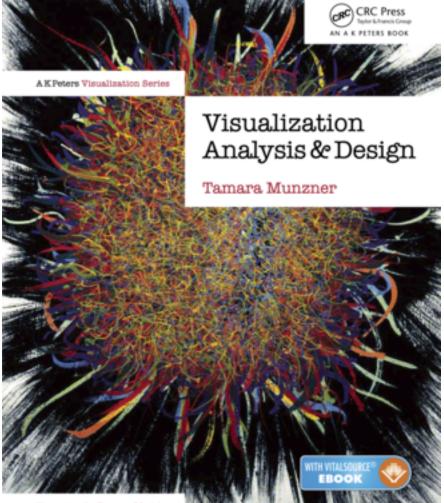
Lectures 3&4: Facet & Reduce

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DSCI 532, Data Visualization 2 Week 2, Jan 9 / Jan 11 2018

www.cs.ubc.ca/~tmm/courses/mds-viz2-17



Illustrations by Eamonn Maguire

<u>@tamaramunzner</u>

Facet Into Multiple Views



Facet

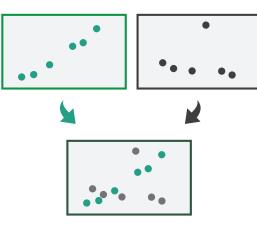




Partition







3

Juxtapose and coordinate views

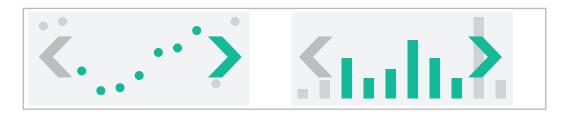
- → Share Encoding: Same/Different
 - → Linked Highlighting



→ Share Data: All/Subset/None



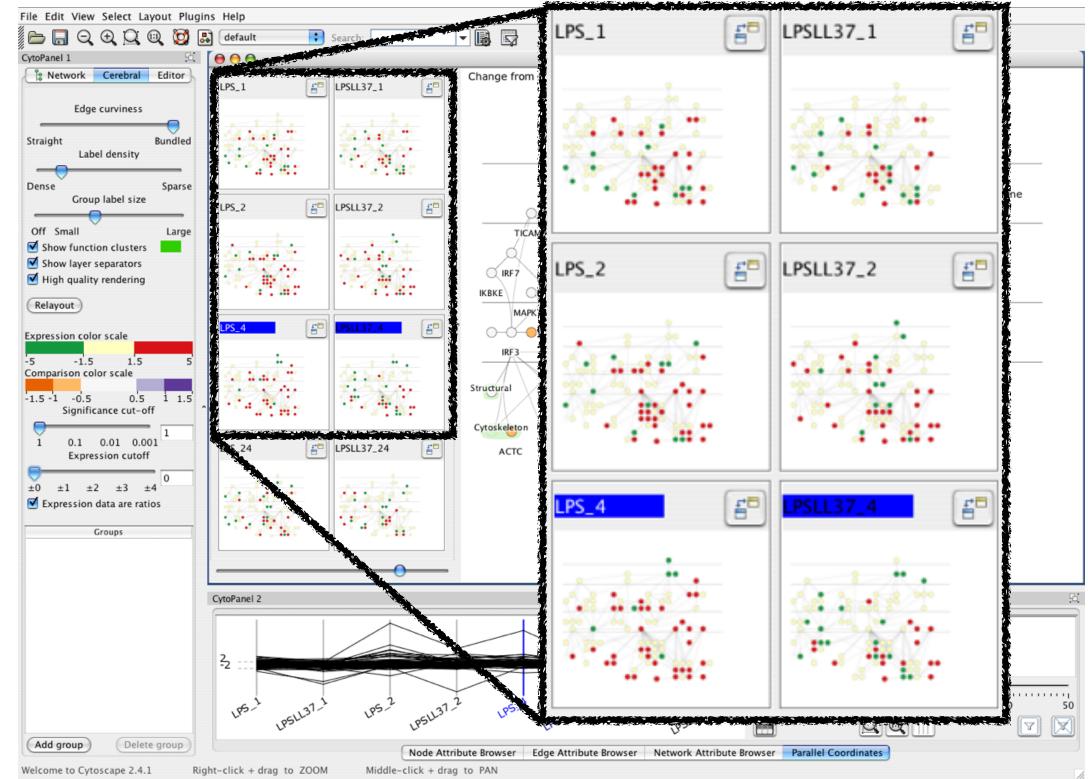
→ Share Navigation



4

Idiom: Small multiples

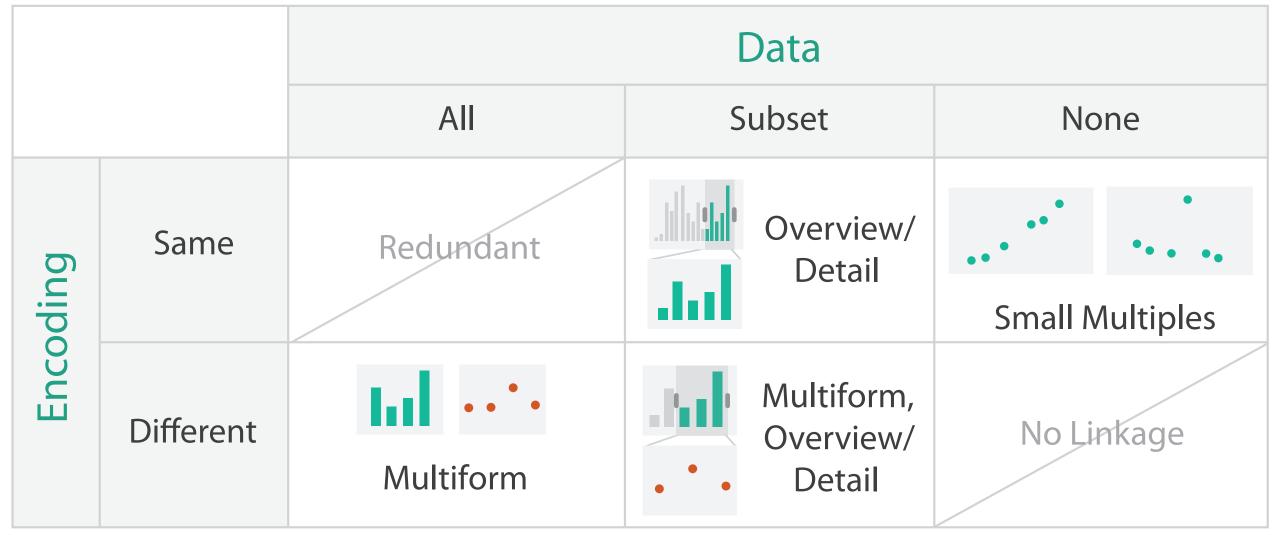
- encoding: same
- data: none shared
 - -different attributes for node colors
 - -(same network layout)
- navigation: shared



[Cerebral: Visualizing Multiple Experimental Conditions on a Graph with Biological Context. Barsky, Munzner, Gardy, and Kincaid. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14:6 (2008), 1253–1260.]

System: Cerebral

Coordinate views: Design choice interaction

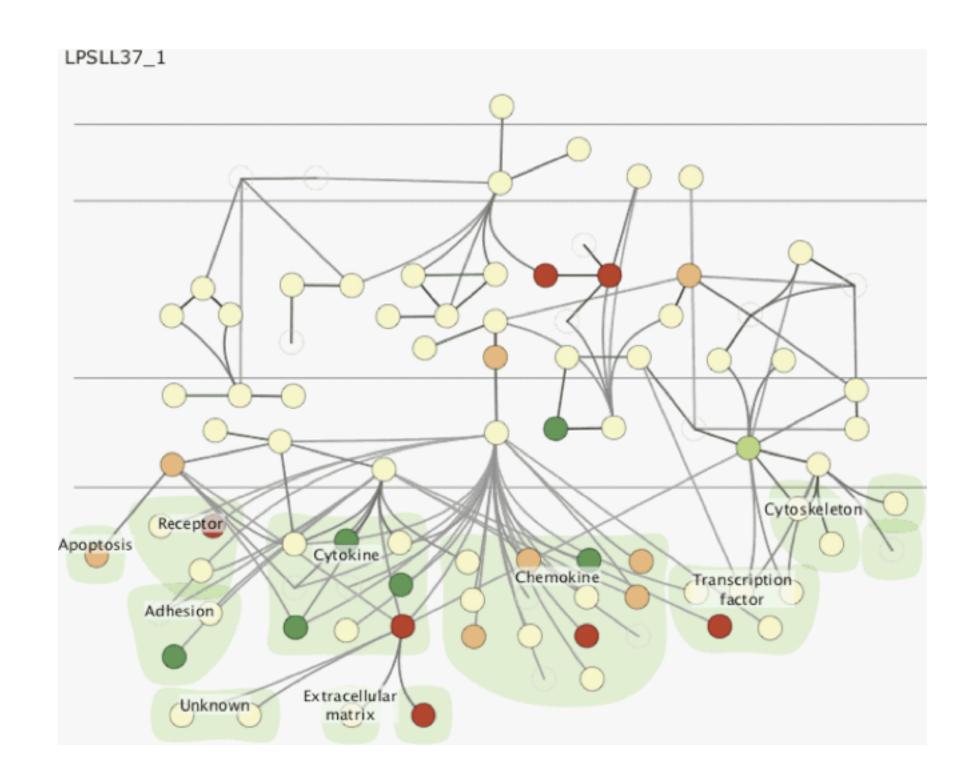


- why juxtapose views?
 - -benefits: eyes vs memory
 - lower cognitive load to move eyes between 2 views than remembering previous state with single changing view
 - -costs: display area, 2 views side by side each have only half the area of one view

Why not animation?

- disparate frames and regions: comparison difficult
 - -vs contiguous frames
 - -vs small region
 - -vs coherent motion of group
- safe special case

 animated transitions



Eyes beat memory

- principle: external cognition vs. internal memory -easy to compare by moving eyes between side-by-side views -harder to compare visible item to memory of what you saw
- implications for animation
 - -great for choreographed storytelling
 - -great for transitions between two states
 - -poor for many states with changes everywhere
 - consider small multiples instead

literal	abstract
animation	small multiples
show time with time	show time with space

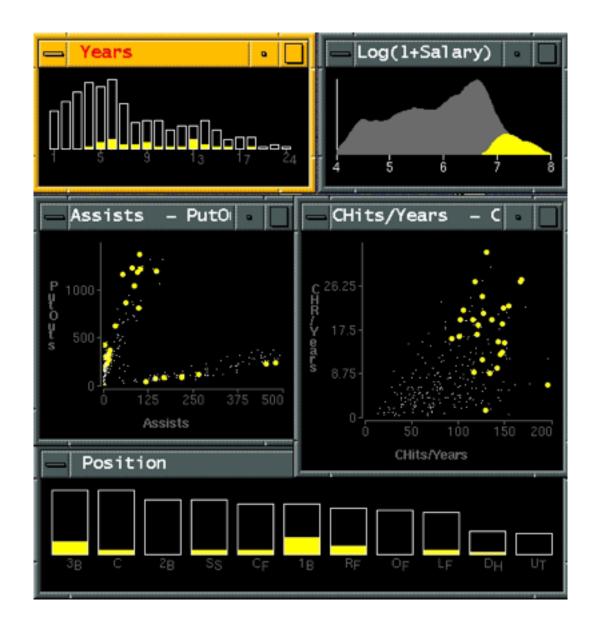
nultiples n space

Change blindness

- if attention is directed elsewhere, even drastic changes not noticeable -door experiment
- change blindness demos -mask in between images

Idiom: Linked highlighting

- see how regions contiguous in one view are distributed within another
 - -powerful and pervasive interaction idiom
- encoding: different -multiform
- data: all shared
- aka: brushing and linking

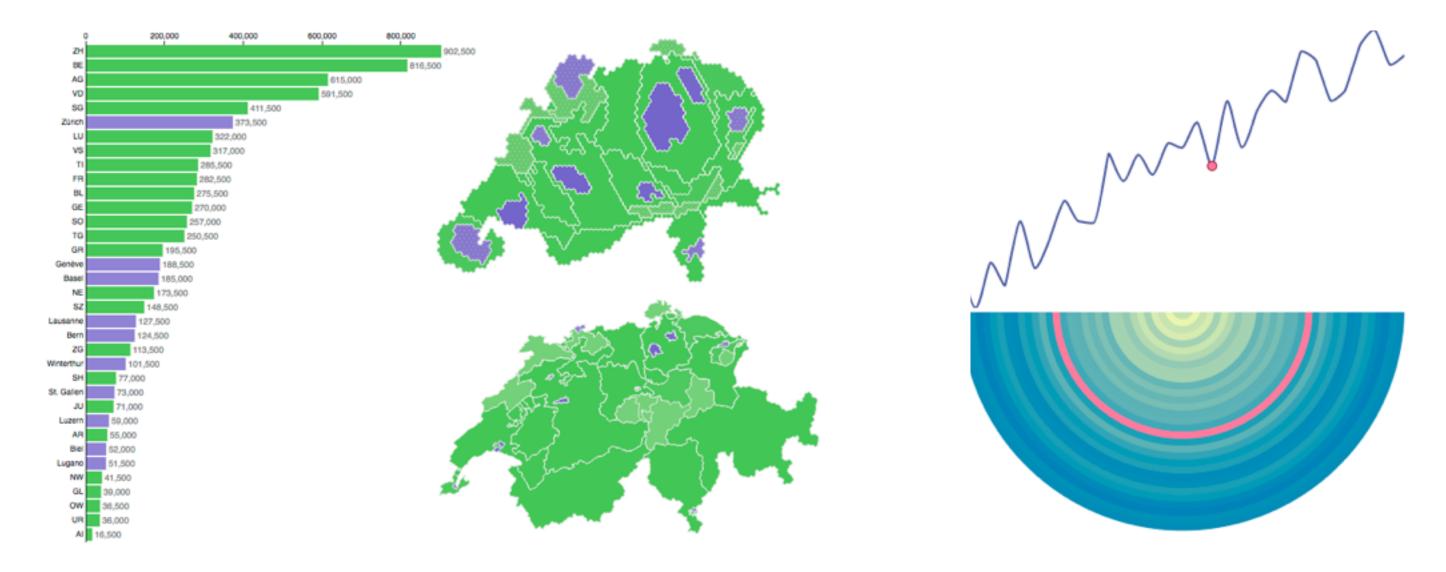


[Visual Exploration of Large Structured Datasets.Wills. Proc. New Techniques and Trends in Statistics (NTTS), pp. 237–246. IOS Press, 1995.]

