citeseer.nj.nec.com/davidson01cluster.html

Mini-Course Outline

Perception
Frameworks
Color
Space/Order
Depth/Occlusion
High Dimensionality
Interaction
Navigation/Zooming
Focus+Context
Graphs/Trees
Scalability
Task-Centered Design

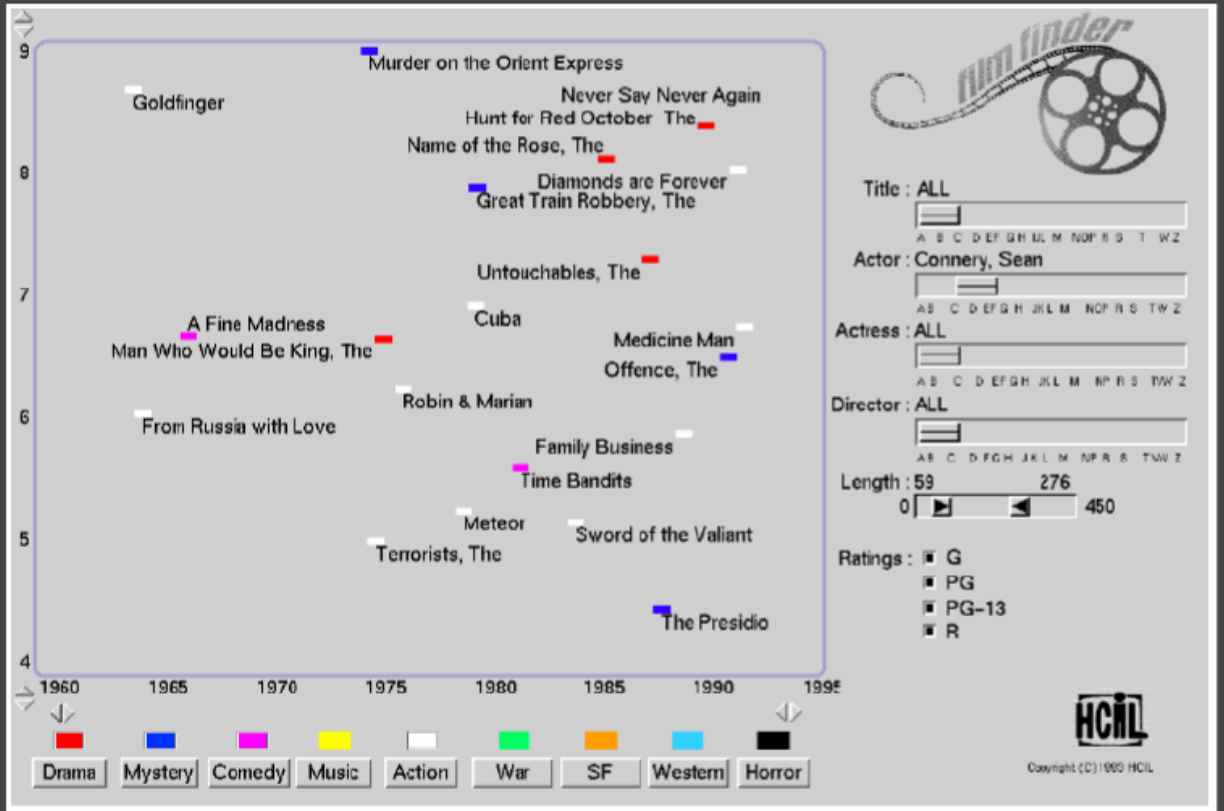
Dynamic Queries



Ahlberg & Shneiderman, Color plate 1. The FilmFinder.

