University of British Columbia
CPSC 314 Computer Graphics
Jan-Apr 2013

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Visualization

http://www.ugrad.cs.ubc.ca/~cs314/Vjan2013

Nonspatial/Information Visualization

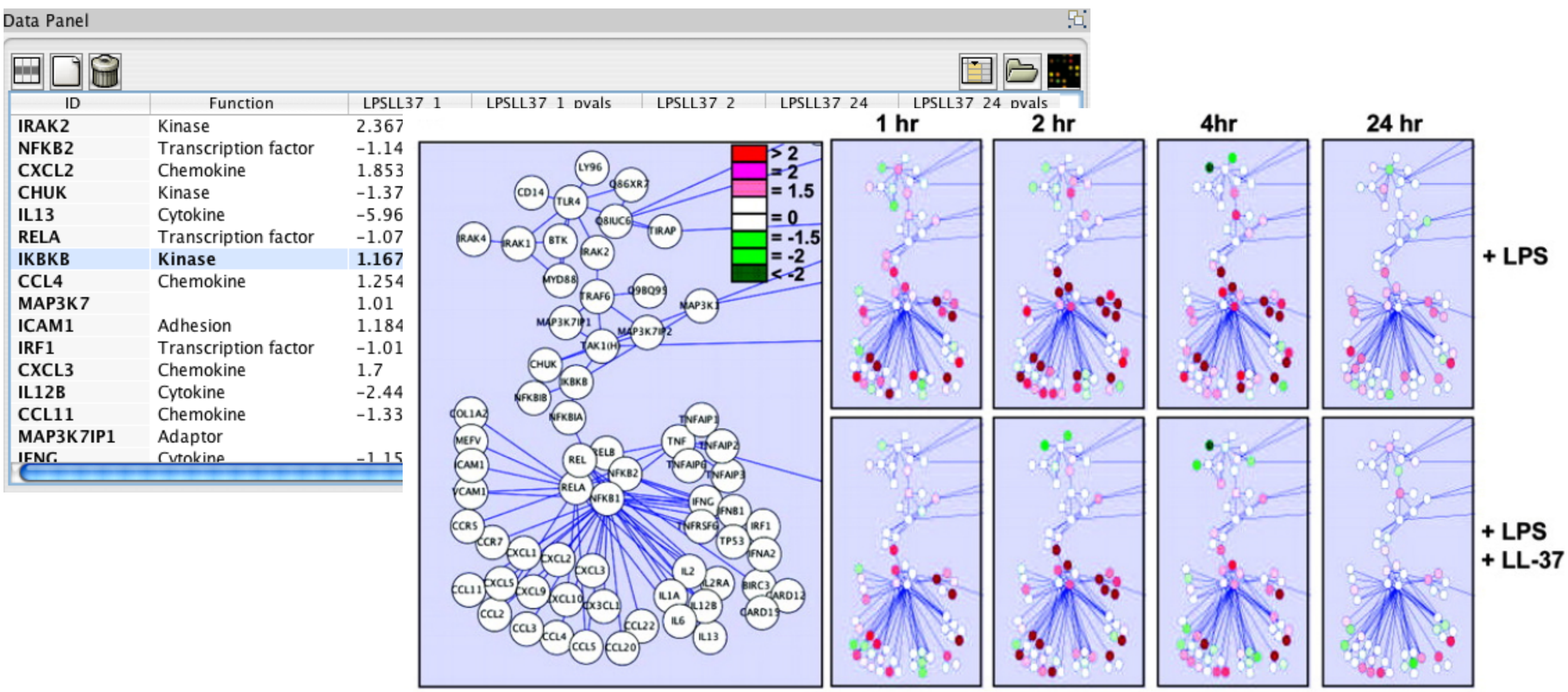
Reading

- FCG Chap 27
  - N/A 2nd edition, available online at

    http://www.cs.ubc.ca/labs/imager/tr/2009/VisChapter

Why Do Visualization?

- pictures help us think
  - substitute perception for cognition
  - external memory: free up limited cognitive/memory resources for higher-level problems



Information Visualization

- interactive visual representation of abstract data
  - help human perform some task more effectively
- bridging many fields
  - computer graphics: interact in realtime
  - cognitive psychology: find appropriate representation
  - HCI: use task to guide design and evaluation
- external representation
  - reduces load on working memory
  - offload cognition
  - familiar example: multiplication/division
  - infovis example: topic graphs

External Representation: Topic Graphs

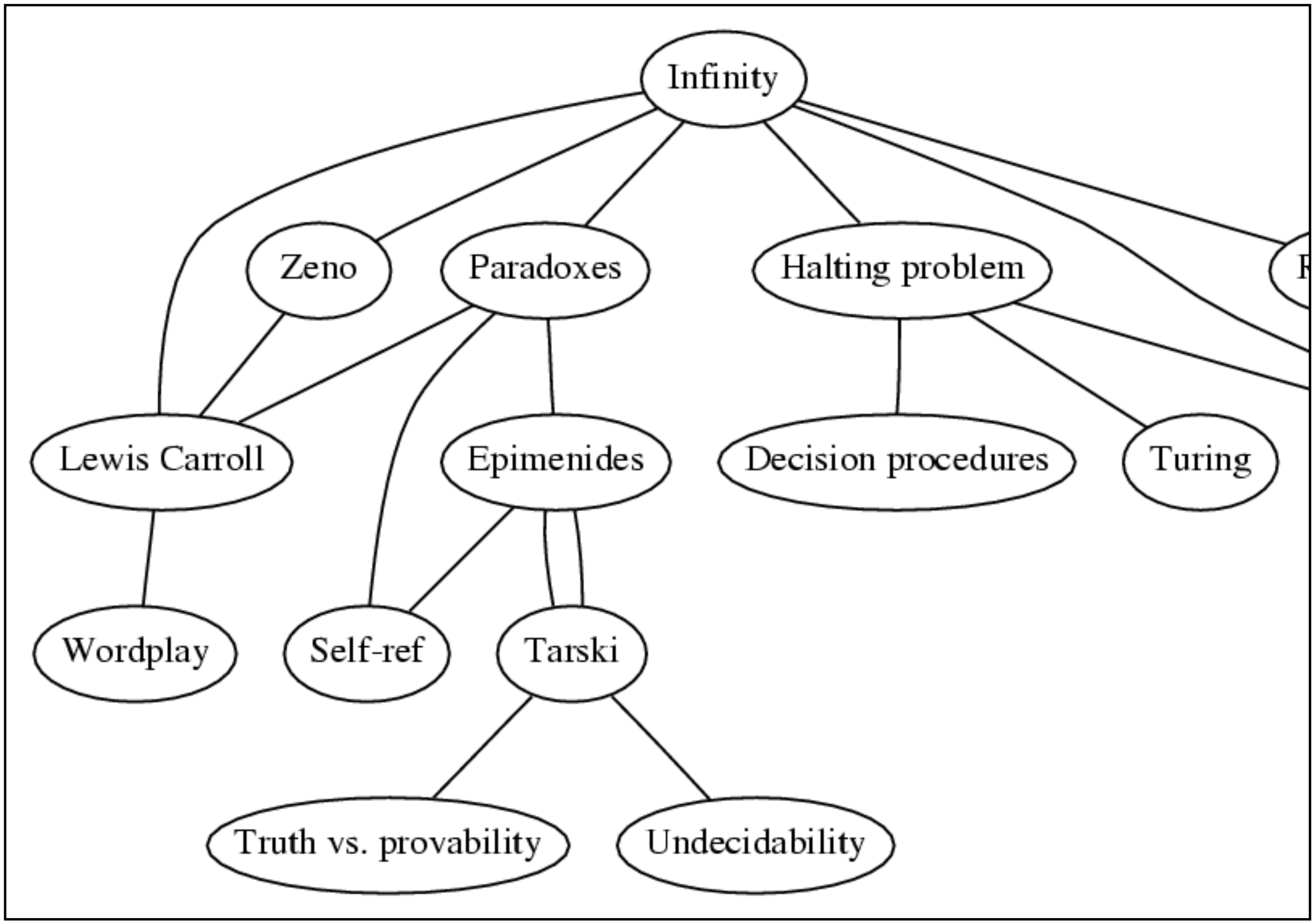
- hard to find topics two hops away from target

[Godel, Escher, Bach: The Eternal Golden Braid. Hofstadter 1979]

- **Paradoxes** - Lewis Carroll
- Turing - Halting problem
- Halting problem - Infinity
- Paradoxes - Infinity
- Infinity - Lewis Carroll
- Infinity - Unpredictably long searches
- Infinity - Recursion
- Infinity - Zeno
- Infinity - Paradoxes
- Lewis Carroll - Zeno
- Lewis Carroll - Wordplay
- Halting problem - Decision procedures
- BlooP and FlooP - AI
- Halting problem - Unpredictably long searches
- BlooP and FlooP - Unpredictably long searches
- BlooP and FlooP - Recursion
- Tarski - Truth vs. provability
- Tarski - Epimenides
- Tarski - Undecidability
- Paradoxes - Self-ref
- [...]

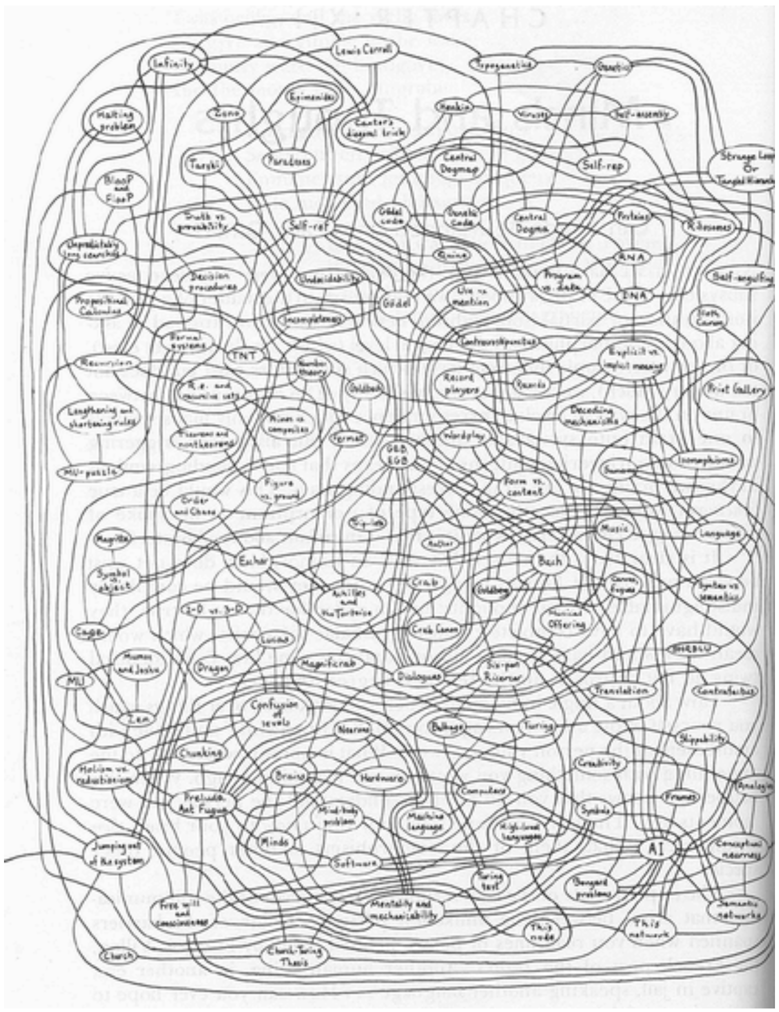
External Representation: Topic Graphs

- offload cognition to visual system



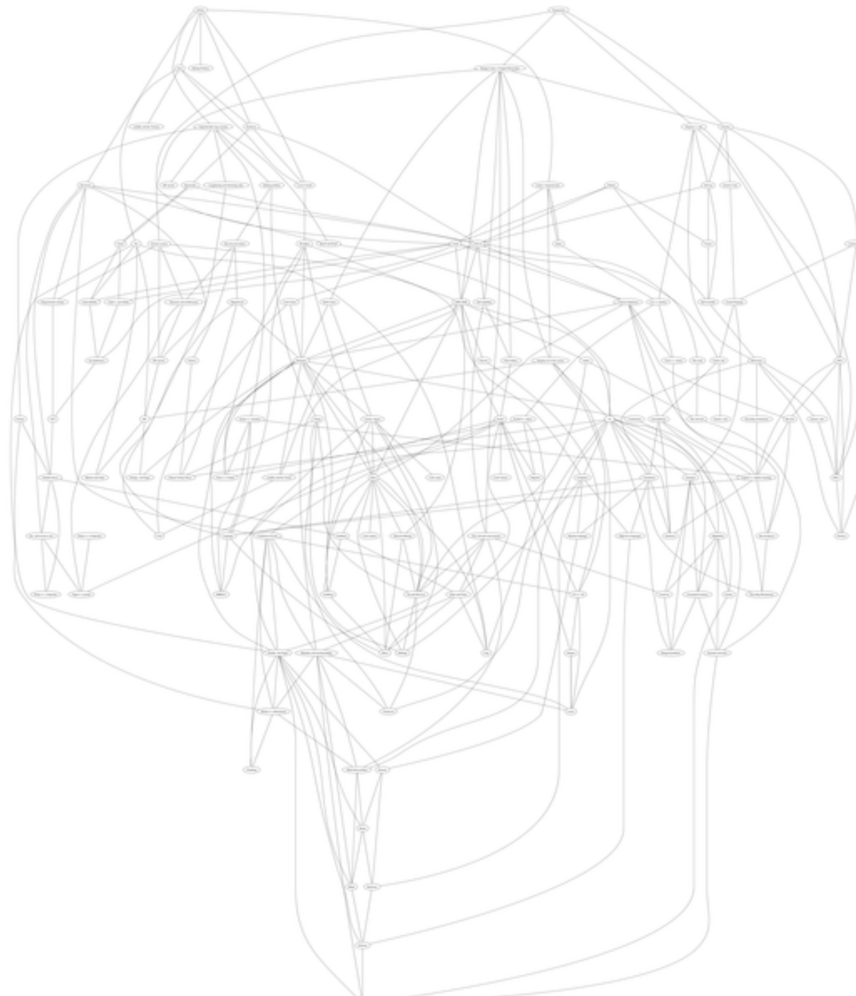
Automatic Node-Link Graph Layout

- manual: hours, days



[Godel, Escher, Bach. Hofstadter 1979]