System: **EDV**

Linked views

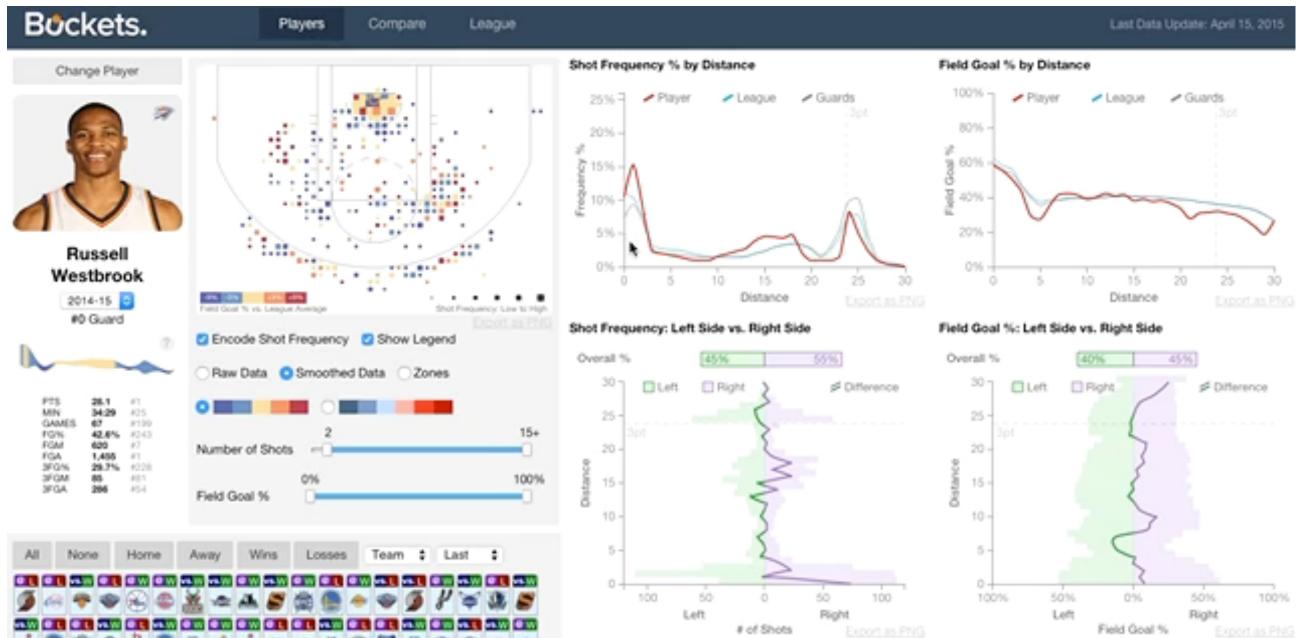
• unidirectional vs bidirectional linking



http://www.ralphstraumann.ch/projects/swiss-population-cartogram/

http://peterbeshai.com/linked-highlighting-react-d3-reflux/

Linked views: Multidirectional linking



http://buckets.peterbeshai.com/

https://medium.com/@pbesh/linked-highlighting-with-react-d3-js-and-reflux-16e9c0b2210b

System: **Buckets**

Idiom: Overview-detail views

- encoding: same
- data: subset shared
- navigation: shared -bidirectional linking
- differences
 - -viewpoint
 - -(size)
- special case: birds-eye map



[A Review of Overview+Detail, Zooming, and Focus+Context Interfaces. Cockburn, Karlson, and Bederson. ACM Computing Surveys 41:1 (2008), 1-31.]

System: Google Maps

Idiom: Overview-detail navigation

- encoding: same
- data: subset shared
- navigation: shared
 - -unidirectional linking
 - -select in small overview

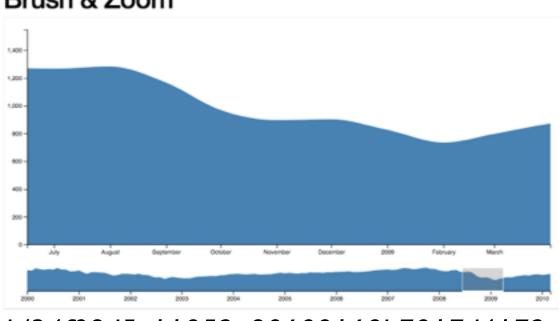
-change extent in large detail view

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https://www.highcharts.com/ demo/dynamic-master-detail



Brush & Zoom

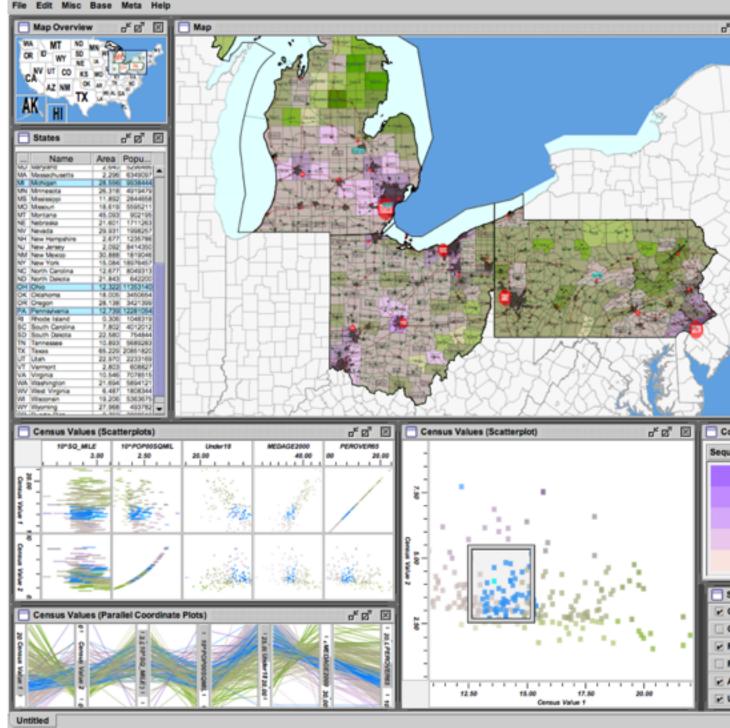


https://bl.ocks.org/mbostock/34f08d5e11952a80609169b7917d4172

Popular / Abour

System: Improvise

- investigate power of multiple views
 - -pushing limits on view count, interaction complexity
 - -how many is ok?
 - open research question
 - -reorderable lists
 - easy lookup
 - useful when linked to other encodings

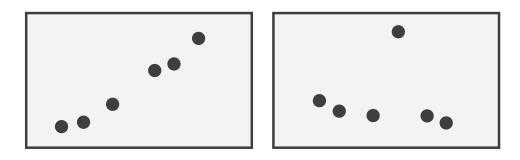


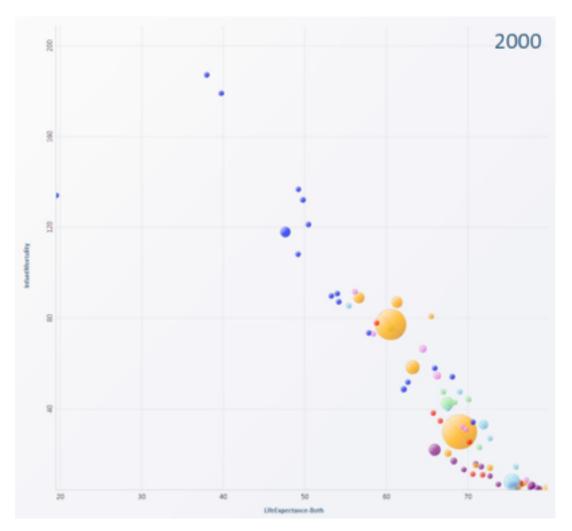
[Building Highly-Coordinated Visualizations In Improvise. Weaver. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 159–166, 2004.]

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Partition into views

- how to divide data between views
 Partition into Side-by-Side Views
 - -split into regions by attributes
 - -encodes association between items using spatial proximity
 - -order of splits has major implications for what patterns are visible
- no strict dividing line
 - -view: big/detailed
 - contiguous region in which visually encoded data is shown on the display
 - -glyph: small/iconic
 - object with internal structure that arises from multiple marks

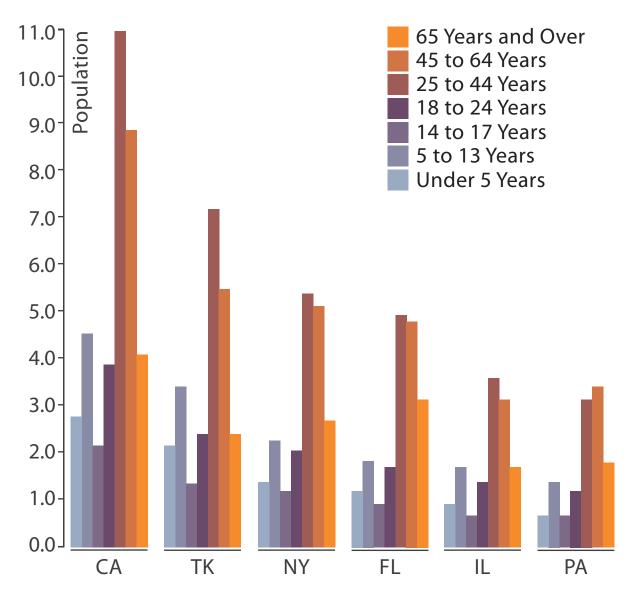






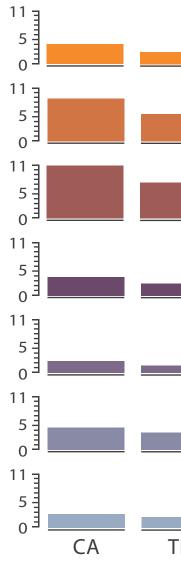
Partitioning: List alignment

- single bar chart with grouped bars
 - -split by state into regions
 - complex glyph within each region showing all ages
 - -compare: easy within state, hard across ages



- - -split by age into regions
 - one chart per region
 - -compare: easy within age, harder across states





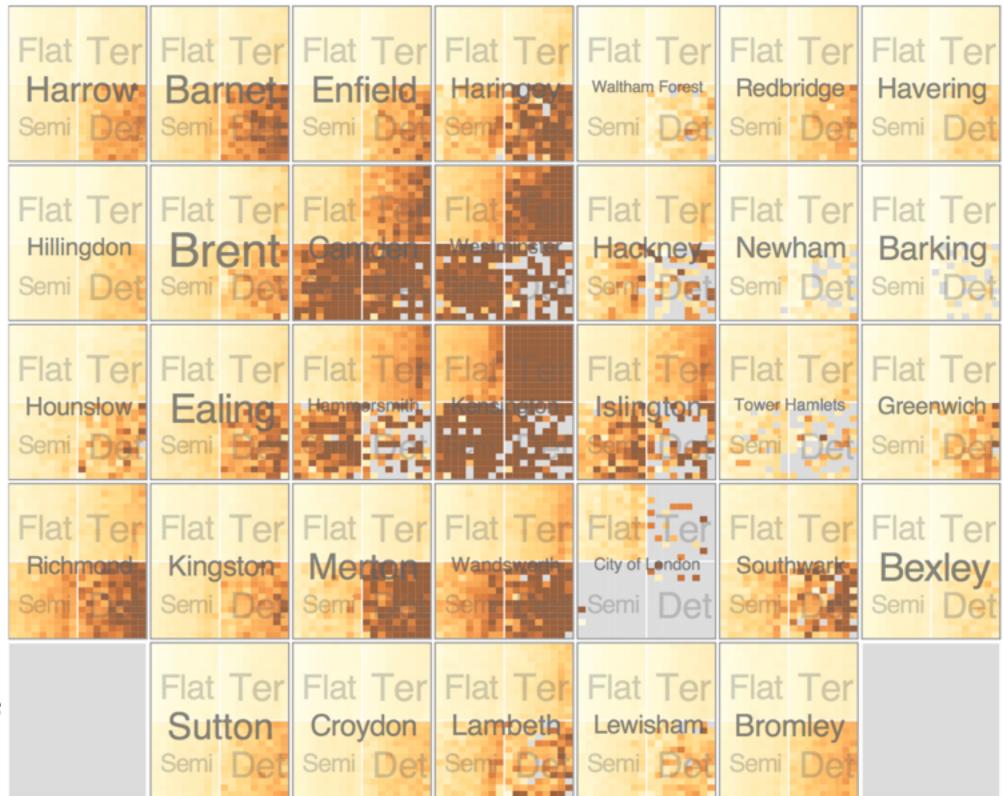
• small-multiple bar charts

ΓK	NY	FL	IL	PA

17

- split by neighborhood
- then by type
- then time
 - -years as rows
 - -months as columns
- color by price
- neighborhood patterns -where it's expensive -where you pay much more for detached type

[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 977–984.]