[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahlberg and Shneiderman, Proc SIGCHI '94. citeseer.ist.psu.edu/ahlberg94visual.html]

Dynamic Queries



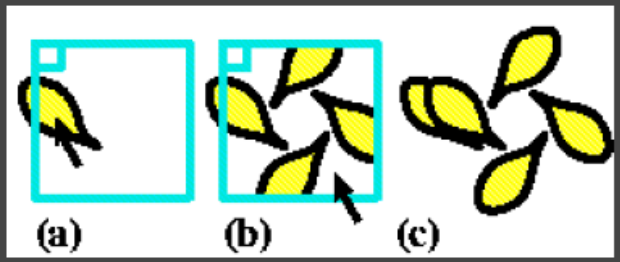
Ahlberg & Shneiderman, Color plate 2. Categories have been selected, the displayed is zoomed

[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahlberg and Shneiderman, Proc SIGCHI '94, citeseer.ist.psu.edu/ahlberg94visual.html]

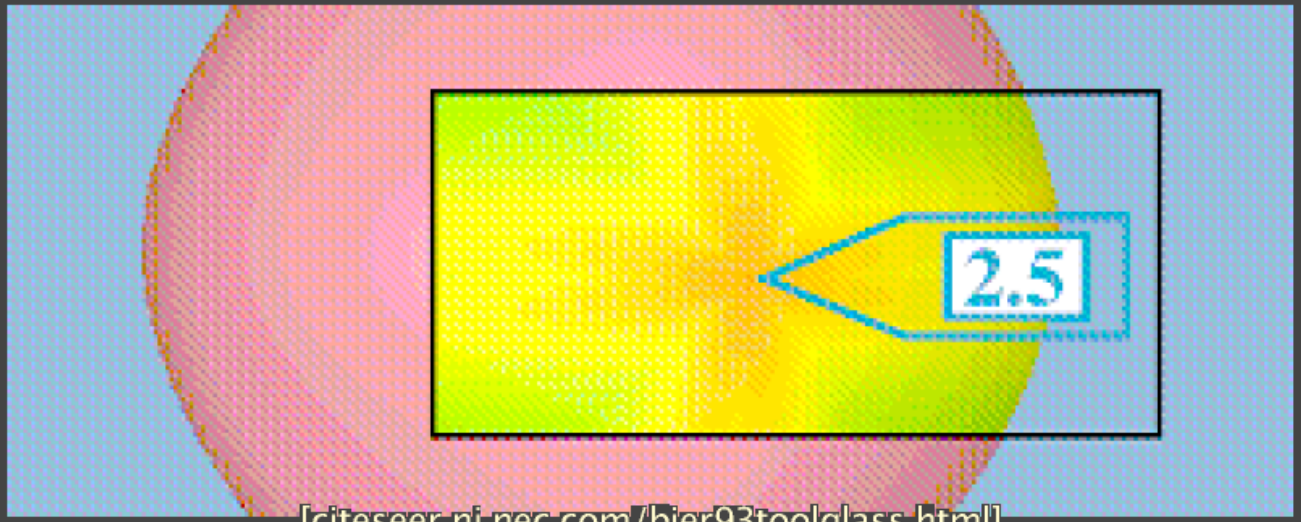
Toolglass and Magic Lens

- see-through
- two-handed

symmetry glass



curvature lens



[citeseer.nj.nec.com/bier93toolglass.html]

Linked Views

linked highlighting/brushing/

- extremely powerful technique

- Brushing Scatterplots, Becker and Cleveland, Technometrics 1987 vol 29, pp 127–142

coordinated views

- linked navigation

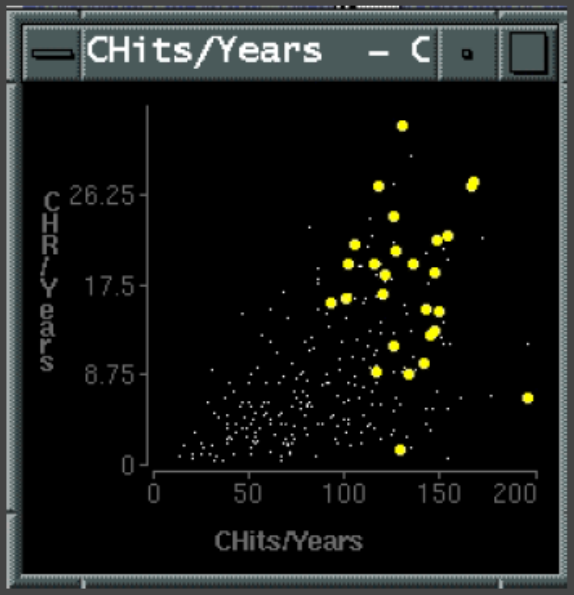
- CMV: International Conference on Coordinated & Multiple Views in Exploratory Visualization

example: Exploratory Data Visualizer

- Visual Exploration of Large Structured Databases, Graham J. Wills, in New Techniques and Trends in Statitics, pp 237–246, IOS Press 1995.