- automatic: seconds



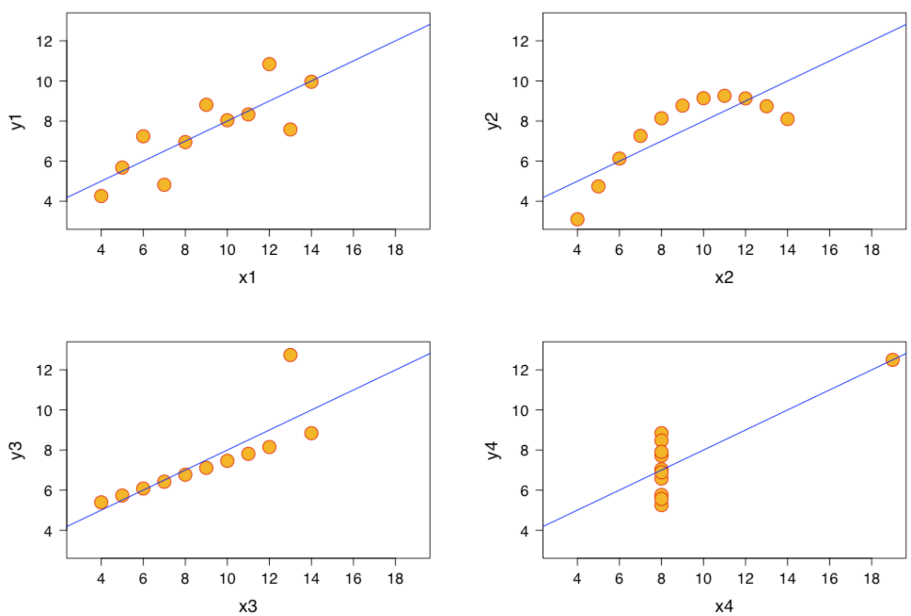
[dot, Gansner et al, 1973.]

When To Do Vis?

- need a human in the loop
  - augment, not replace, human cognition
  - for problems that cannot be (completely) automated
- simple summary not adequate
  - statistics may not adequately characterize complexity of dataset distribution

Anscombe's quartet: same

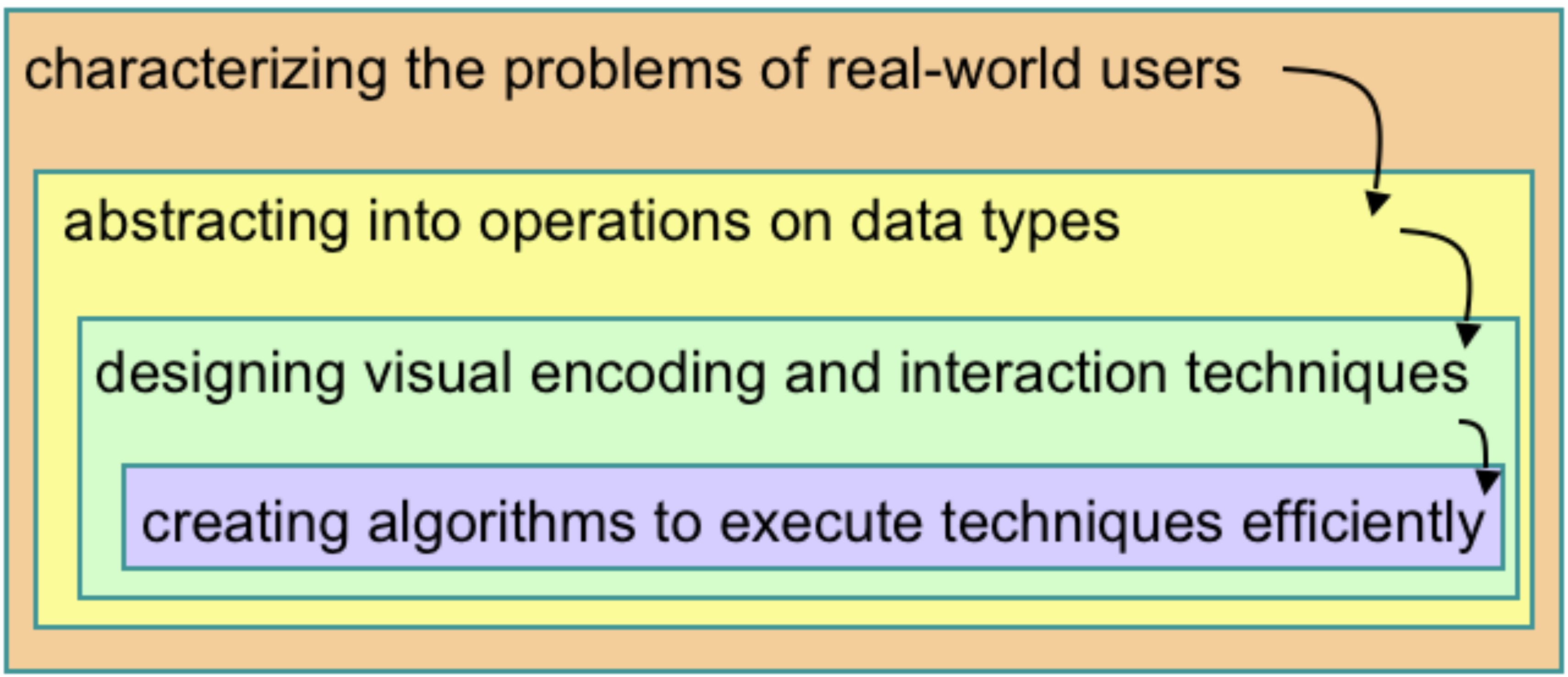
- mean
- variance
- correlation coefficient
- linear regression line



http://upload.wikimedia.org/wikipedia/commons/b/b6/Anscombe.svg

Visualization Design Layers

- depends on both data and task



Visual Encoding

marks: geometric primitives

points lines areas

attributes

position

size

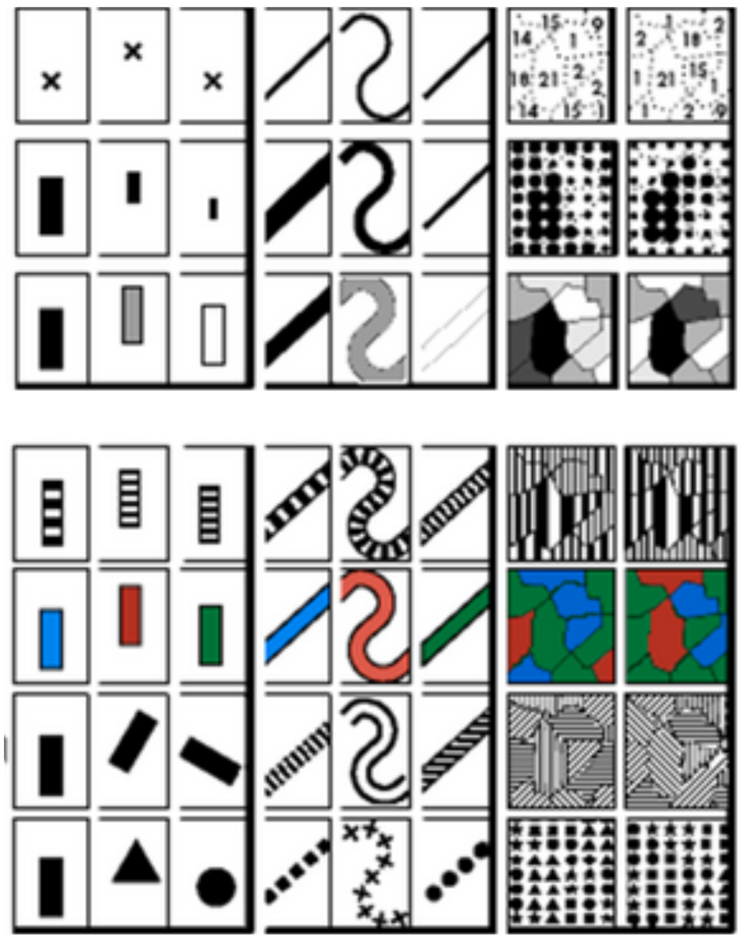
grey level

texture

color

orientation

shape

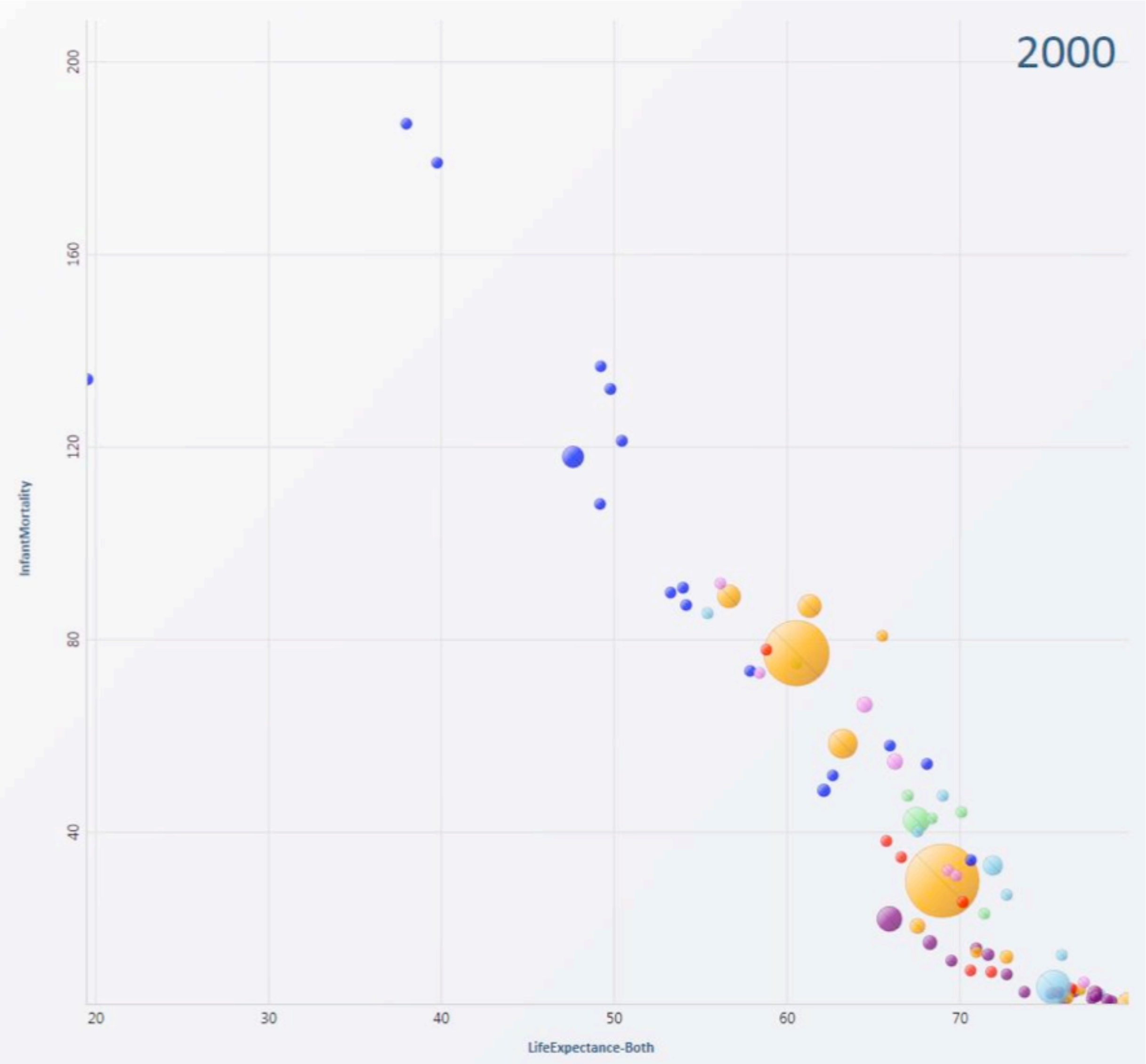


- attributes
  - parameters control mark appearance
  - separable channels flowing from retina to brain