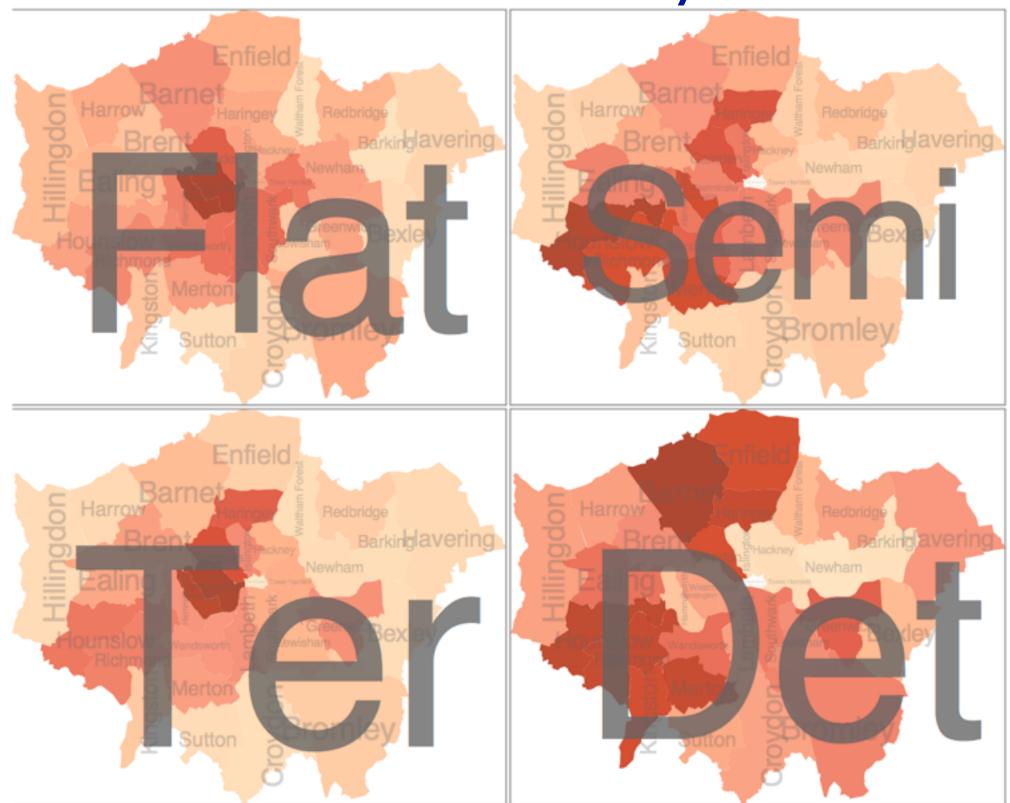


- switch order of splits -type then neighborhood
- switch color
 - -by price variation
- type patterns
 - -within specific type, which neighborhoods inconsistent



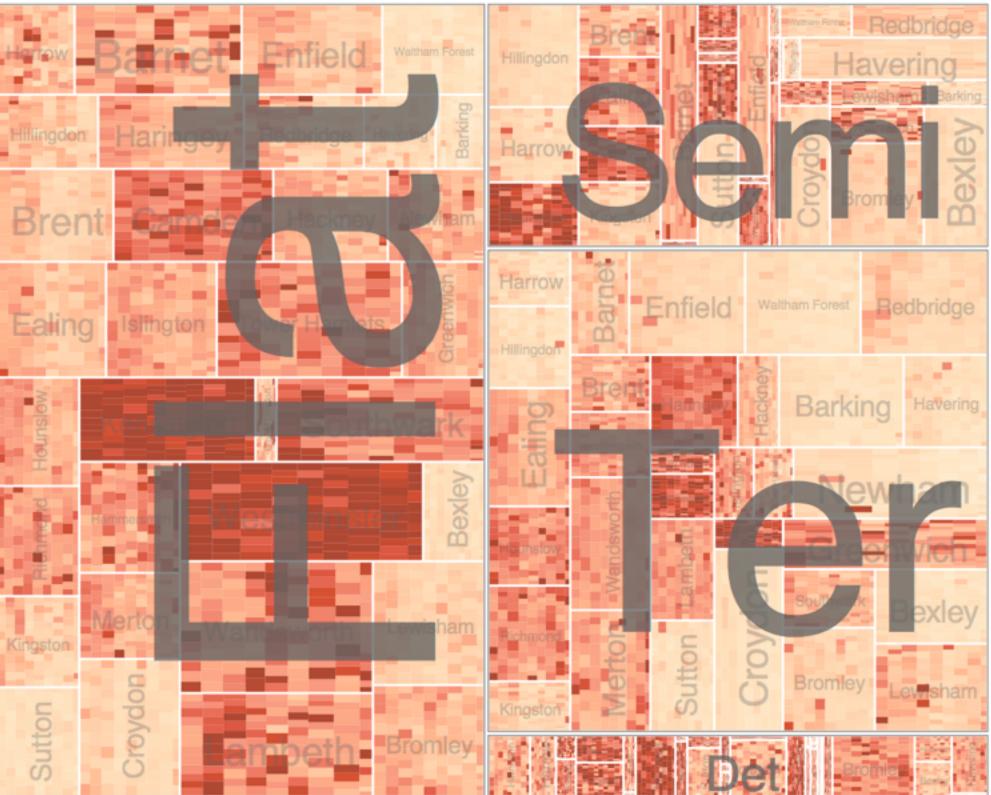
[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 977–984.]

 different encoding for second-level regions -choropleth maps



[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 977–984.]

- size regions by sale counts -not uniformly
- result: treemap

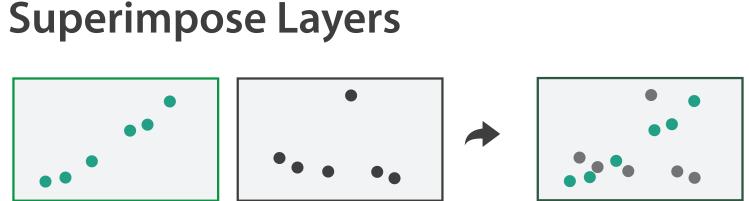


[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 977–984.]

Superimpose layers

- *layer*: set of objects spread out over region

 –each set is visually distinguishable group
 –extent: whole view
 Superior
- design choices
 - -how many layers, how to distinguish?
 - encode with different, nonoverlapping channels
 - two layers achieveable, three with careful design
 - -small static set, or dynamic from many possible?



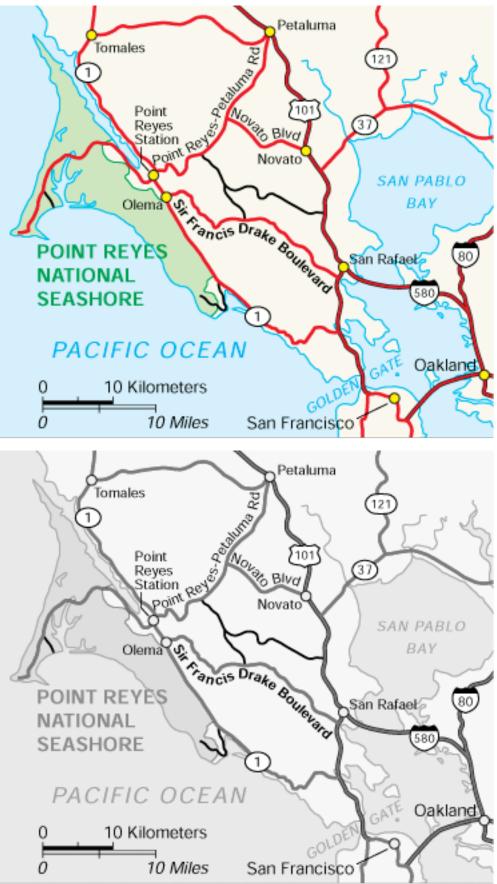
Static visual layering

- foreground layer: roads -hue, size distinguishing main from minor -high luminance contrast from background
- background layer: regions -desaturated colors for water, parks, land areas
- user can selectively focus attention
- "get it right in black and white" -check luminance contrast with greyscale view

[Get it right in black and white. Stone. 2010. http://www.stonesc.com/wordpress/2010/03/get-it-right-in-black-and-white]

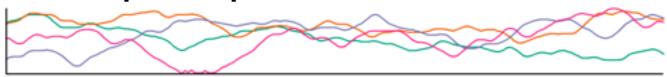


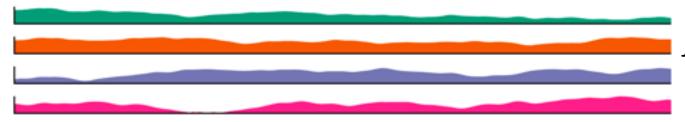




Superimposing limits

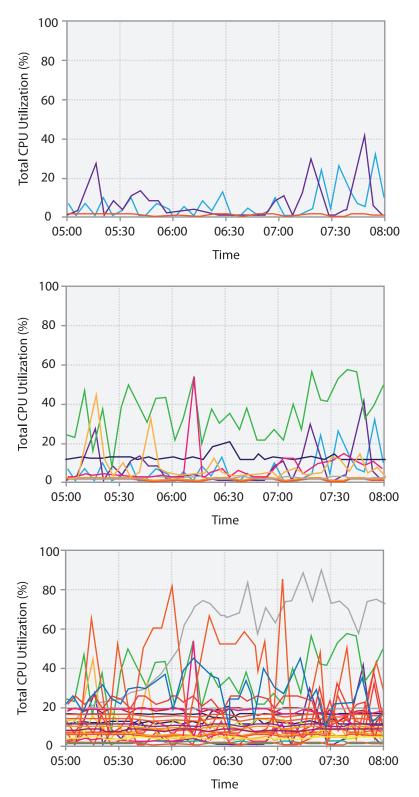
- few layers, but many lines
 - -up to a few dozen
 - -but not hundreds
- superimpose vs juxtapose: empirical study
 - -superimposed for local, multiple for global
 - -tasks
 - local: maximum, global: slope, discrimination
 - -same screen space for all multiples vs single superimposed





[Graphical Perception of Multiple Time Series. Javed, McDonnel, and Elmqvist. IEEE Transactions on Visualization and Computer Graphics (Proc. IEEE InfoVis 2010) 16:6 (2010), 927–934.]

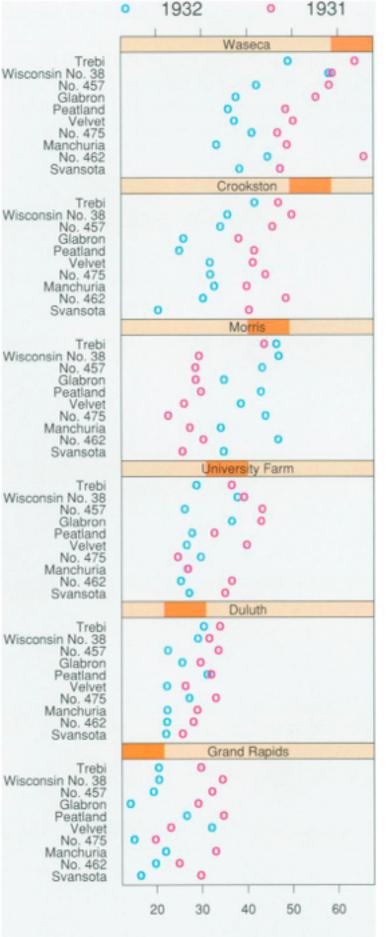




Idiom: Trellis plots

superimpose within same frame – color code by year

- partitioning
 - -split by site, rows are wheat varieties
- main-effects ordering
 - -derive value of median for group, use to order
 - -order rows within view by variety median
 - -order views themselves by site median