Highlighting (Focusing)

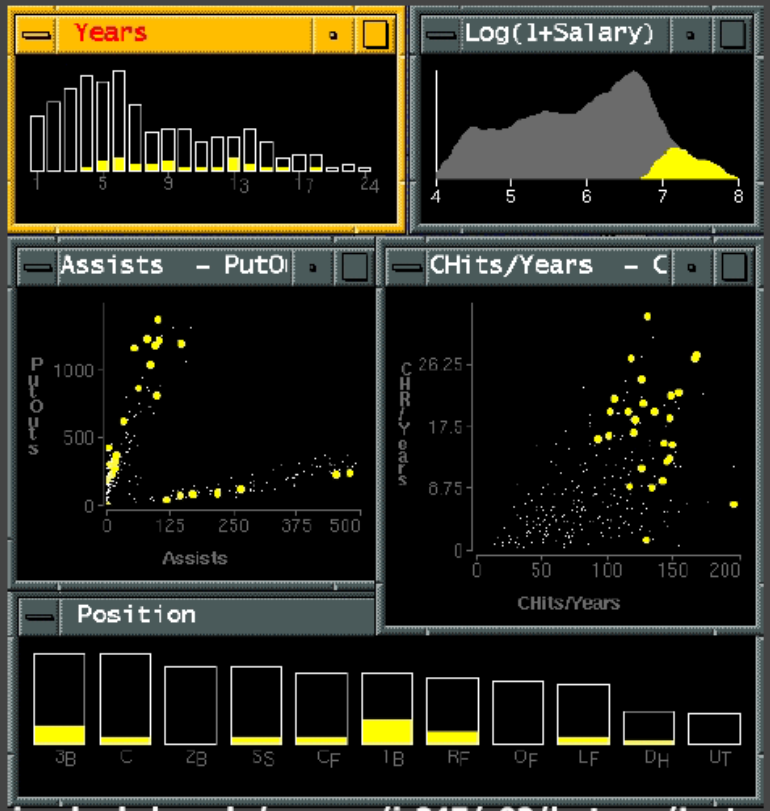
Focus user attention on a subset of the data within one graph (from Wills 95)



[www.sims.berkeley.edu/courses/is247/s02/lectures/Lecture3.ppt]

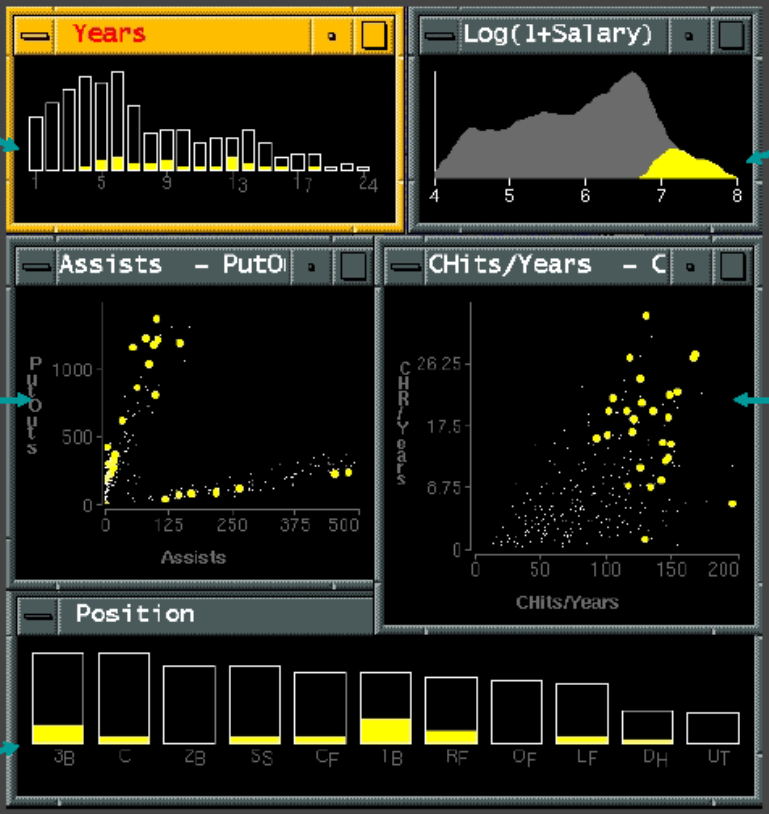
Link different types of graphs: Scatterplots and histograms and bars