Semiology of Graphics. Jacques Bertin, Gauthier-Villars 1967, EHESS 1998

Visual Encoding Example: Scatterplot

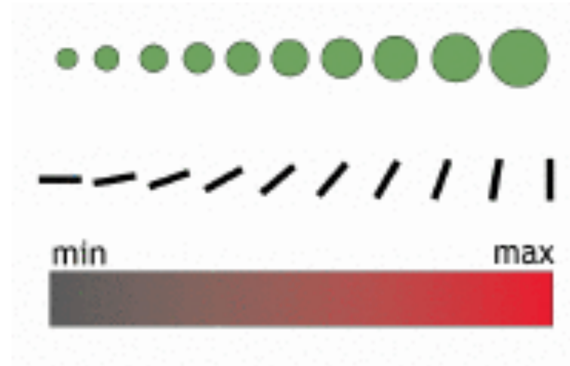
- x position
- y position
- hue
- size



Robertson et al. Effectiveness of Animation in Trend Visualization. IEEE TVCG (Proc. InfoVis08) 14:6 (2008), 1325–1332.

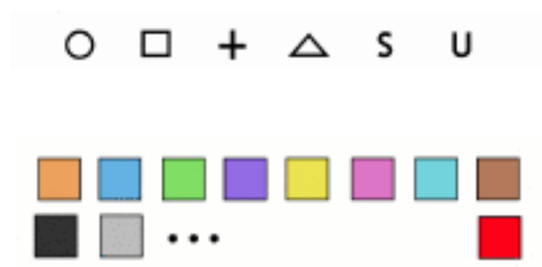
Data Types

- quantitative
  - lengths: 10 inches, 17 inches, 23 inches



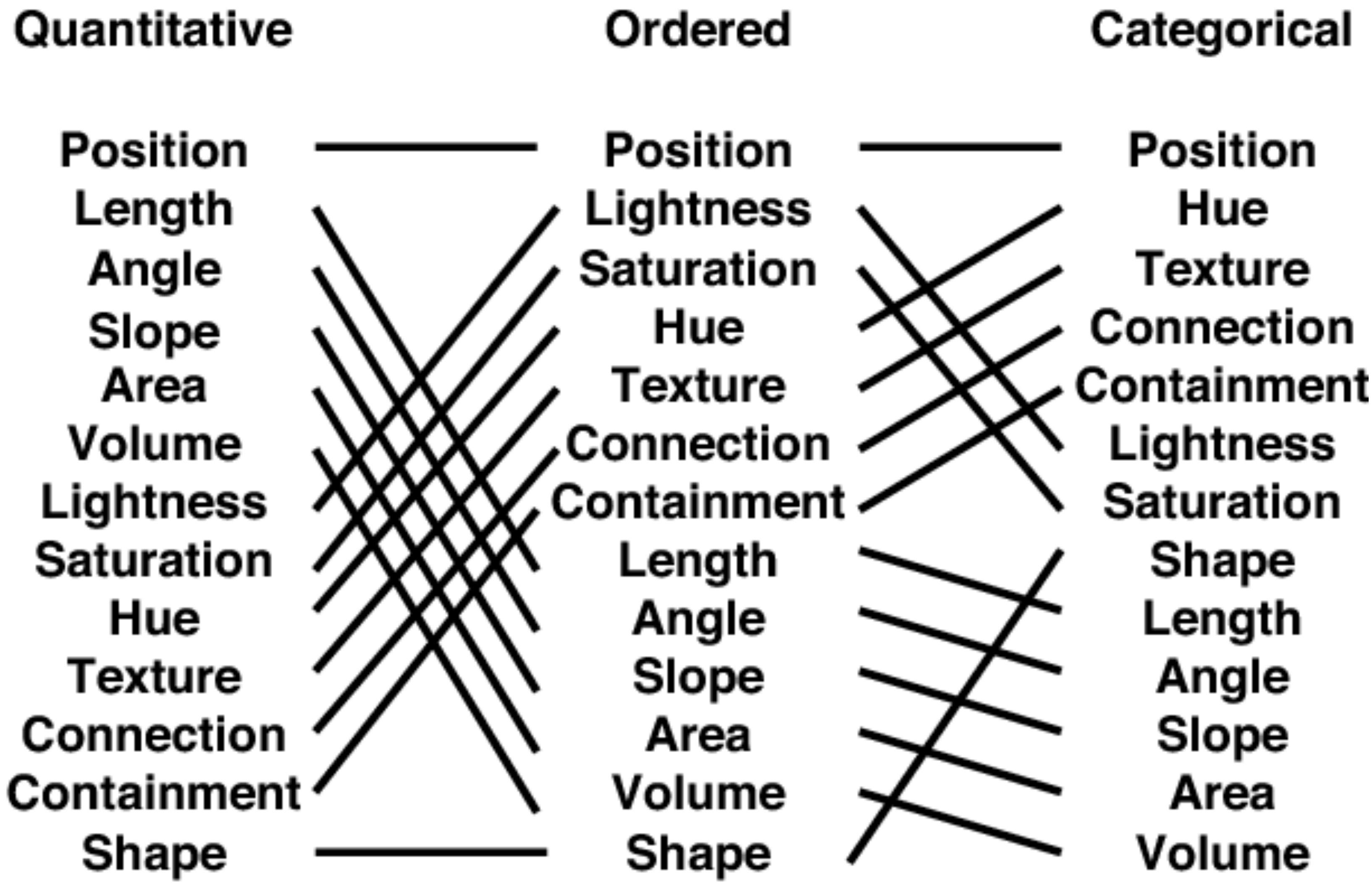
- ordered
  - sizes: small, medium, large
  - days: Mon, Tue, Wed, ...

- categorical
  - fruit: apples, oranges, bananas



[Stolte and Hanrahan. Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Proc InfoVis 2000. graphics.stanford.edu/projects/polaris/]

Channel Ranking Varies By Data Type



[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]

Integral vs. Separable Dimensions

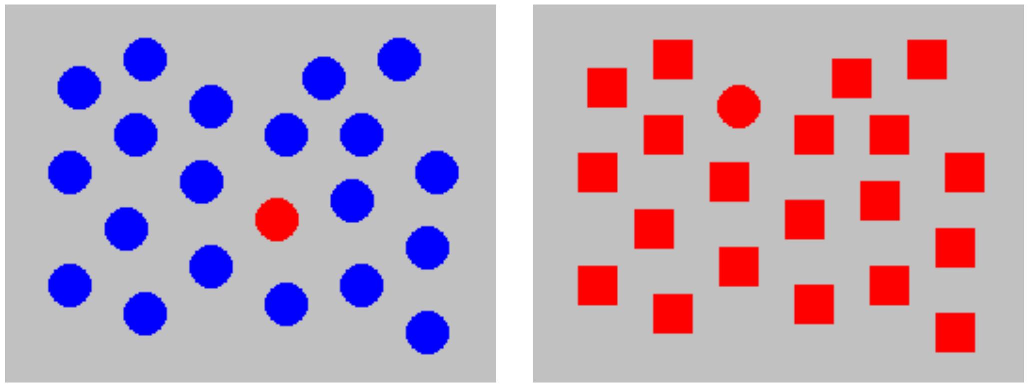
- not all dimensions separable

color location | color motion | color shape | size orientation | x-size y-size | red-green yellow-blue

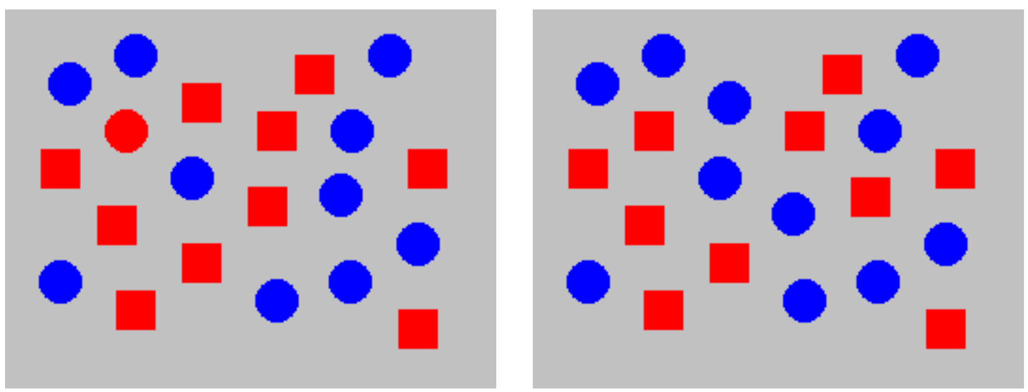
[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

Preattentive Visual Channels

- color alone, shape alone: preattentive



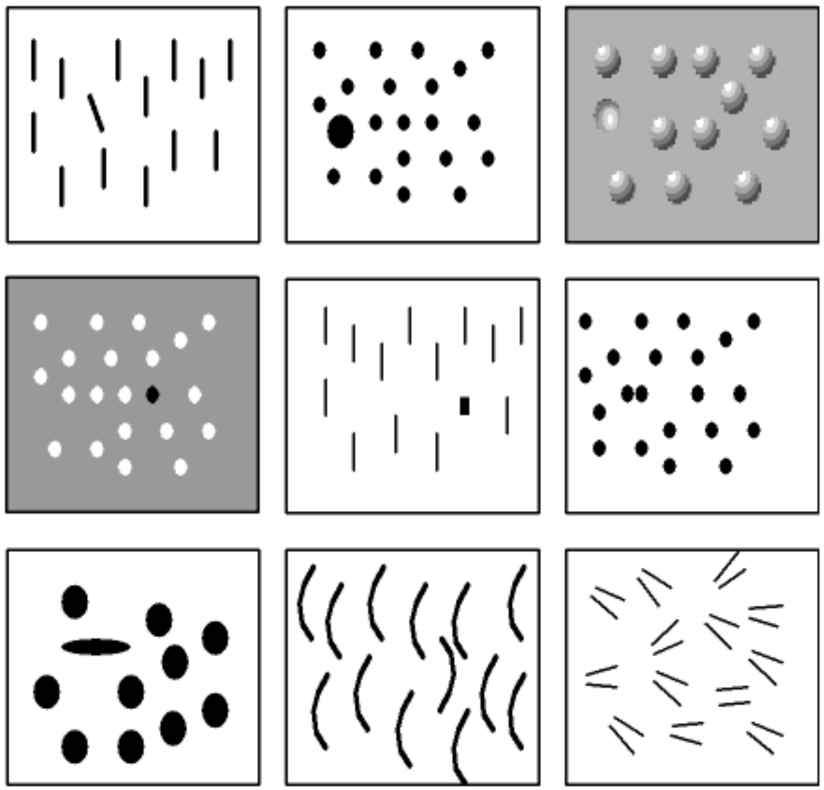
- combined color and shape: requires attention
  - search speed linear with distractor count



[Christopher Healey, [www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive Visual Channels