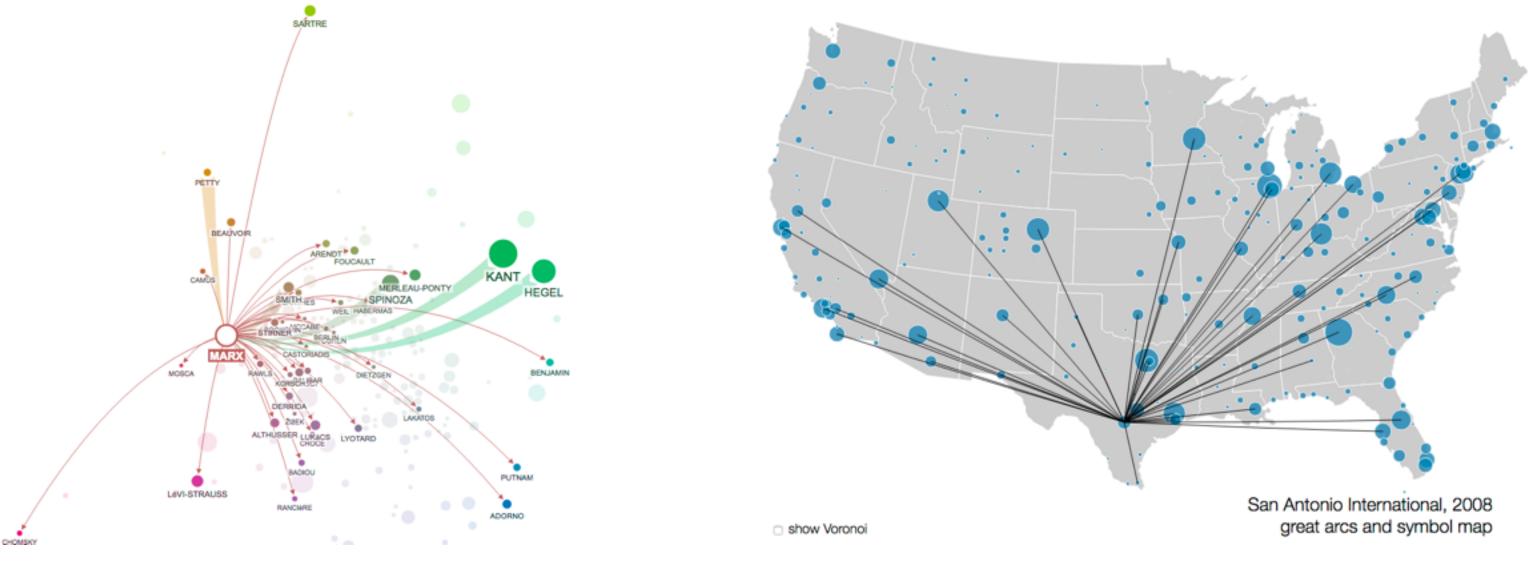


Barley Yield (bushels/acre)

25

Dynamic visual layering

- interactive based on selection
- one-hop neighbour highlighting demos: click vs hover (lightweight)



http://mariandoerk.de/edgemaps/demo/

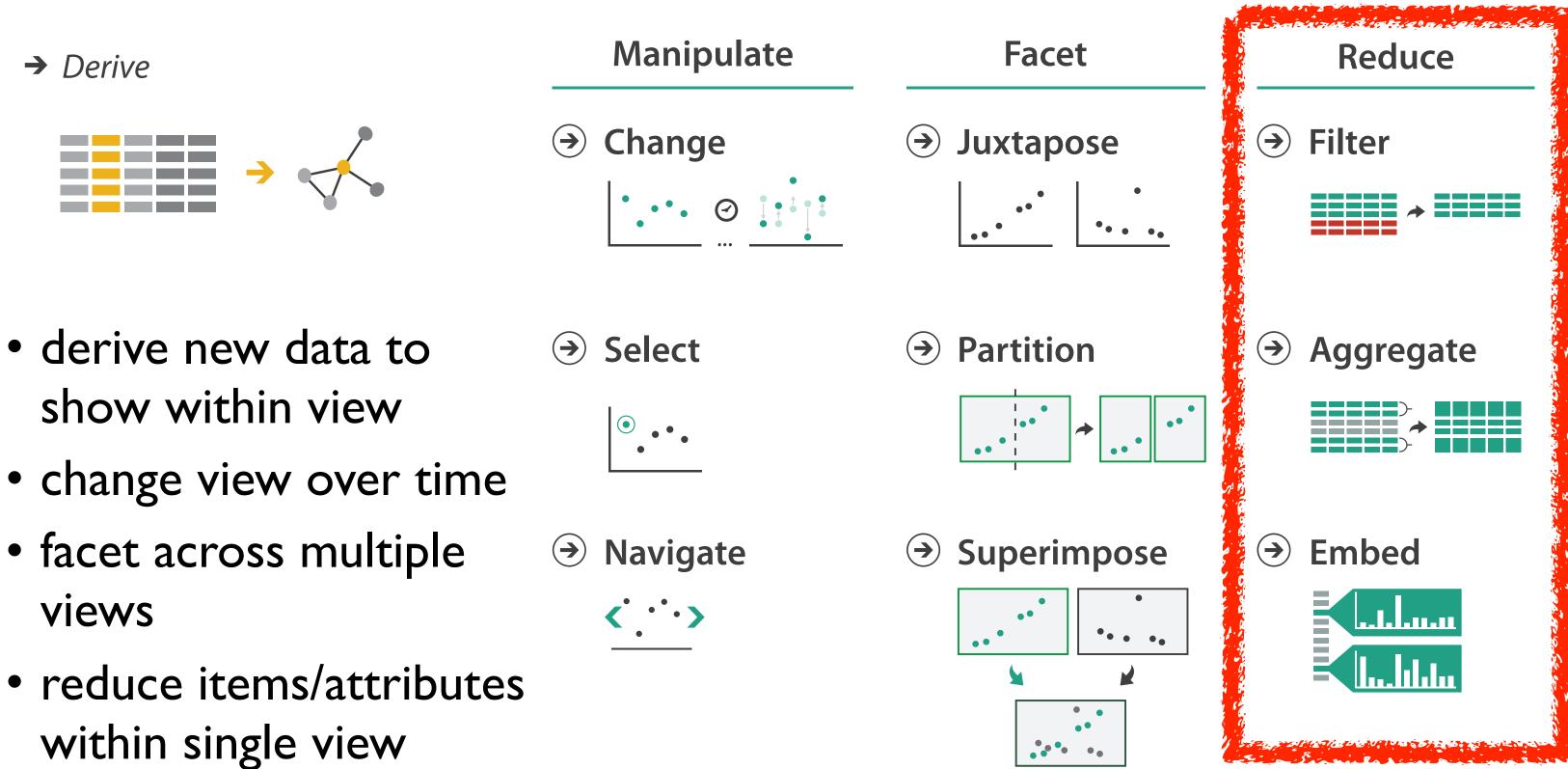
http://mbostock.github.io/d3/talk/2011116/airports.html

Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014. -Chap 12: Facet Into Multiple Views
- A Review of Overview+Detail, Zooming, and Focus+Context Interfaces. Cockburn, Karlson, and Bederson. ACM Computing Surveys 41:1 (2008), 1–31.
- A Guide to Visual Multi-Level Interface Design From Synthesis of Empirical Study Evidence. Lam and Munzner. Synthesis Lectures on Visualization Series, Morgan Claypool, 2010.
- Zooming versus multiple window interfaces: Cognitive costs of visual comparisons. Plumlee and Ware. ACM Trans. on Computer-Human Interaction (ToCHI) 13:2 (2006), 179–209.
- Exploring the Design Space of Composite Visualization. Javed and Elmqvist. Proc. Pacific Visualization Symp. (Pacific Vis), pp. 1–9, 2012.
- Visual Comparison for Information Visualization. Gleicher, Albers, Walker, Jusufi, Hansen, and Roberts. Information Visualization 10:4 (2011), 289–309.
- Guidelines for Using Multiple Views in Information Visualizations. Baldonado, Woodruff, and Kuchinsky. In Proc. ACM Advanced Visual Interfaces (AVI), pp. 110–119, 2000.
- Cross-Filtered Views for Multidimensional Visual Analysis. Weaver. IEEE Trans. Visualization and Computer Graphics 16:2 (Proc. InfoVis 2010), 192–204, 2010.
- Linked Data Views. Wills. In Handbook of Data Visualization, Computational Statistics, edited by Unwin, Chen, and Härdle, pp. 216-241. Springer-Verlag, 2008.
- Glyph-based Visualization: Foundations, Design Guidelines, Techniques and Applications. Borgo, Kehrer, Chung, Maguire, Laramee, Hauser, Ward, and Chen. In Eurographics State of the Art Reports, pp. 39–63, 2013.



How to handle complexity: I previous strategy + 3 more



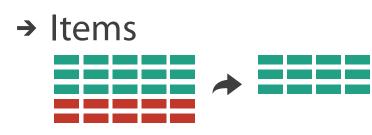
Reduce items and attributes

- reduce/increase: inverses
- filter
 - -pro: straightforward and intuitive
 - to understand and compute
 –con: out of sight, out of mind
- aggregation
 - -pro: inform about whole set
 - -con: difficult to avoid losing signal
- not mutually exclusive

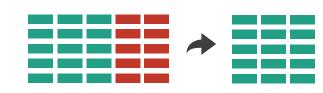
 combine filter, aggregate
 combine reduce, change, facet

Reducing Items and Attri





→ Attributes

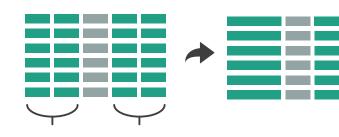








→ Attributes

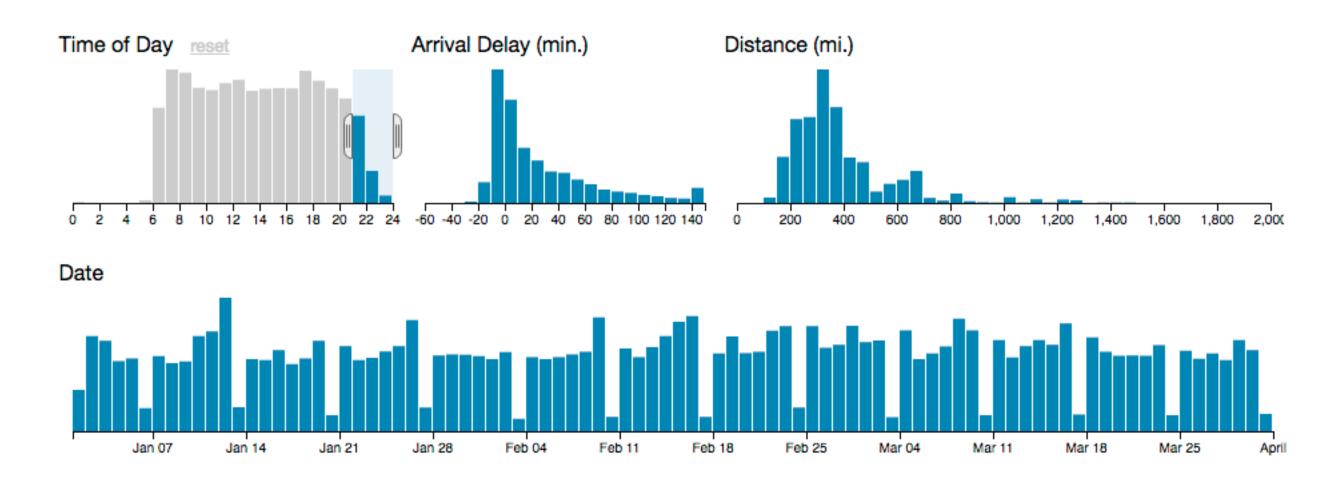


ibutes	Reduce					
	 → Aggregate 					
	L.I.I.I.I.I.I.I.I.I.I.I.I.I.I.I.I.I.I.I					



Idiom: cross filtering

- item filtering
- coordinated views/controls combined
 - all scented histogram bisliders update when any ranges change



[http://square.github.io/crossfilter/]



31

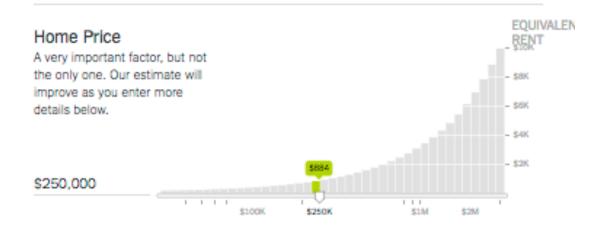
Idiom: cross filtering

TheUpshot

Is It Better to Rent or Buy?

By MIKE BOSTOCK, SHAN CARTER and ARCHIE TSE

The choice between buying a home and renting one is among the biggest financial decisions that many adults make. But the costs of buying are more varied and complicated than for renting, making it hard to tell which is a better deal. To help you answer this question, our calculator takes the most important costs associated with buying a house and computes the equivalent monthly rent. RELATED ARTICLE



How Long Do You Plan to Stay?