(from Wills 95)



[www.sims.berkeley.edu/courses/is247/s02/lectures/Lecture3.ppt]

Baseball data: Scatterplots and histograms and bars
(from Wills 95)



how long in majors

select high salaries

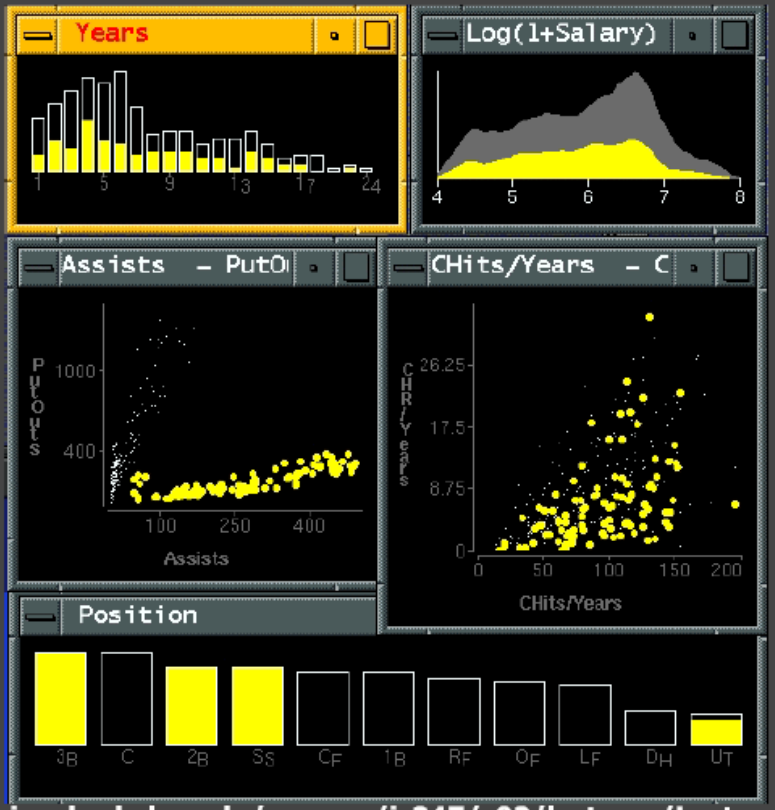
avg assists vs avg putouts (fielding ability)

avg career HRs vs avg career hits (batting ability)

distribution of positions played

[www.sims.berkeley.edu/courses/is247/s02/lectures/Lecture3.ppt]

Linking types of assist behavior to position played (from Wills 95)



[www.sims.berkeley.edu/courses/is247/s02/lectures/Lecture3.ppt]

More Reading

Visual information seeking: Tight coupling of dynamic query filters with starfield displays. Chris Ahlberg and Ben Shneiderman, Proc SIGCHI '94, pages 313–317. http://citeseer.ist.psu.edu/ahlberg94visual.html

Toolglass and magic lenses: the see-through interface
Eric A. Bier, Maureen C. Stone, Ken Pier, William Buxton, and Tony D. DeRose, Proc. SIGGRAPH'93, pp. 73–76. http://citeseer.nj.nec.com/bier93toolglass.html

Brushing Scatterplots, Becker and Cleveland
Technometrics, vol 29, pp 127–142, 1987
Reprinted in Dynamic Graphics for Data Analysis, edited by W. S. Cleveland and M. E. McGill, Chapman and Hall, New York, (1988)

Visual Exploration of Large Structured Databases, Graham J. Wills, in New Techniques and Trends in Statitics, pp 237–246, IOS Press 1995.