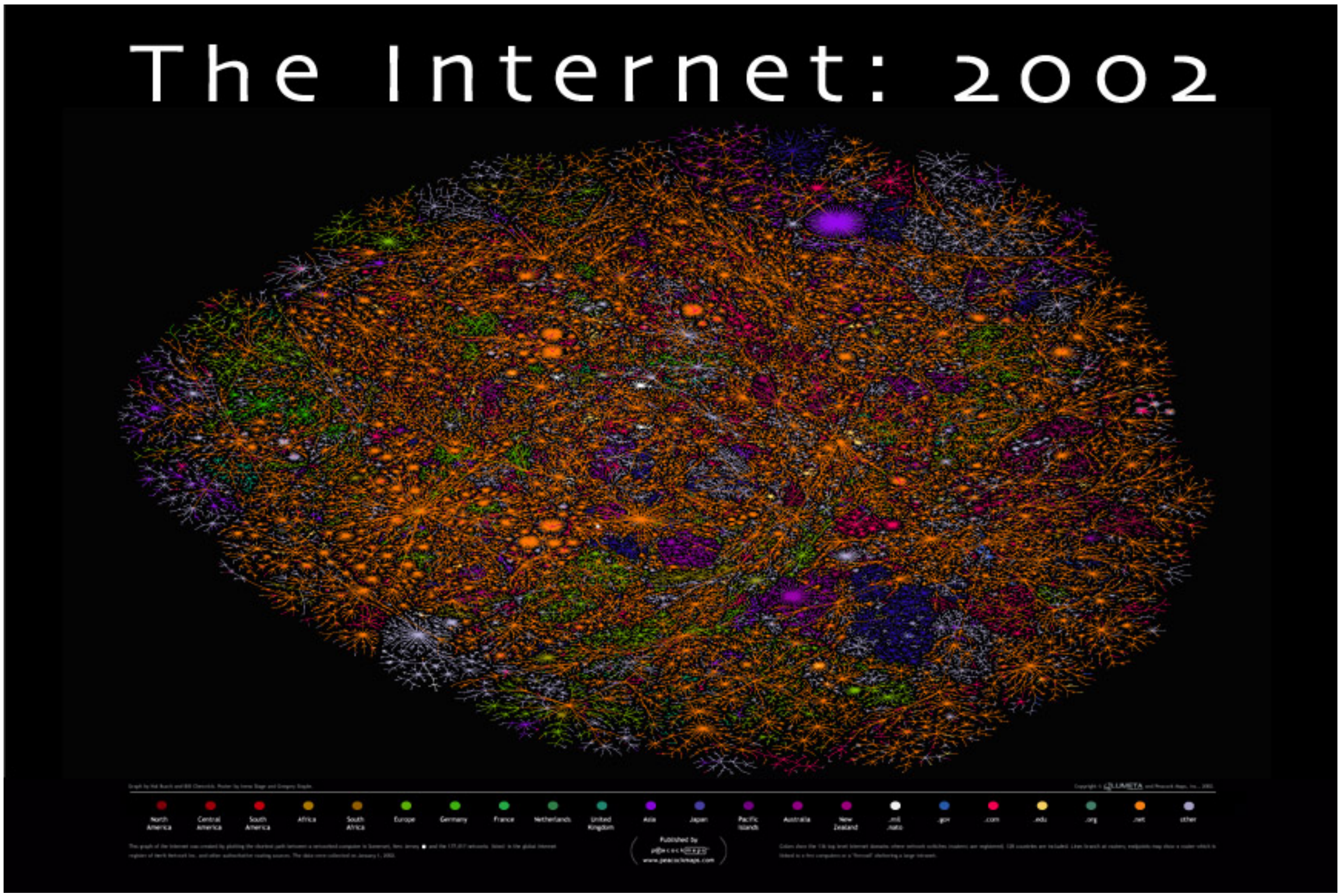
- preattentive channels include
  - hue
  - shape
  - texture
  - length
  - width
  - size
  - orientation
  - curvature
  - intersection
  - intensity
  - flicker
  - direction of motion
  - stereoscopic depth
  - lighting direction
  - many more...



[Healey, [www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Coloring Categorical Data

- 22 colors, but only ~8 distinguishable



[www.peacockmaps.com, research.lumeta.com/ches/map]

Coloring Categorical Data

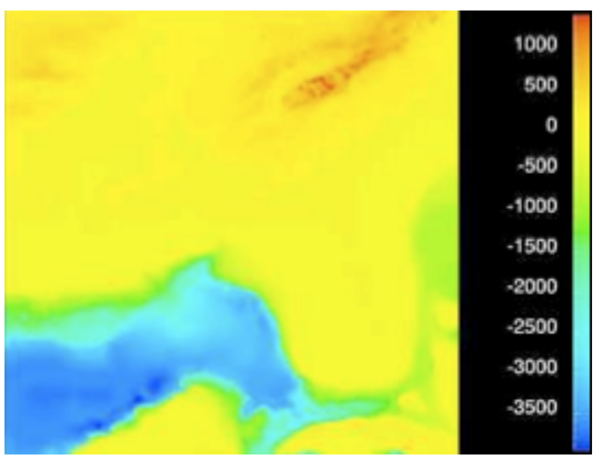
- discrete small patches separated in space
- limited distinguishability: around 8-14
  - channel dynamic range low
  - best to choose bins explicitly
- maximal saturation for small areas

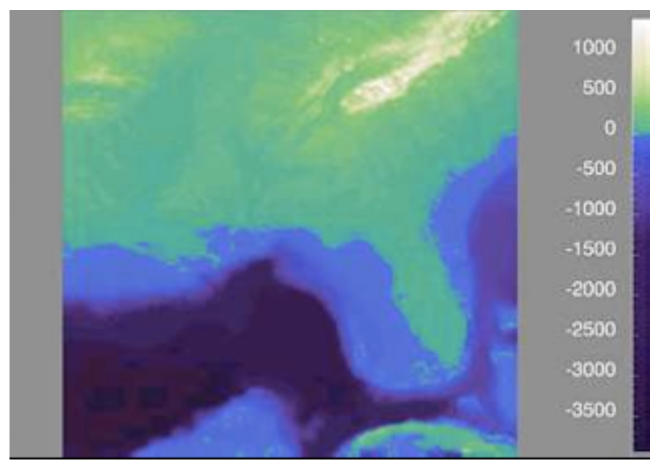
[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

Quantitative Colormaps

- dangers of rainbows
  - perceptually nonlinear
  - arbitrary not innate ordering

- other approaches
  - explicitly segmented colormaps
  - monotonically increasing/(decreasing) luminance, plus hue to semantically distinguish regions

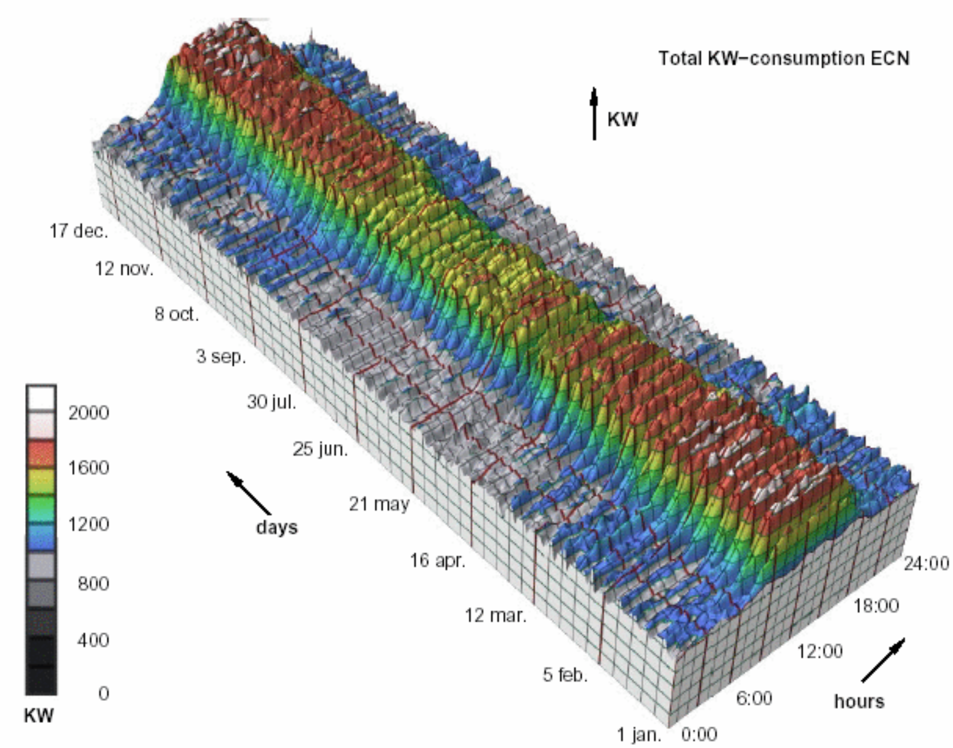


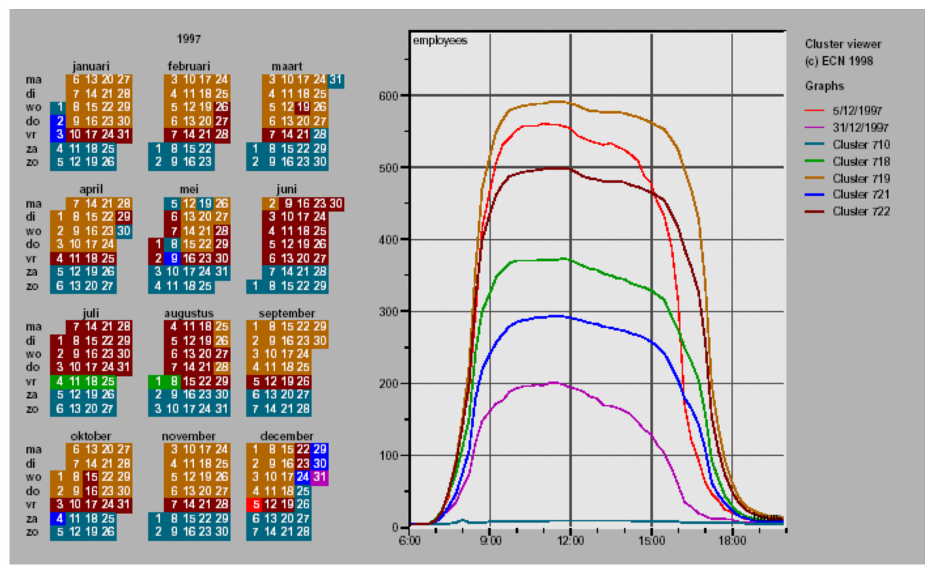


Rogowitz and Treinish. Data Visualization: The End of the Rainbow. IEEE Spectrum 35(12):52-59, Dec 1998.

3D vs 2D Representations

- curve comparison difficult: perspective distortion, occlusion
  - dataset is abstract, not inherently spatial
  - after data transformation to clusters, linked 2D views of representative curves show more

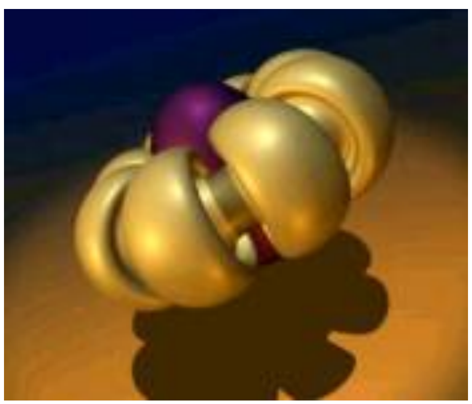


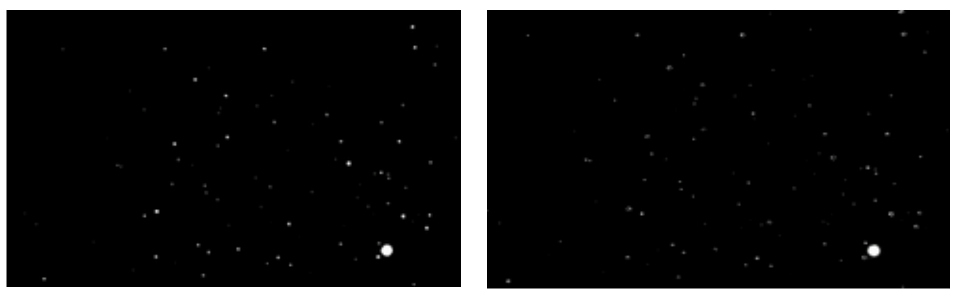


[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, InfoVis99

Space vs Time: Showing Change

- animation: show time using temporal change
  - good: show process
  - good: flip between two things
  - bad: flip between between many things
    - interference between intermediate frames