Buying tends to be are spread out ove	better the longer you stay r many years.	because the up	front fees	EQUIV. RENT
9 years	5884			- \$2K
	9	20	30	40

[https://www.nytimes.com/interactive/2014/upshot/buy-rent-calculator.html? r=0]

Idiom: histogram

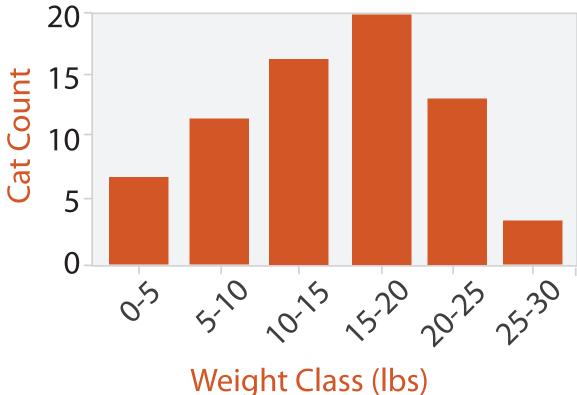
- static item aggregation
- task: find distribution
- data: table
- derived data

-new table: keys are bins, values are counts

bin size crucial

-pattern can change dramatically depending on discretization

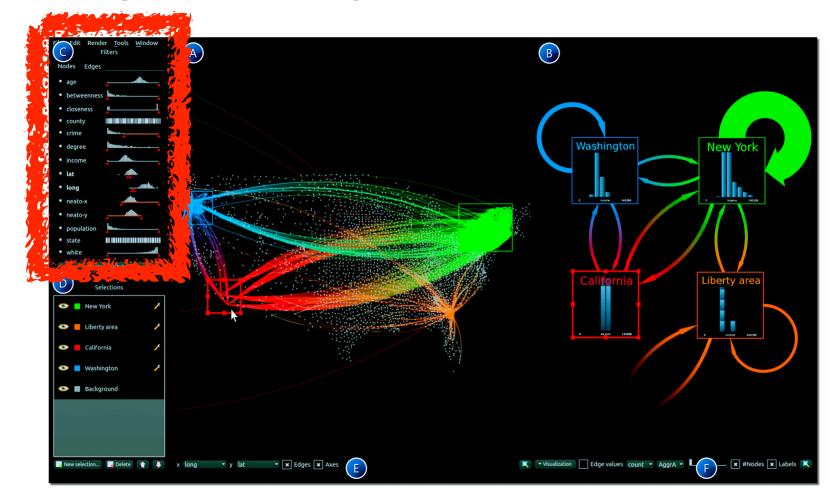
-opportunity for interaction: control bin size on the fly



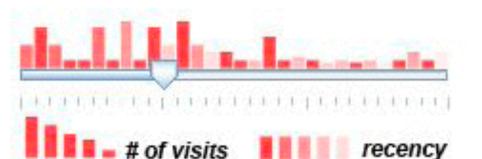
Idiom: scented widgets

- augmented widgets show information scent

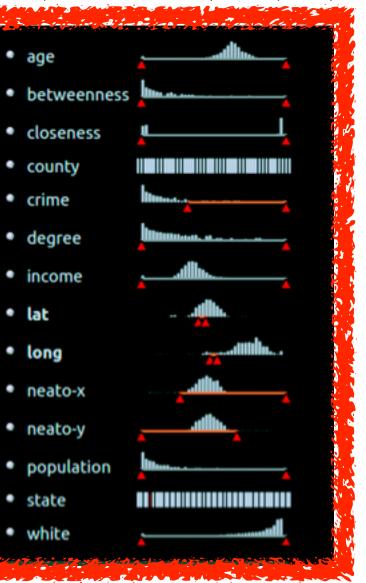
 cues to show whether value in drilling down
 further vs looking elsewhere
- concise use of space: histogram on slider



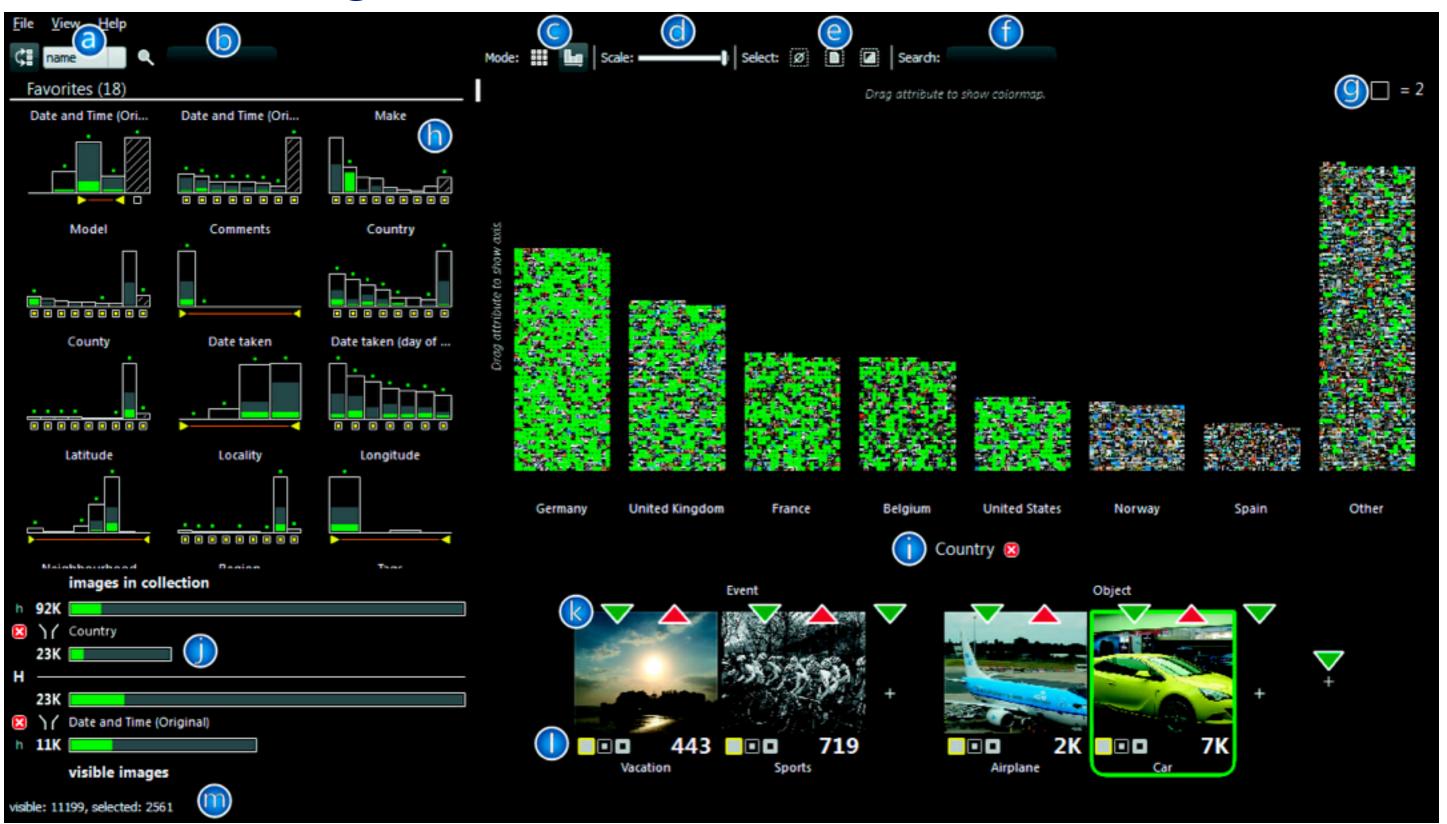
[Multivariate Network Exploration and Presentation: From Detail to Overview via Selections and Aggregations. van den Elzen, van Wijk, IEEETVCG 20(12): 2014 (Proc. InfoVis 2014).]



[Scented Widgets: Improving Navigation Cues with Embedded Visualizations. Willett, Heer, and Agrawala. IEEE TVCG (Proc. InfoVis 2007) 13:6 (2007), 1129–1136.]



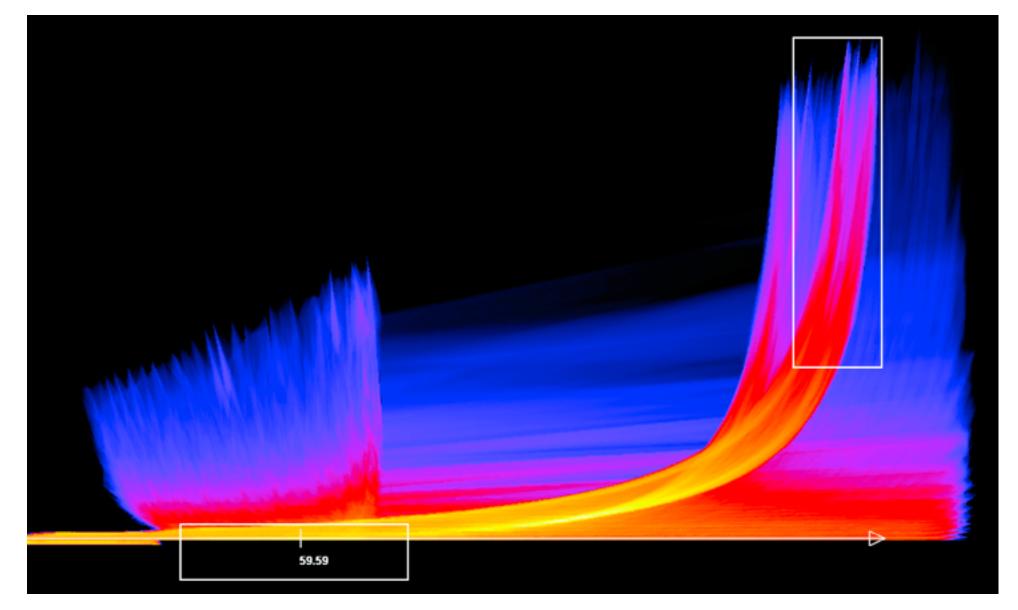
Scented histogram bisliders: detailed



[ICLIC: Interactive categorization of large image collections. van der Corput and van Wijk. Proc. PacificVis 2016.]

Idiom: Continuous scatterplot

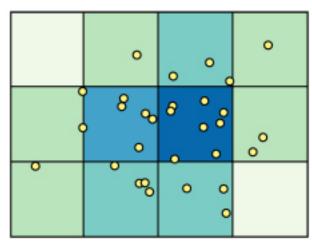
- static item aggregation
- data: table
- derived data: table
 - key attribs x,y for pixels
 - quant attrib: overplot density
- dense space-filling 2D matrix
- color: sequential categorical hue + ordered luminance colormap

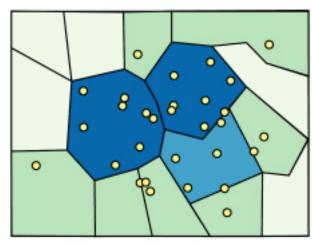


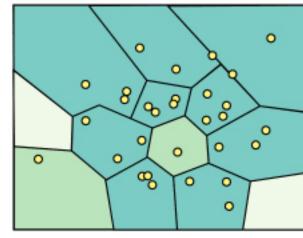
[Continuous Scatterplots. Bachthaler and Weiskopf. IEEE TVCG (Proc.Vis 08) 14:6 (2008), 1428–1435. 2008.]

Spatial aggregation

- MAUP: Modifiable Areal Unit Problem
 - -gerrymandering (manipulating voting district boundaries) is only one example! -zone effects

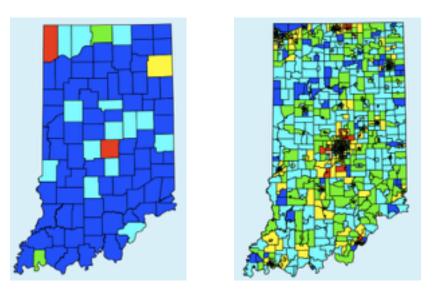






[http://www.e-education.psu/edu/geog486/l4_p7.html, Fig 4.cg.6]





https://blog.cartographica.com/blog/2011/5/19/ the-modifiable-areal-unit-problem-in-gis.html



Idiom: **boxplot**

- static item aggregation
- task: find distribution
- data: table
- derived data
 - -5 quant attribs
 - median: central line
 - lower and upper quartile: boxes
 - lower upper fences: whiskers
 - -values beyond which items are outliers
 - -outliers beyond fence cutoffs explicitly shown

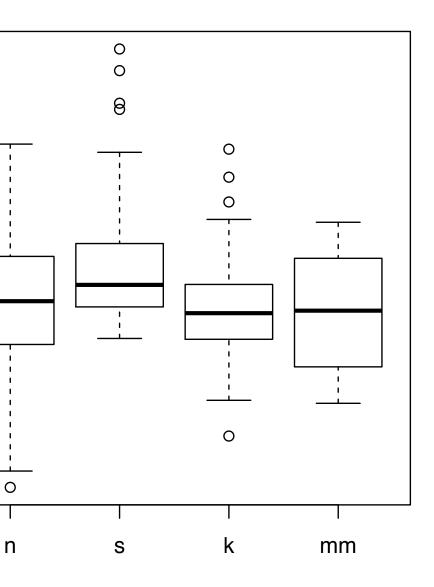
[40 years of boxplots. Wickham and Stryjewski. 2012. had.co.nz]

4

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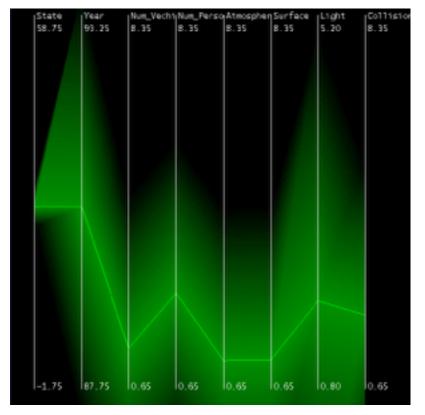
0