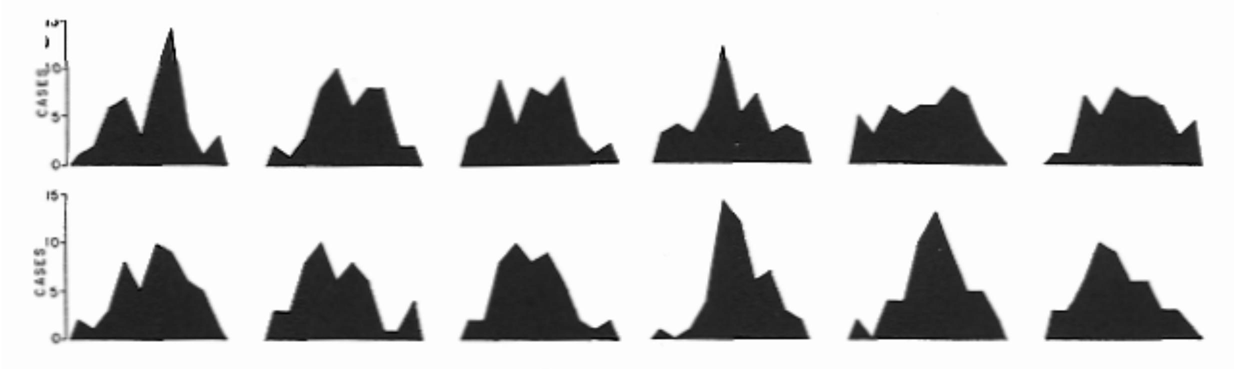




[Outside In excerpt. www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]
[www.astroshow.com/ccdpho/pluto.gif]
[Edward Tufte. The Visual Display of Quantitative Information, p 172]

Space vs Time: Showing Change

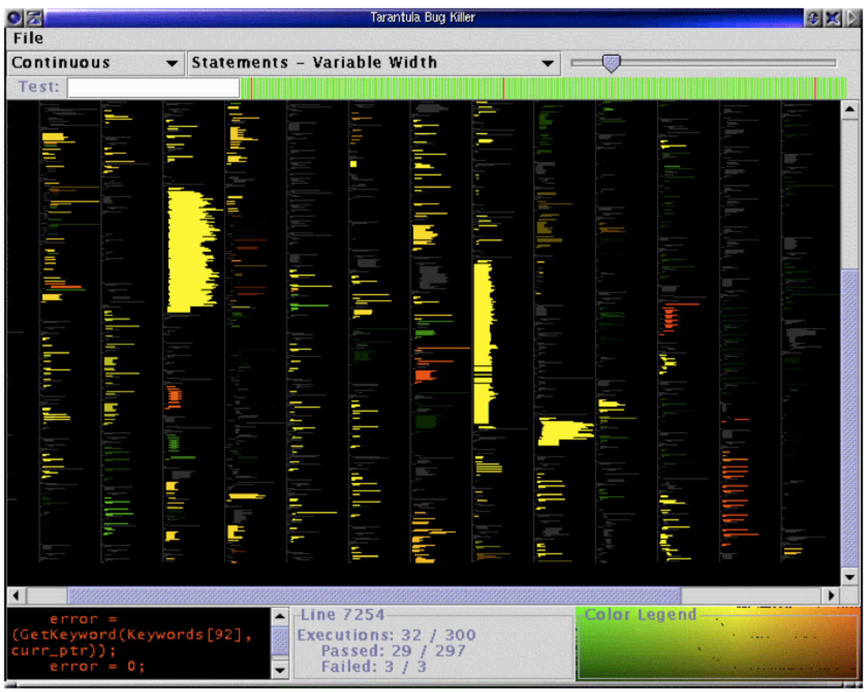
- small multiples: show time using space
  - overview: show each time step in array
  - compare: side by side easier than temporal
    - external cognition vs internal memory
  - general technique, not just for temporal changes



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

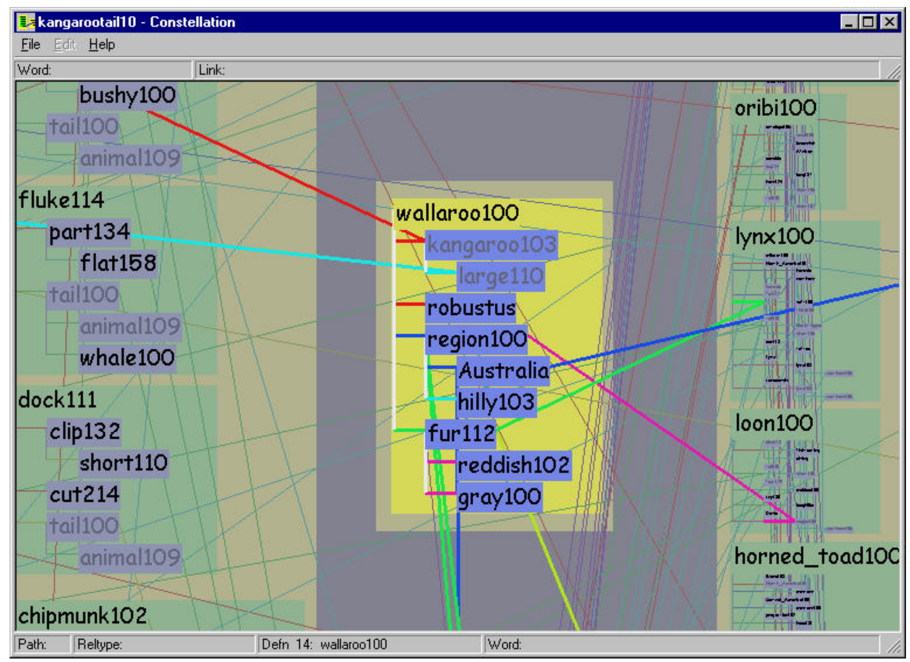
Composite Views

- pixel-oriented views
  - overviews with high information density



[Jones, Harrold, and Stasko. Visualization of Test Information to Assist Fault Localization. Proc. ICSE 2002, p 467-477.]

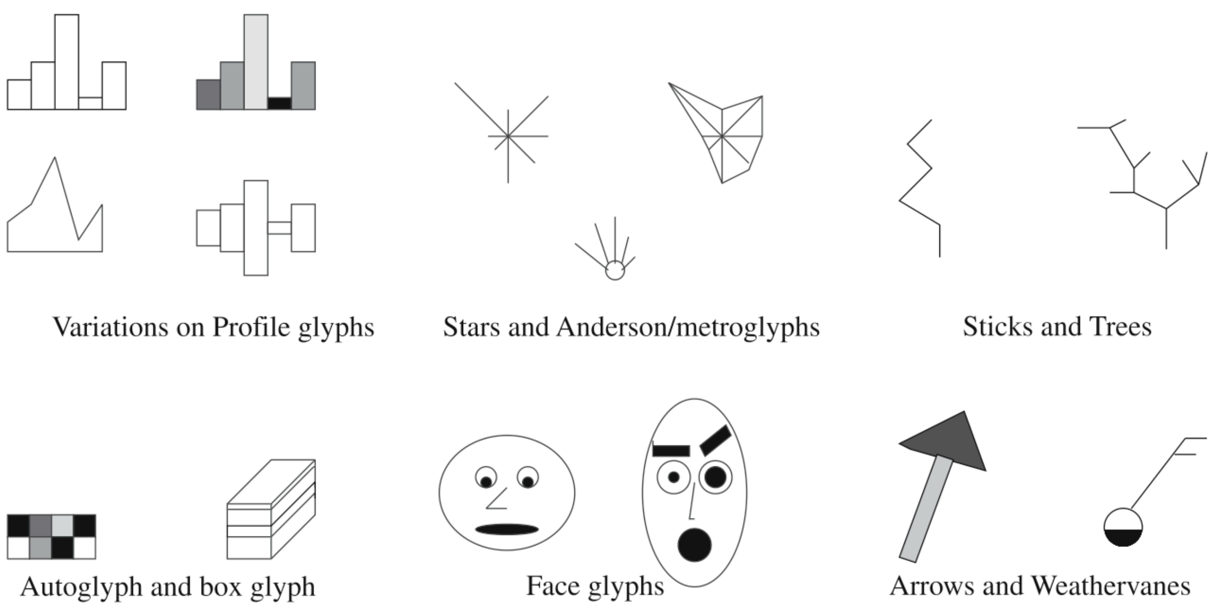
- superimposing/layering
  - shared coordinate frame
  - redundant visual encoding

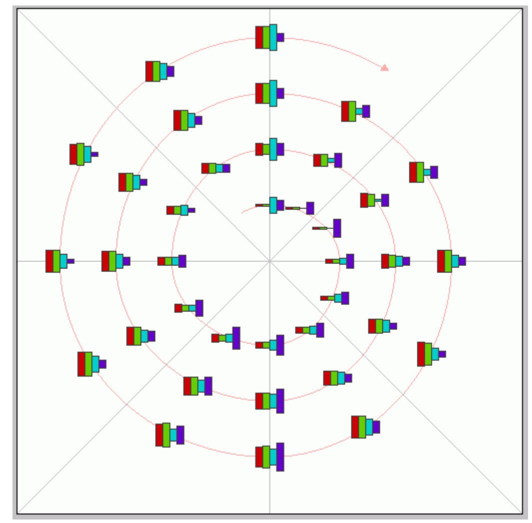


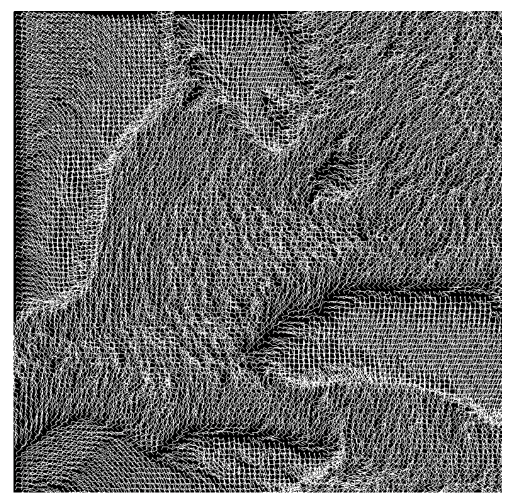
[Munzner. Interactive Visualization of Large Graphs and Networks. Stanford CS, 2000]

Composite Views: Glyphs

- internal structure where subregions have different visual channel encodings





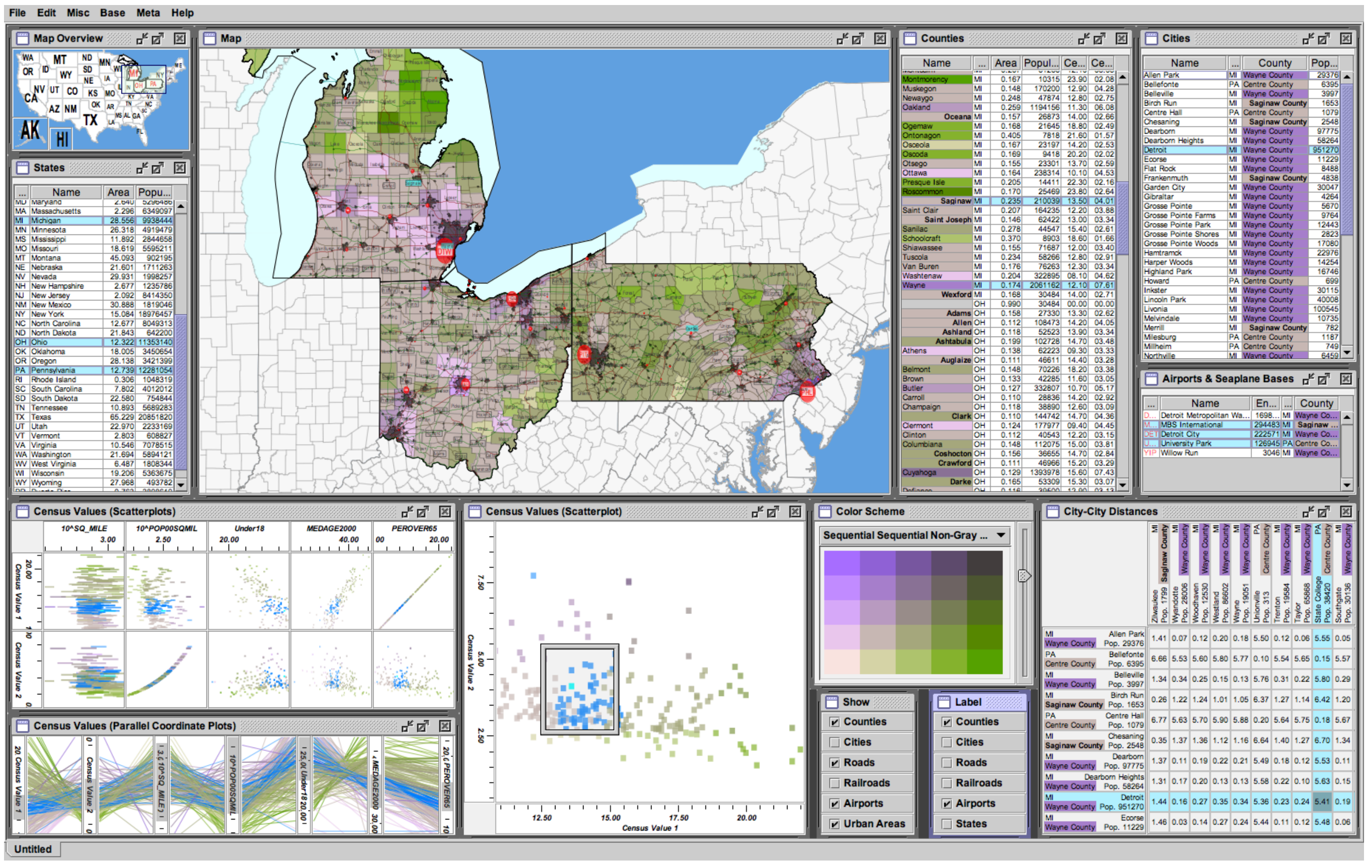


[Ward. A Taxonomy of Glyph Placement Strategies for Multidimensional Data Visualization. Information Visualization Journal 1:3-4 (2002), 194--210.]

[Smith, Grinstein, and Bergeron. Interactive data exploration with a supercomputer. Proc. IEEE Visualization, p 248-254, 1991.]

Adjacent: Multiple Views

- different visual encodings show different aspects of the data
- linked highlighting to show where contiguous in one view distributed within another



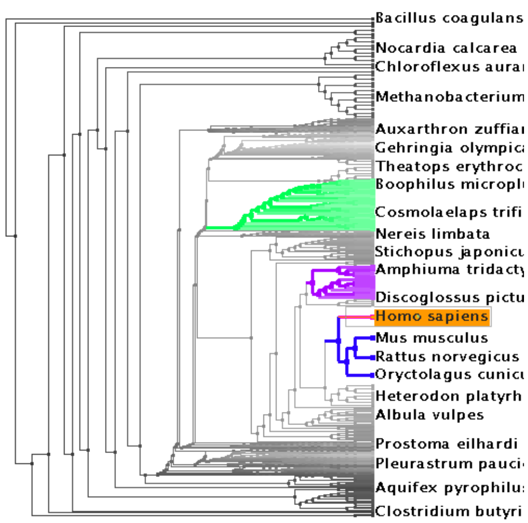
[Weaver. http://www.personal.psu.edu/cew15/improvise/examples/census]

Adjacent Views

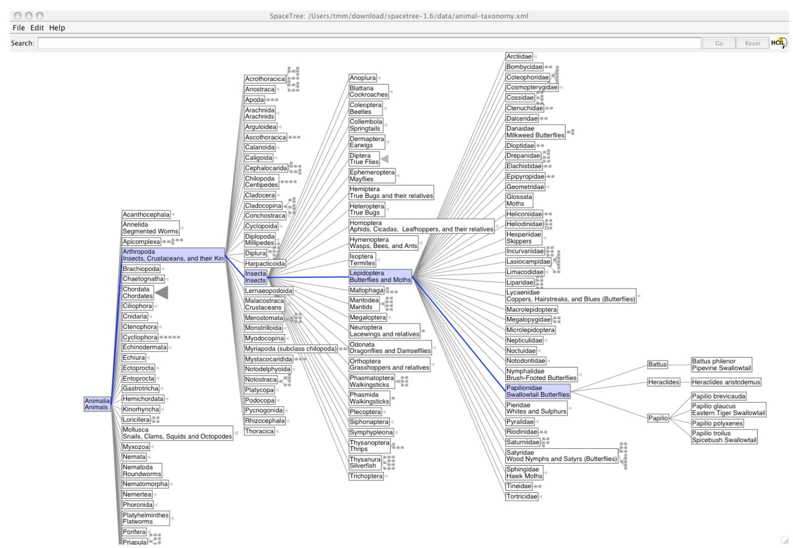
- overview and detail
  - same visual encoding, different resolutions
- small multiples
  - same visual encoding, different data

Data Reduction

- overviews as aggregation
- focus+context
  - show details embedded within context
    - distortion: TreeJuxtaposer video
    - filtering: SpaceTree demo



[Munzner et al. TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility. Proc SIGGRAPH 2003, p 453-462]



[Plaisant, Grosjean, and Bederson. SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Proc. InfoVis 2002

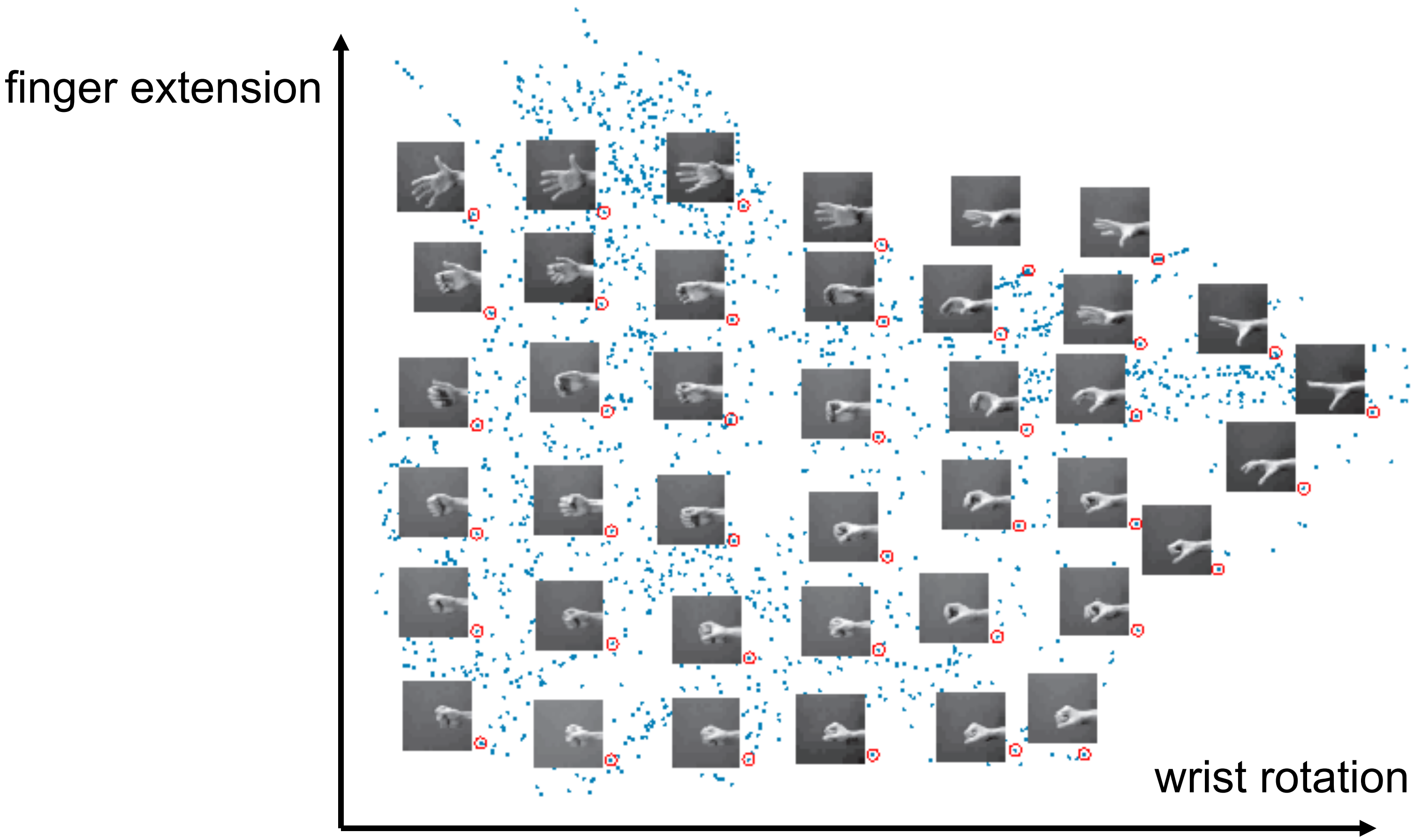
Dimensionality Reduction

- mapping from high-dimensional space into space of fewer dimensions
  - generate new synthetic dimensions

- why is lower-dimensional approximation useful?
  - assume **true/intrinsic** dimensionality of dataset is (much) lower than measured dimensionality!
    - only indirect measurement possible?
      - fisheries: want spawn rates.
        have water color, air temp, catch rates...
    - sparse data in verbose space?
      - documents: word occurrence vectors.
        10K+ dimensions, want dozens of topic clusters

DR Example: Image Database

- 4096 D (pixels) to 2D (hand gesture)
  - no semantics of new synthetic dimensions from alg.
    - assigned by humans after inspecting results



[A Global Geometric Framework for Nonlinear Dimensionality Reduction. Tenenbaum, de Silva and Langford. *Science* 290 (5500): 2319-2323, 2000, isomap.stanford.edu]

DR Technique: MDS

- multidimensional scaling
  - minimize differences between interpoint distances in high and low dimensions
- minimize objective function: stress

$$stress(D,\Delta) = \sqrt{\frac{\sum_{ij}(d_{ij}-\delta_{ij})^2}{\sum_{ij}\delta_{ij}^2}}$$

D: matrix of lowD distances d_{ij}

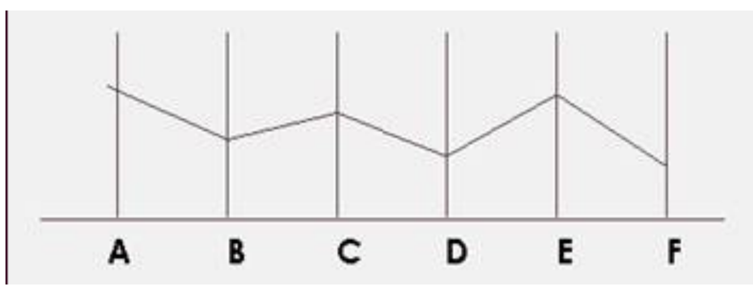
Δ: matrix of hiD distances δ_{ij}

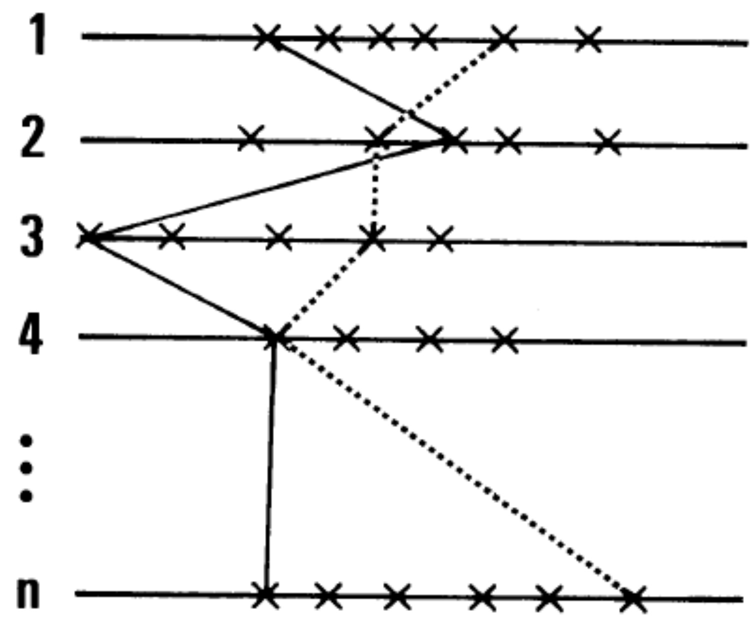
- Glimmer: MDS on the GPU

[Ingram, Munzner, Olano. Glimmer: Multiscale MDS on the GPU. IEEE TVCG 15(2):249-261, 2009.

Parallel Coordinates

- only two orthogonal axes in the plane
- instead, use parallel axes!