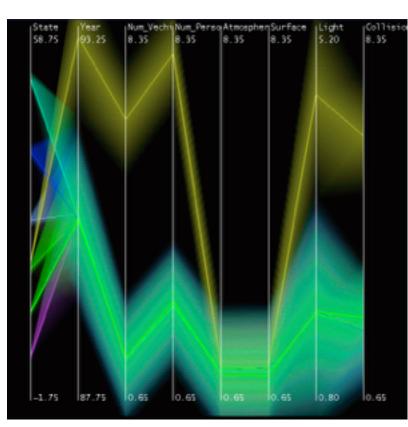
N

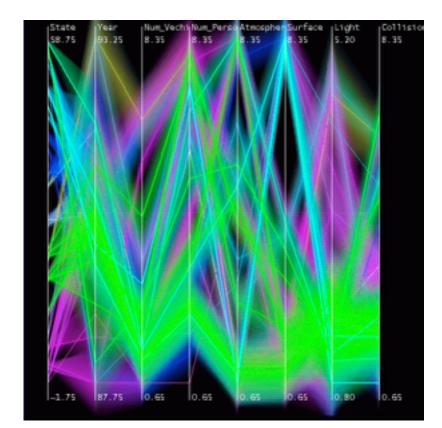


Idiom: Hierarchical parallel coordinates

dynamic item aggregation





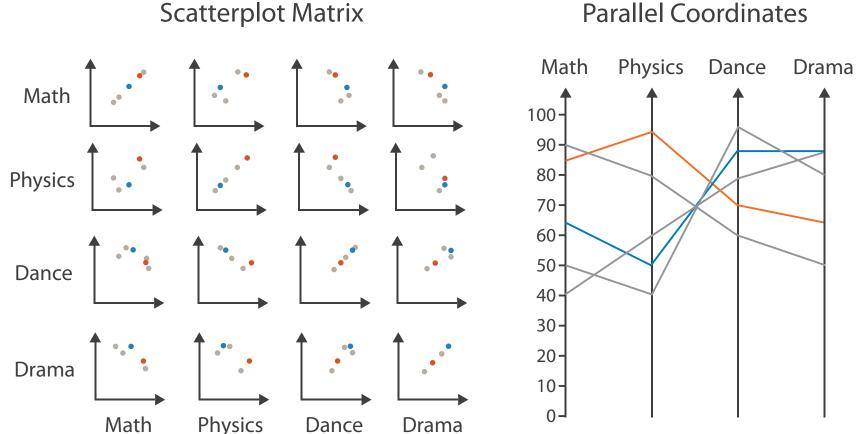


[Hierarchical Parallel Coordinates for Exploration of Large Datasets. Fua, Ward, and Rundensteiner. Proc. IEEE Visualization Conference (Vis '99), pp. 43–50, 1999.]



Idioms: scatterplot matrix, parallel coordinates

- scatterplot matrix (SPLOM)
 - -rectilinear axes, point mark
 - -facet: all possible pairs of axes
 - -scalability
 - one dozen attribs
 - dozens to hundreds of items
- parallel coordinates
 - -parallel axes, jagged line representing item
 - -rectilinear axes, item as point
 - axis ordering is major challenge
 - -scalability
 - dozens of attribs
 - hundreds of items



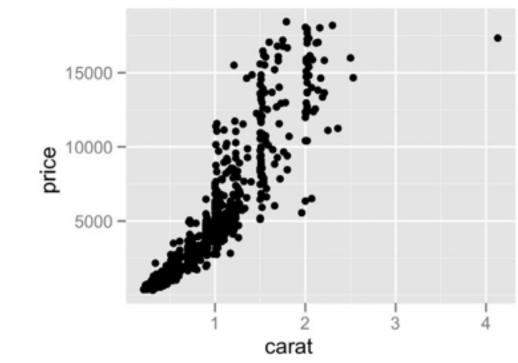
Table

Math	Physics	Dance	Drama
85	95	70	65
90	80	60	50
65	50	90	90
50	40	95	80
40	60	80	90

Task: Correlation

- scatterplot matrix -positive correlation
 - diagonal low-to-high
 - -negative correlation
 - diagonal high-to-low
 - -uncorrelated: spread out
- parallel coordinates
 - -positive correlation
 - parallel line segments
 - -negative correlation
 - all segments cross at halfway point
 - -uncorrelated
 - scattered crossings

[Hyperdimensional Data Analysis Using Parallel Coordinates. Wegman. Journ. American Statistical Association 85:411 (1990), 664–675.]



[A layered grammar of graphics. Wickham. Journ. Computational and Graphical Statistics 19:1 (2010), 3-28.]

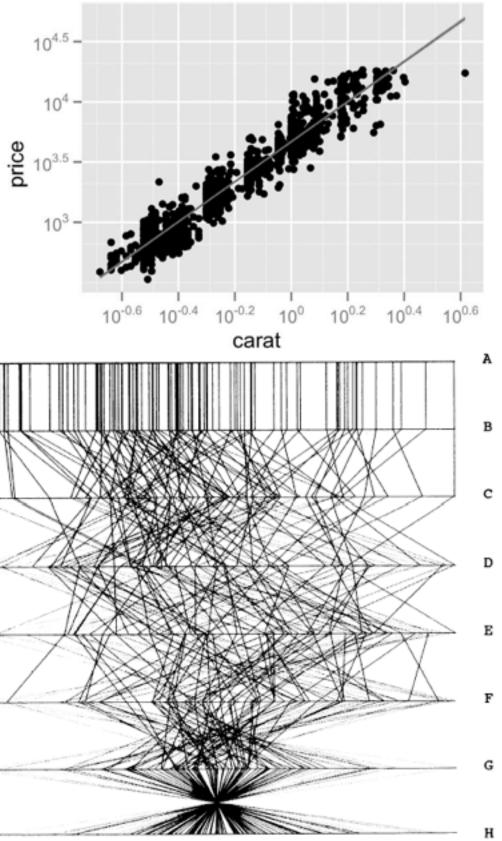
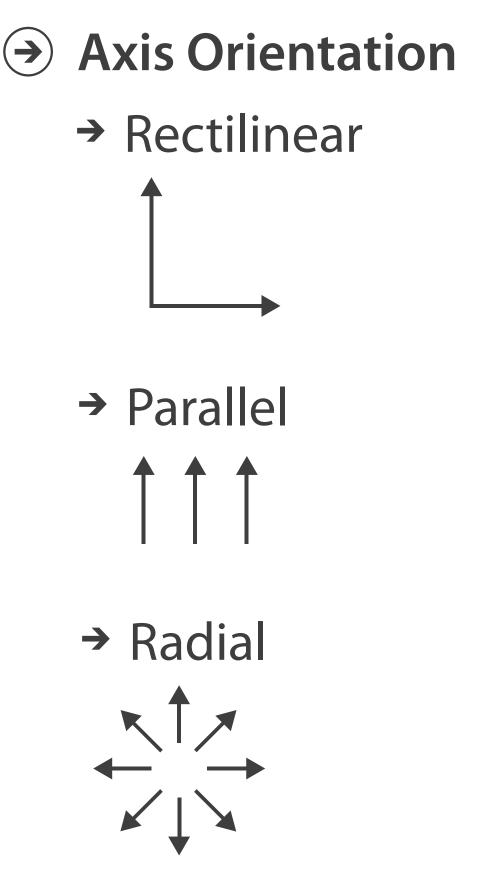


Figure 3. Parallel Coordinate Plot of Six-Dimensional Data Illustrating Correlations of $\rho = 1, .8, .2, 0, -.2, -.8, and -1$.

Orientation limitations

- rectilinear: scalability wrt #axes
 - 2 axes best
 - 3 problematic
 - 4+ impossible
- parallel: unfamiliarity, training time

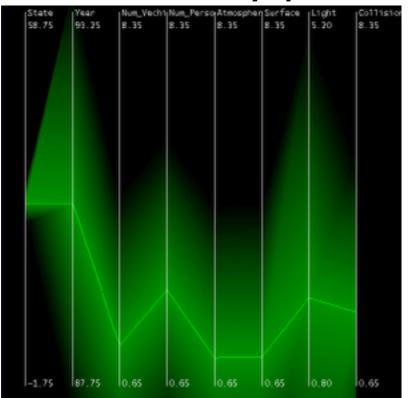


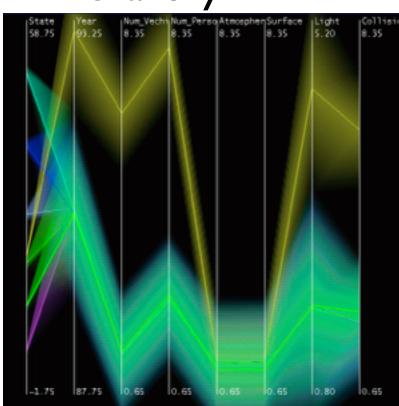
Idiom: Hierarchical parallel coordinates

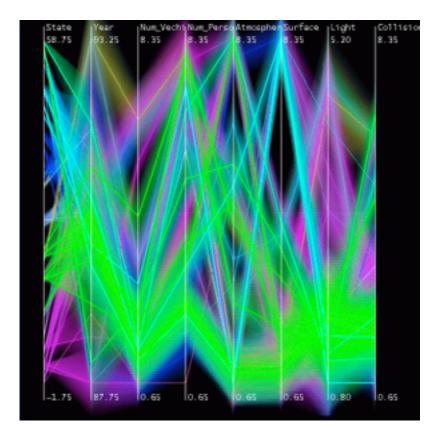
- dynamic item aggregation
- derived data: hierarchical clustering
- encoding:

-cluster band with variable transparency, line at mean, width by min/max values

-color by proximity in hierarchy





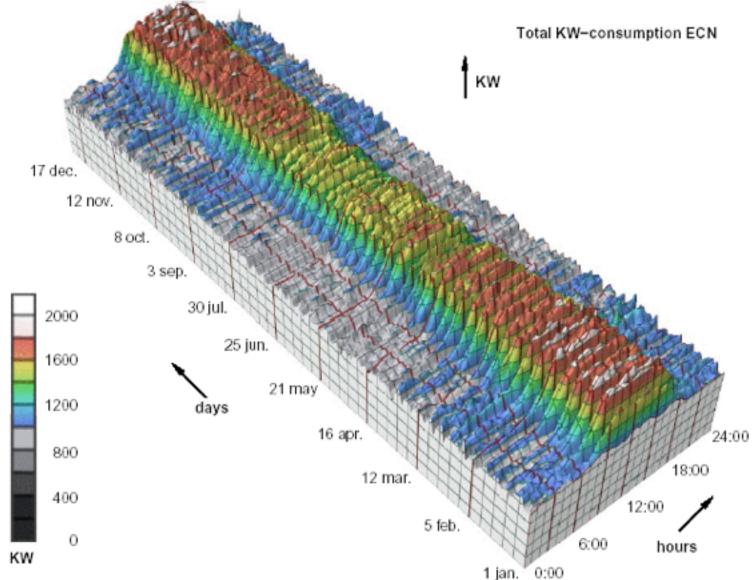


[Hierarchical Parallel Coordinates for Exploration of Large Datasets. Fua, Ward, and Rundensteiner. Proc. IEEE Visualization Conference (Vis '99), pp. 43–50, 1999.]



Hierarchical clustering example: time-series data

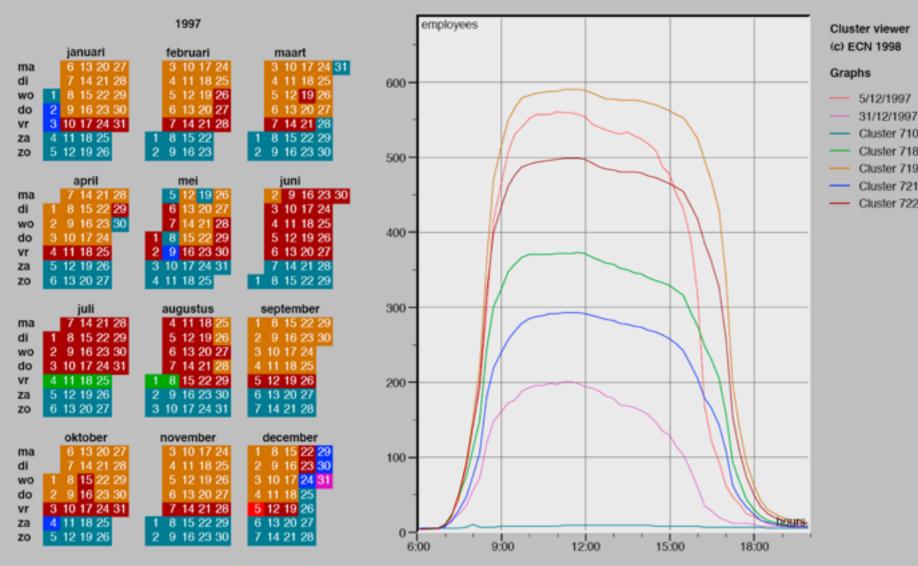
• unjustified 3D with extruded curves: detailed comparisons impossible



[Cluster and Calendar based Visualization of Time Series Data. van Wijk and van Selow, Proc. InfoVis 99.]