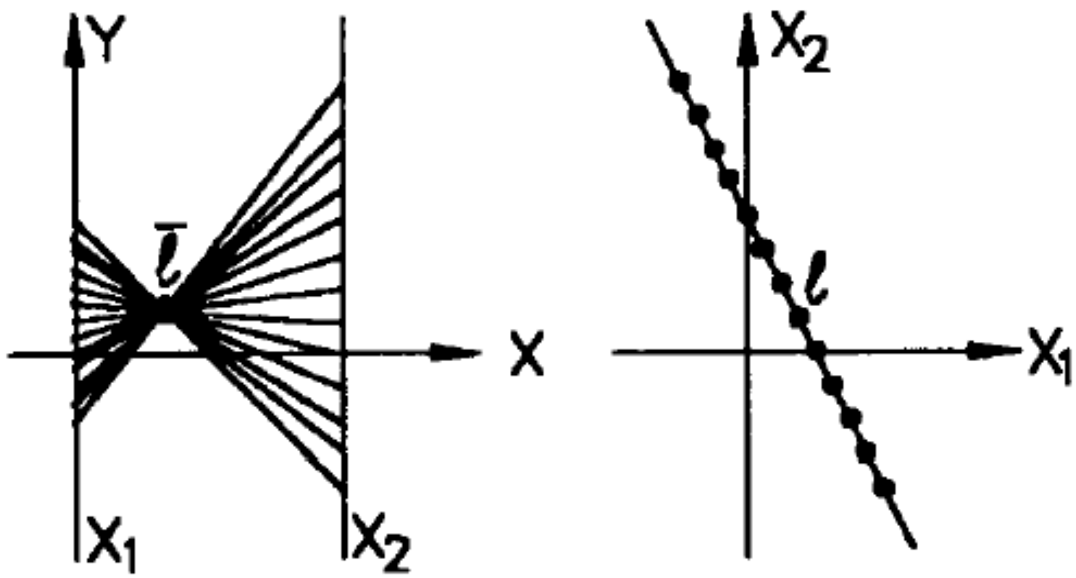




[Hyperdimensional Data Analysis Using Parallel Coordinates. Edward J. Wegman. Journal of the American Statistical Association, Vol. 85, No. 411. (Sep., 1990), pp. 664-675.]

Parallel Coordinates

- point in Cartesian coords is line in par coords
- point in par coords is line in Cartesian n-space



[Inselberg and Dimdale. Parallel Coordinates: A Tool for Visualizing Multi-Dimensional Geometry. IEEE Visualization '90.]

Par Coords: Correllation

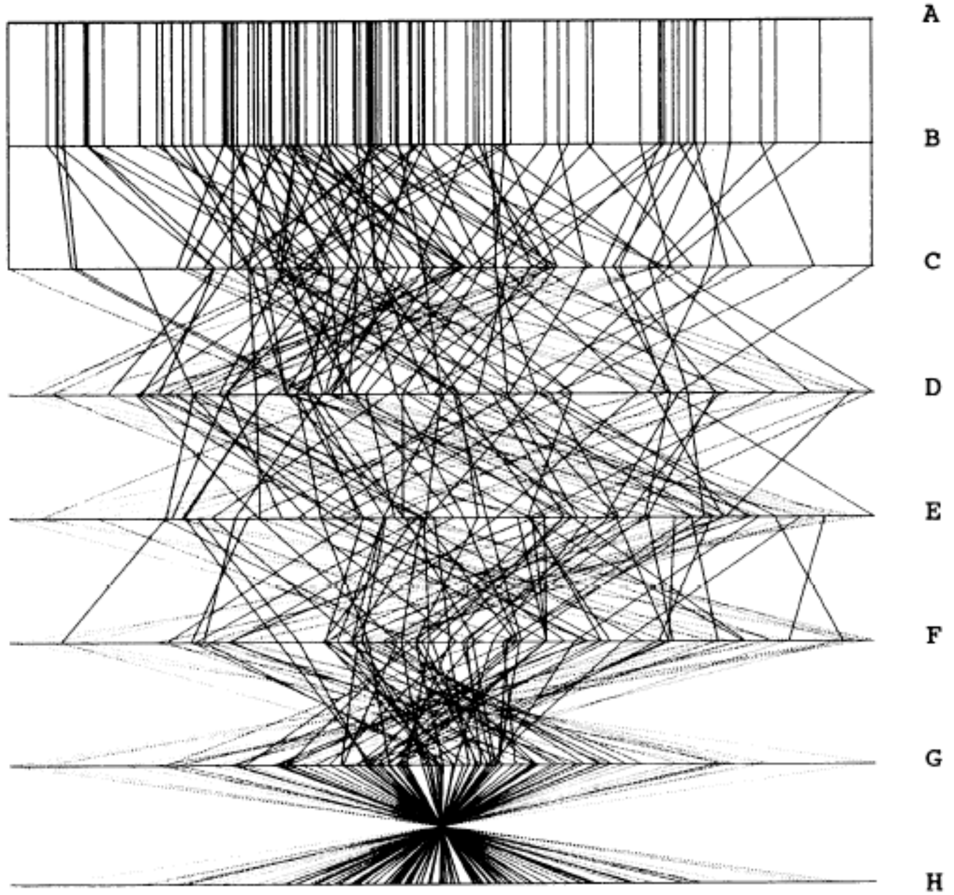
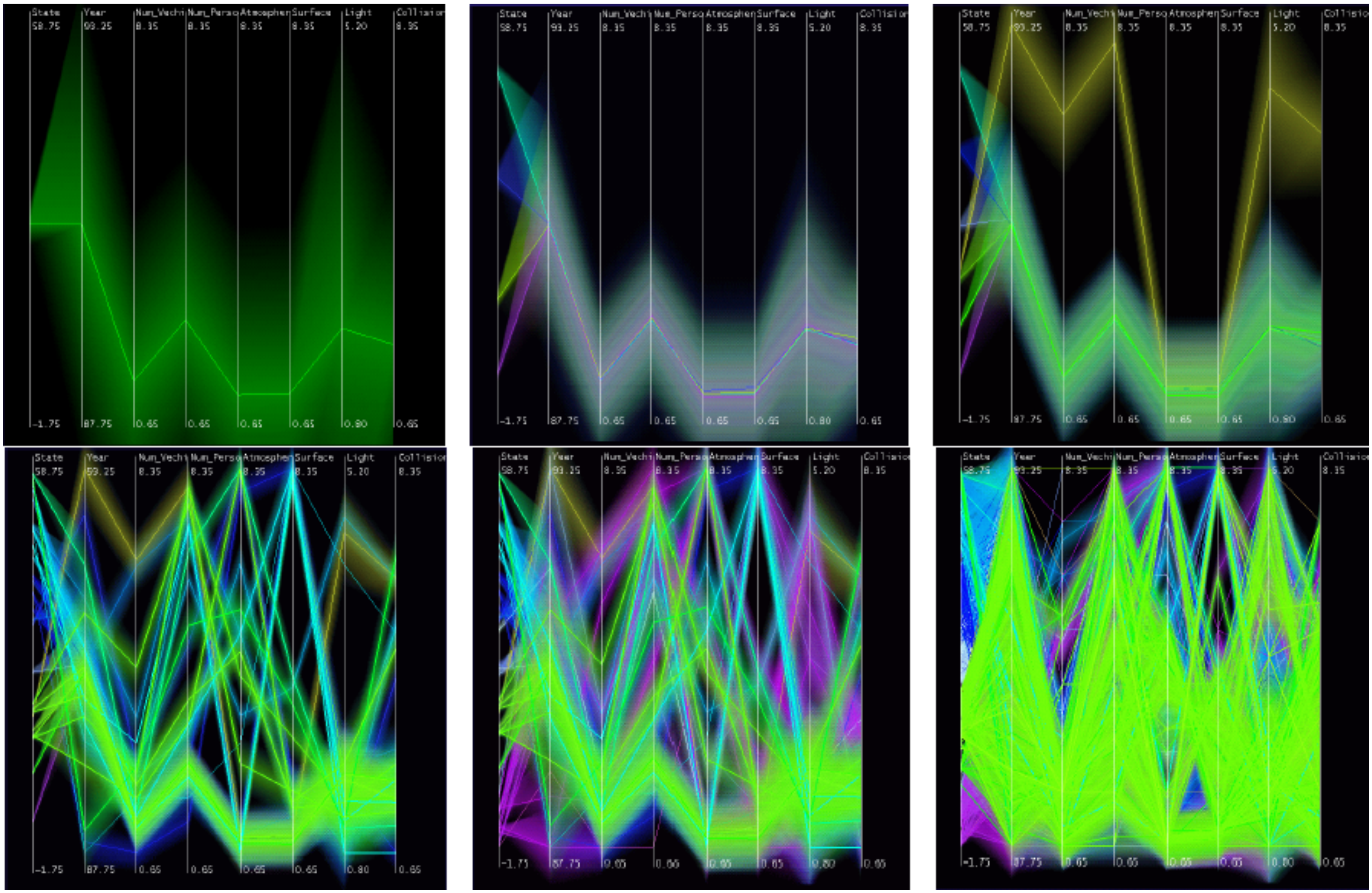


Figure 3. Parallel Coordinate Plot of Six-Dimensional Data Illustrating Correlations of ρ = 1, .8, .2, 0, −.2, −.8, and −1.

[Hyperdimensional Data Analysis Using Parallel Coordinates. Wegman. Journal of the American Statistical Association, Vol. 85, No. 411. (Sep., 1990), pp. 664-675.]

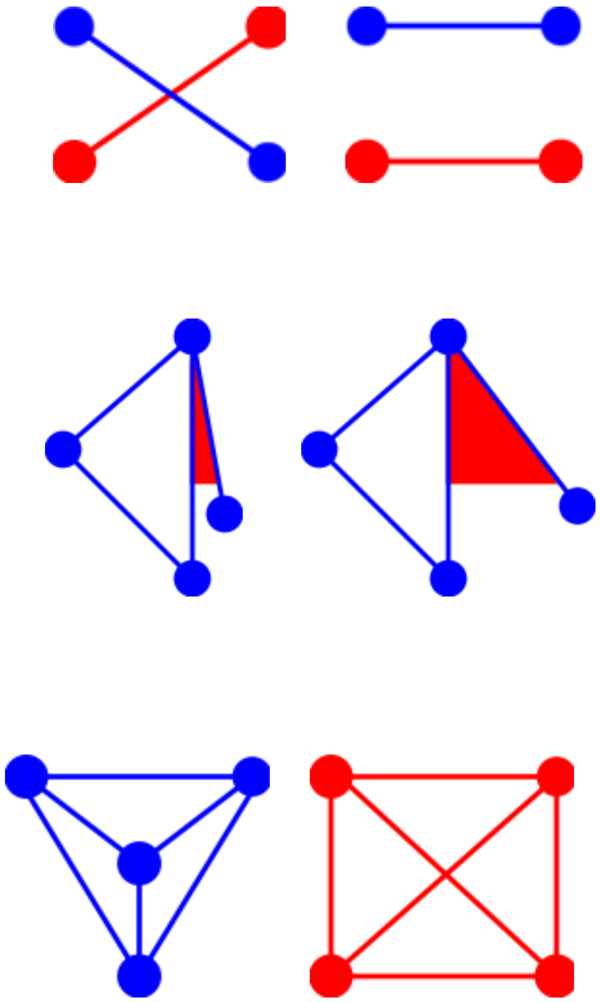
Hierarchical Parallel Coords: LOD



[Hierarchical Parallel Coordinates for Visualizing Large Multivariate Data Sets. Fua, Ward, and Rundensteiner. IEEE Visualization '99.]