Hierarchical clustering example: cluster-calendar

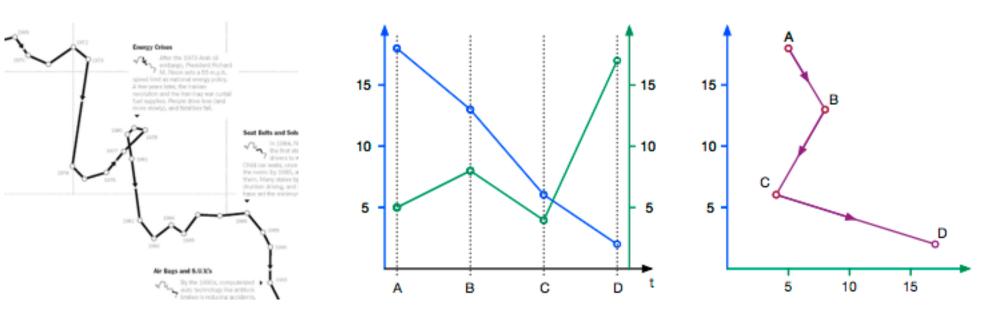
- derived data: cluster hierarchy
- juxtapose multiple views: calendar, superimposed 2D curves



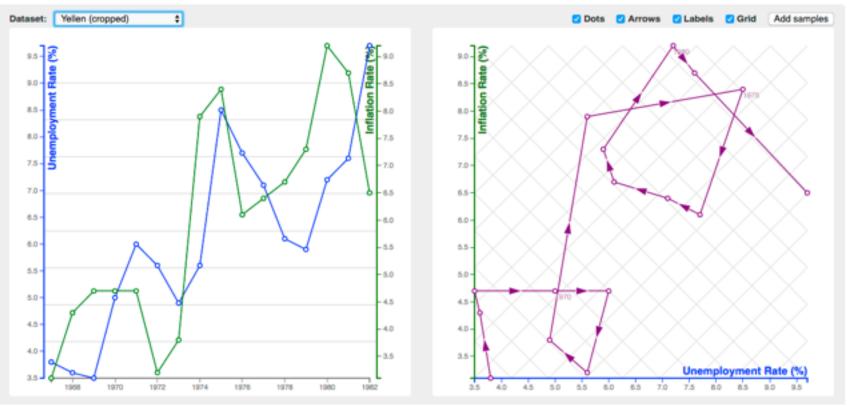
[Cluster and Calendar based Visualization of Time Series Data. van Wijk and van Selow, Proc. InfoVis 99.]

Idiom: connected scatterplots

- scatterplot with line connection marks
 - -popular in journalism
 - -horiz + vert axes: value attribs
 - line connection marks: temporal order
 - -alternative to dual-axis charts
 - horiz: time
 - vert: two value attribs
- empirical study
 - -engaging, but correlation unclear



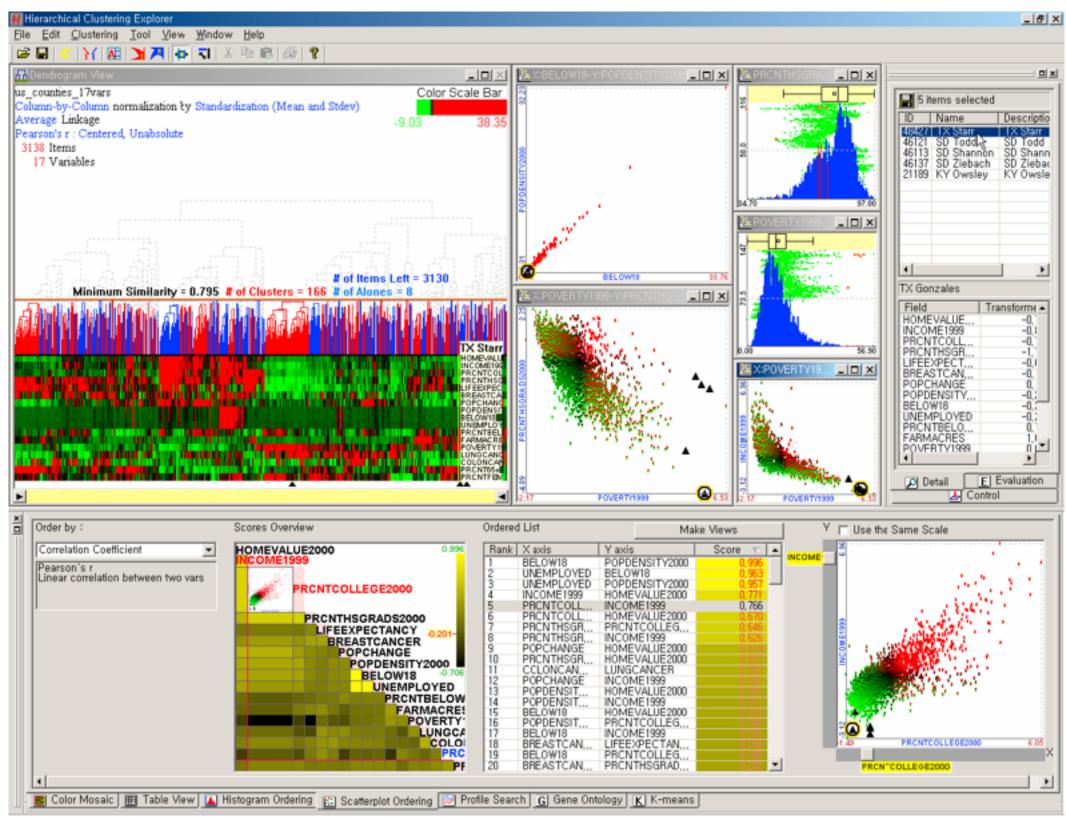
ing it out, brug the points to make your own connected soutterplot



http://steveharoz.com/research/connected_scatterplot/

System: Hierarchical Clustering Explorer

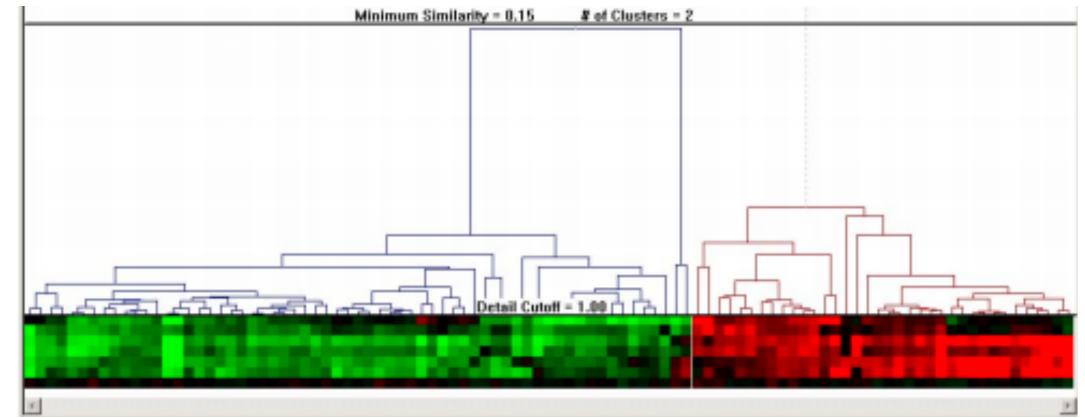
- many linked views
- cluster heatmap
 - dynamic aggregation: hierarchical clustering
 - explicitly visible

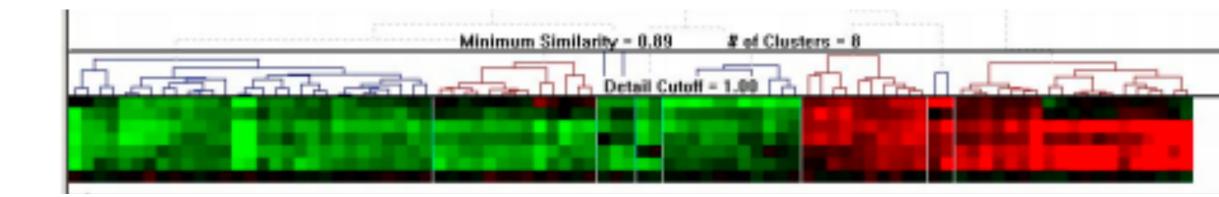


[http://www.cs.umd.edu/hcil/hce/]

System: Hierarchical Clustering Explorer

- drag line to change level of detail
 - coarse: 2 clusters





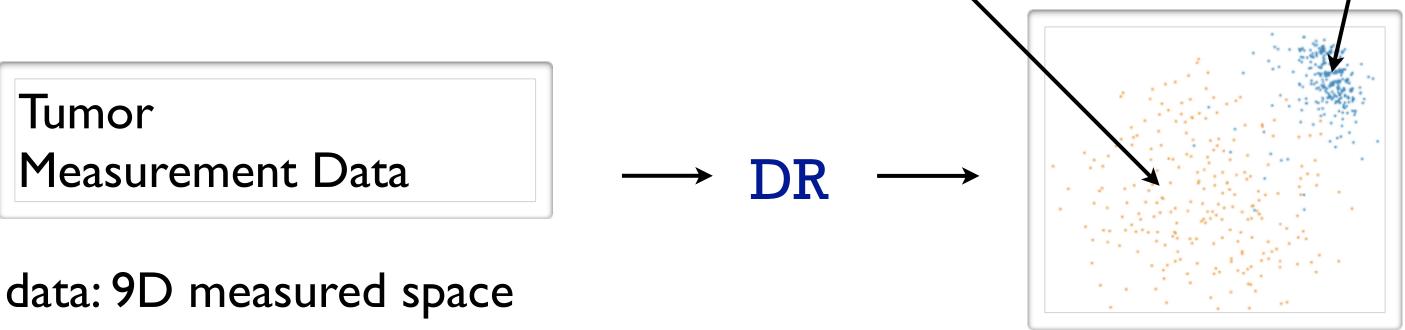
• fine: 8 clusters

[http://www.cs.umd.edu/hcil/hce/]

Dimensionality reduction

- attribute aggregation
 - -derive low-dimensional target space from high-dimensional measured space
 - capture most of variance with minimal error
 - -use when you can't directly measure what you care about
 - true dimensionality of dataset conjectured to be smaller than dimensionality of measurements
 - latent factors, hidden variables

Malignant

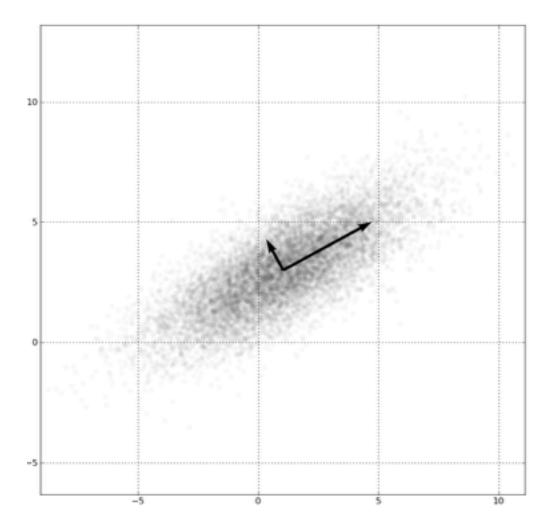


Benign

derived data: 2D target space

Linear dimensionality reduction

- principal components analysis (PCA)
 - -finding axes: first with most variance, second with next most, ...
 - -describe location of each point as linear combination of weights for each axis
 - mapping synthesized dims to original dims



[http://en.wikipedia.org/wiki/File:GaussianScatterPCA.png]

st, ... eights for each axis

Dimensionality vs attribute reduction

- vocab use in field not consistent -dimension/attribute
- attribute reduction: reduce set with filtering -includes orthographic projection
- dimensionality reduction: create smaller set of new dims/attribs -typically implies dimensional aggregation, not just filtering -vocab: projection/mapping

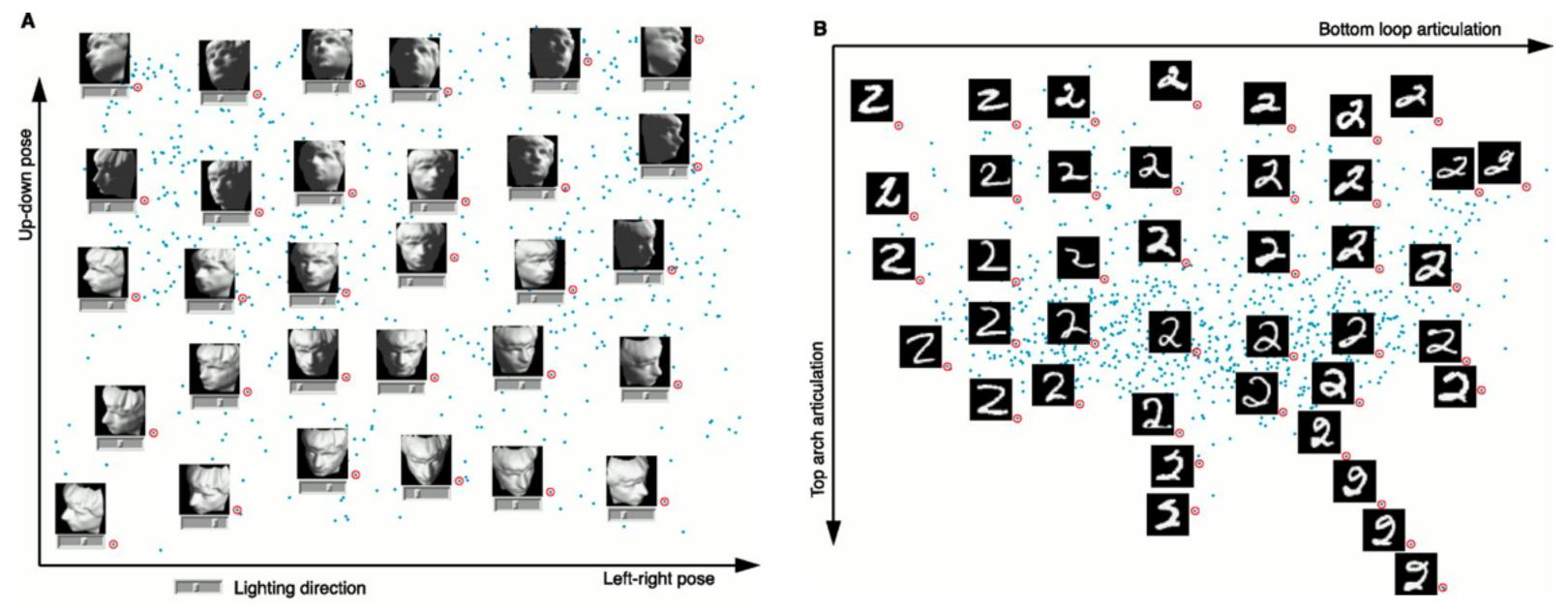
Dimensionality reduction & visualization

- why do people do DR?
 - -improve performance of downstream algorithm
 - avoid curse of dimensionality
 - data analysis
 - if look at the output: visual data analysis
- abstract tasks when visualizing DR data
 - dimension-oriented tasks
 - naming synthesized dims, mapping synthesized dims to original dims
 - cluster-oriented tasks
 - verifying clusters, naming clusters, matching clusters and classes

[Visualizing Dimensionally-Reduced Data: Interviews with Analysts and a Characterization of Task Sequences. Brehmer, SedImair, Ingram, and Munzner. Proc. BELIV 2014.]