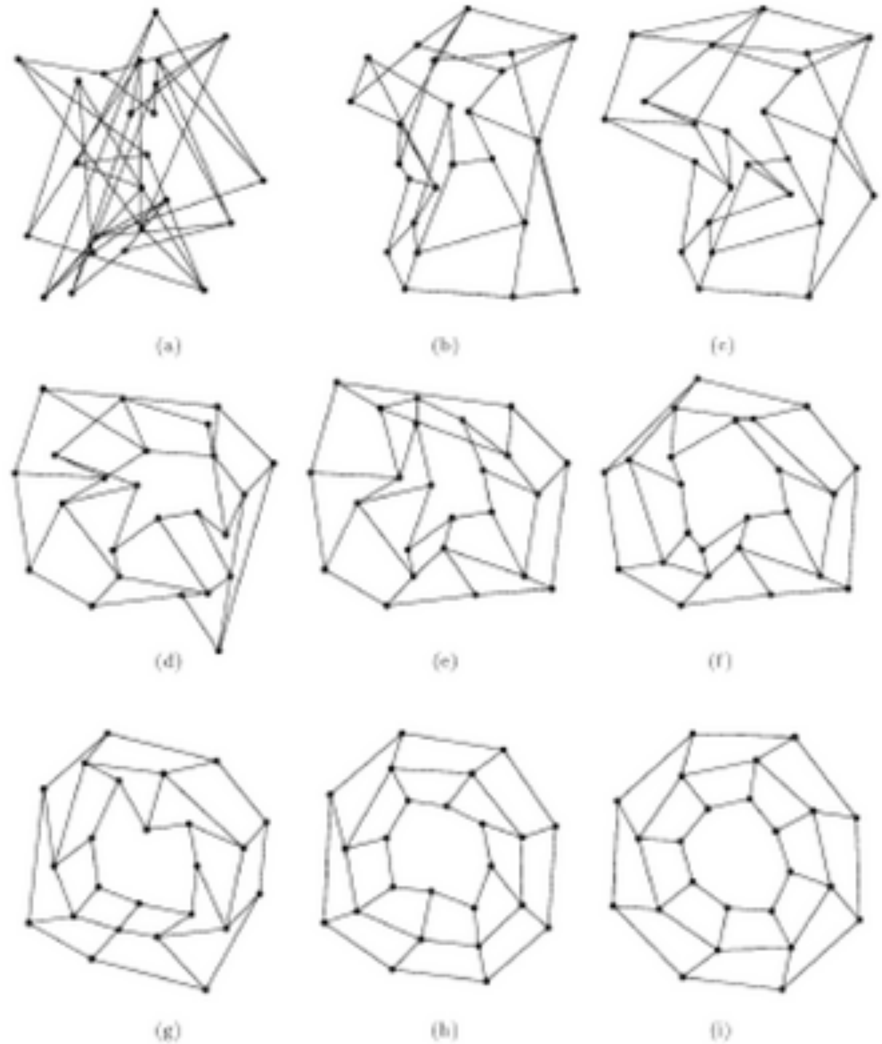
Node-Link Graph Layout

- minimize
  - crossings, area, bends/curves
- maximize
  - angular resolution, symmetry
- most criteria individually NP-hard
  - cannot just compute optimal answer
  - heuristics: try to find something reasonable
- criteria mutually incompatible



Force-Directed Placement

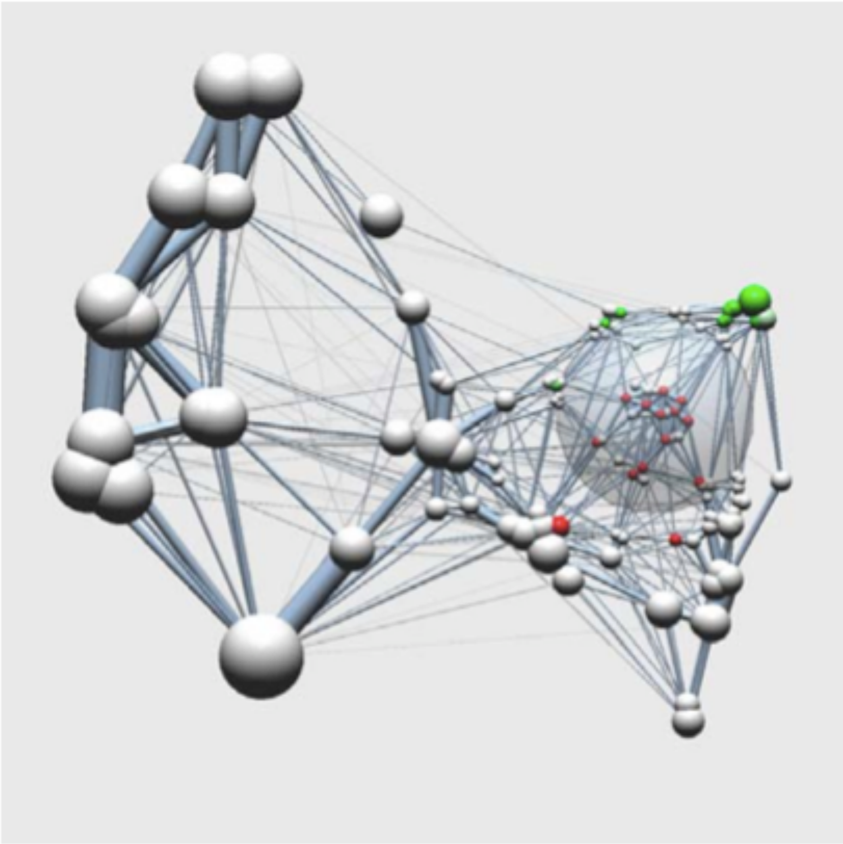
- nodes: repel like magnets
- edges: attract like springs
  - start from random positions, run to convergence
- very well studied area!
  - many people reinvent the wheel



[www.csse.monash.edu.au/~berndm/CSE460/Lectures/cse460-7.pdf]

Interactive Graph Exploration

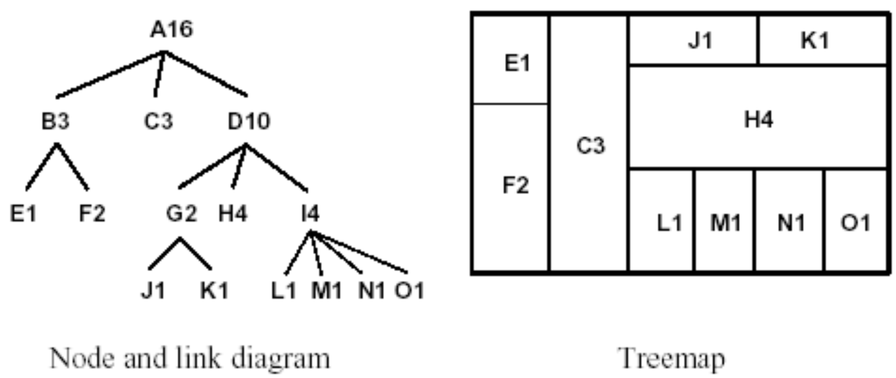
- geometric and semantic fisheye

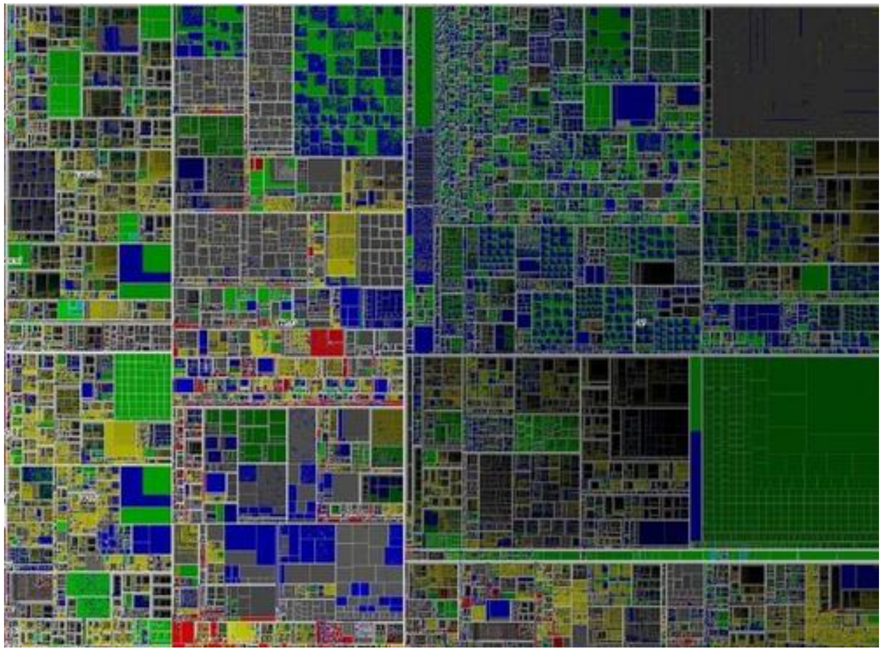


van Ham and van Wijk. Interactive Visualization of Small World Graphs. Proc. InfoVis 2005

Treemaps

- containment rather than connection
  - emphasize node attributes, not topological structure



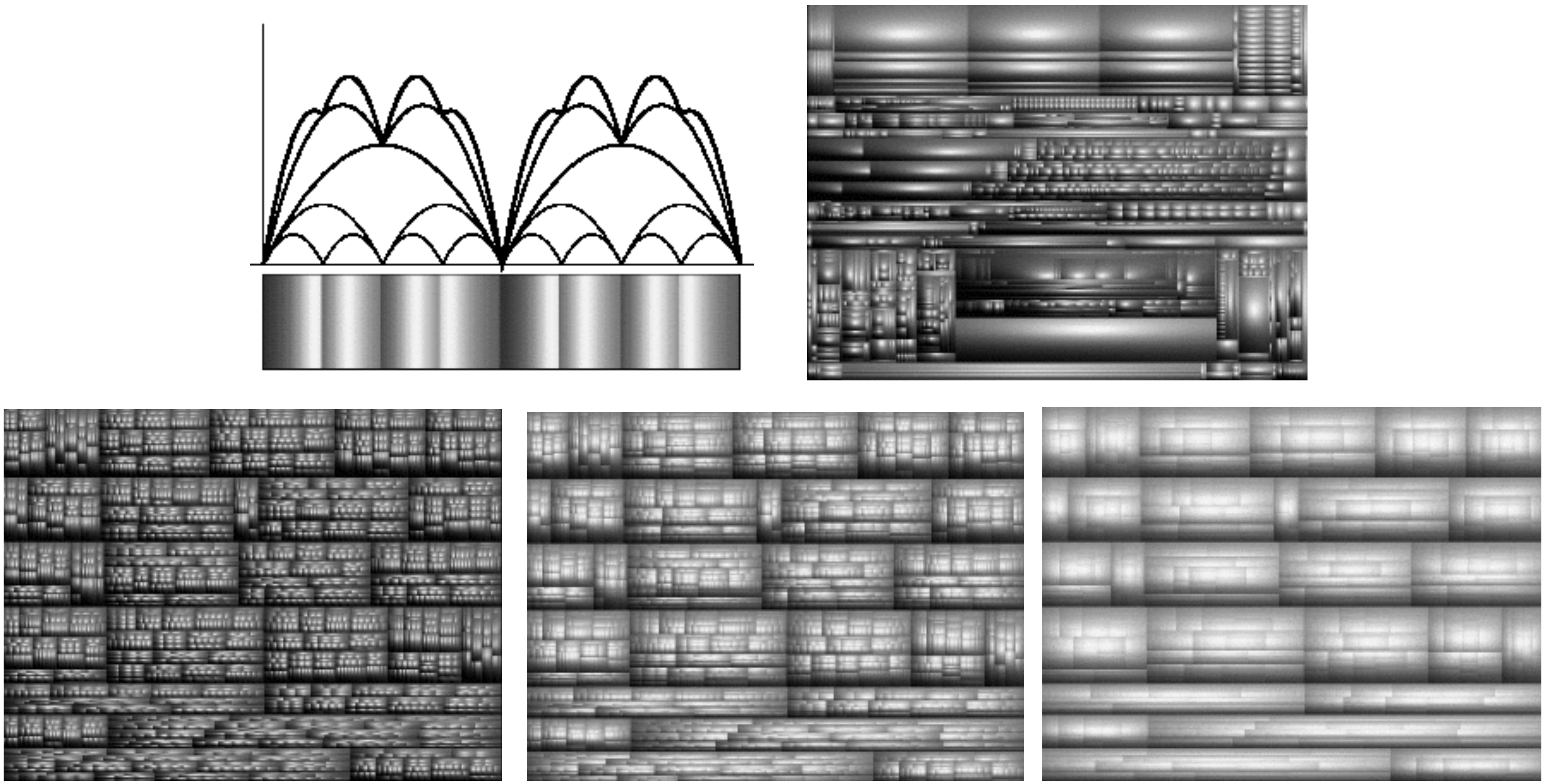


[van Wijk and van de Wetering. Cushion Treemaps. Proc InfoVis 1999]

[Fekete and Plaisant. Interactive Information Visualization of a Million Items. Proc InfoVis 2002.

Cushion Treemaps

- show structure with shading
  - single parameter controls global vs local view



[van Wijk and van de Wetering. Cushion Treemaps. Proc InfoVis 1999]

Now What?

Beyond 314: Other Graphics Courses

- 424: Geometric Modelling
  - was offered this year
- 426: Computer Animation
  - will be offered next year

- 514: Image-Based Rendering - Heidrich
- 526: Algorithmic Animation - van de Panne
- 533A: Digital Geometry - Sheffer
- 533B: Animation Physics - Bridson
- 547: Information Visualization - Munzner

Beyond UBC CS

- SIGGRAPH conference back in Vancouver August 2014!
  - 15K-20K people: incredible combination of research, entertainment, art
  - Electronic Theater, Exhibit, ETech, ...
  - pricey: but student rate, student volunteer program
- local SIGGRAPH chapter
  - talk series, SPARK FX festival, ...
  - http://siggraph.ca