Dimension-oriented tasks

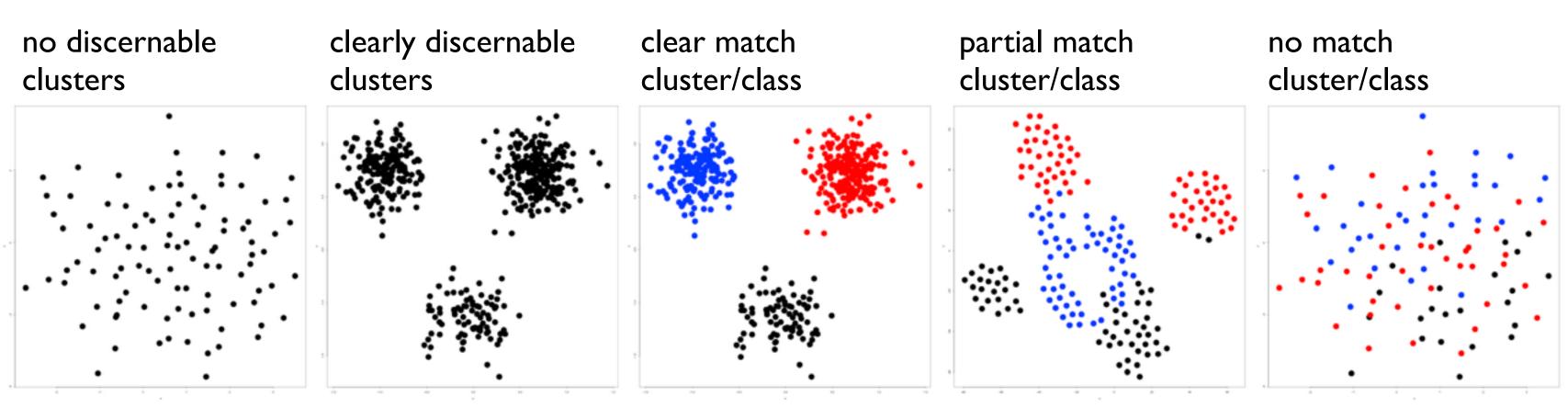
naming synthesized dims: inspect data represented by lowD points



[A global geometric framework for nonlinear dimensionality reduction. Tenenbaum, de Silva, and Langford. Science, 290(5500):2319–2323, 2000.]

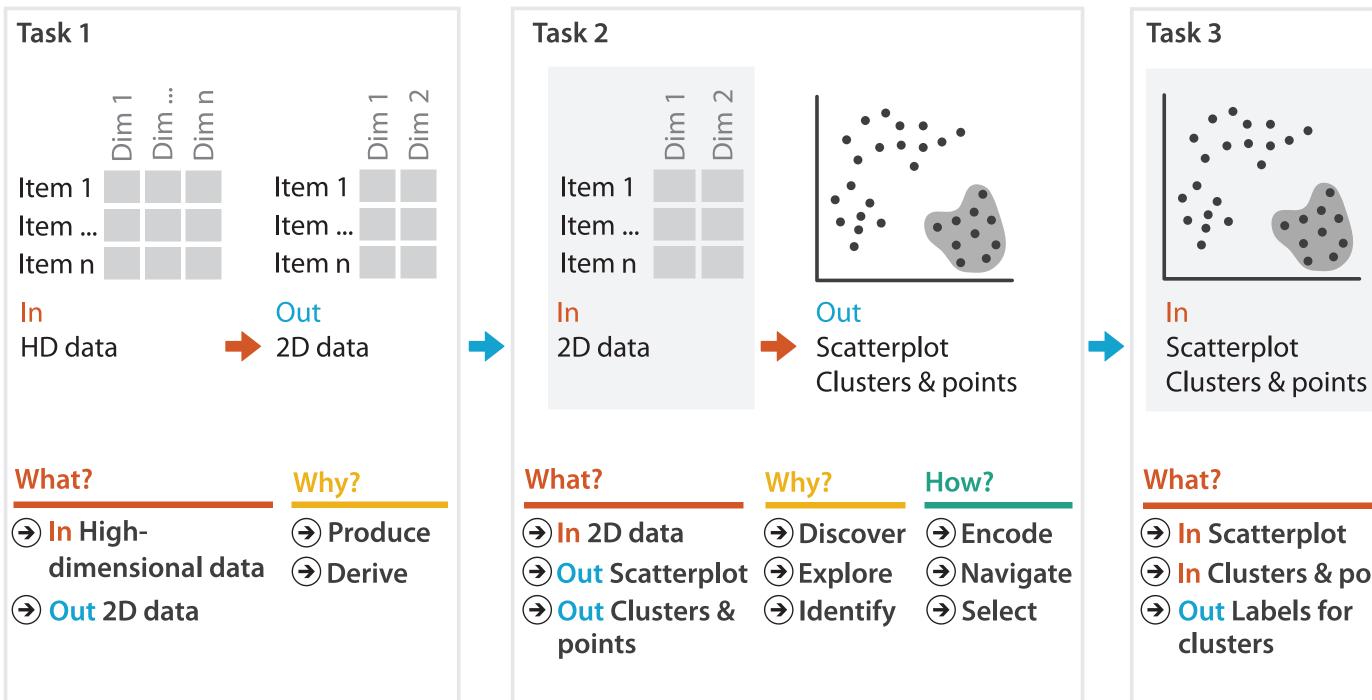
Cluster-oriented tasks

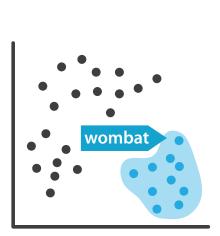
• verifying, naming, matching to classes



[Visualizing Dimensionally-Reduced Data: Interviews with Analysts and a Characterization of Task Sequences. Brehmer, SedImair, Ingram, and Munzner. Proc. BELIV 2014.]

Idiom: Dimensionality reduction for documents





Out Labels for clusters

- → In Clusters & points

Why?

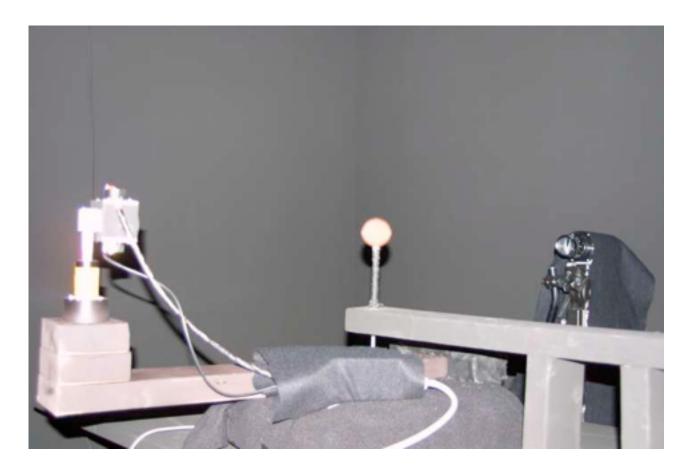
- → Produce
- → Annotate

Nonlinear dimensionality reduction

- pro: can handle curved rather than linear structure
- cons: lose all ties to original dims/attribs
 - -new dimensions often cannot be easily related to originals - mapping synthesized dims to original dims task is difficult
- many techniques proposed
 - -many literatures: visualization, machine learning, optimization, psychology, ...
 - -techniques: t-SNE, MDS (multidimensional scaling), charting, isomap, LLE,...
 - -t-SNE: excellent for clusters
 - but some trickiness remains: <u>http://distill.pub/2016/misread-tsne/</u>
 - -MDS: confusingly, entire family of techniques, both linear and nonlinear
 - minimize stress or strain metrics
 - early formulations equivalent to PCA

VDA with DR example: nonlinear vs linear

- DR for computer graphics reflectance model
 - -goal: simulate how light bounces off materials to make realistic pictures
 - computer graphics: BRDF (reflectance)
 - -idea: measure what light does with real materials

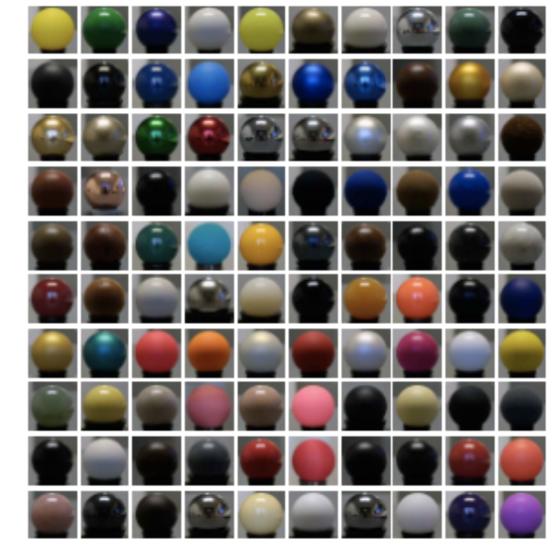


[Fig 2. Matusik, Pfister, Brand, and McMillan. A Data-Driven Reflectance Model. SIGGRAPH 2003]

Capturing & using material reflectance

- reflectance measurement: interaction of light with real materials (spheres)
- result: 104 high-res images of material
 - -each image 4M pixels
- goal: image synthesis
 - -simulate completely new materials
- need for more concise model
 - -104 materials * 4M pixels = 400M dims
 - -want concise model with meaningful knobs
 - how shiny/greasy/metallic
 - DR to the rescue!





SIGGRAPH 2003]

[Figs 5/6. Matusik et al. A Data-Driven Reflectance Model.

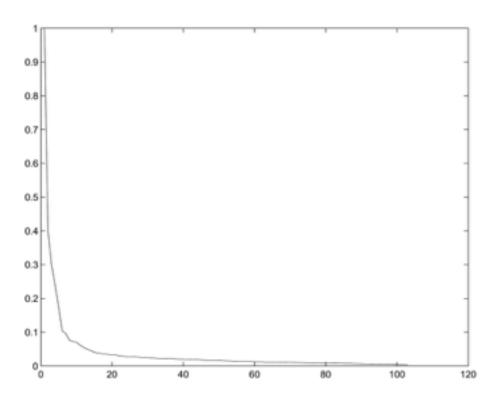
Linear DR

- first try: PCA (linear)
- result: error falls off sharply after ~45 dimensions
 scree plots: error vs number of dimensions in lowD projection
- problem: physically impossible intermediate points when simulating new materials
 – specular highlights cannot have holes!

[Figs 6/7. Matusik et al. A Data-Driven Reflectance Model. SIGGRAPH 2003]



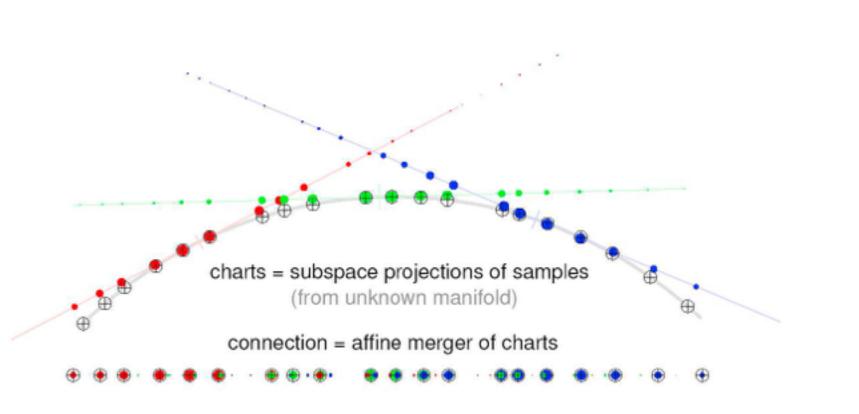


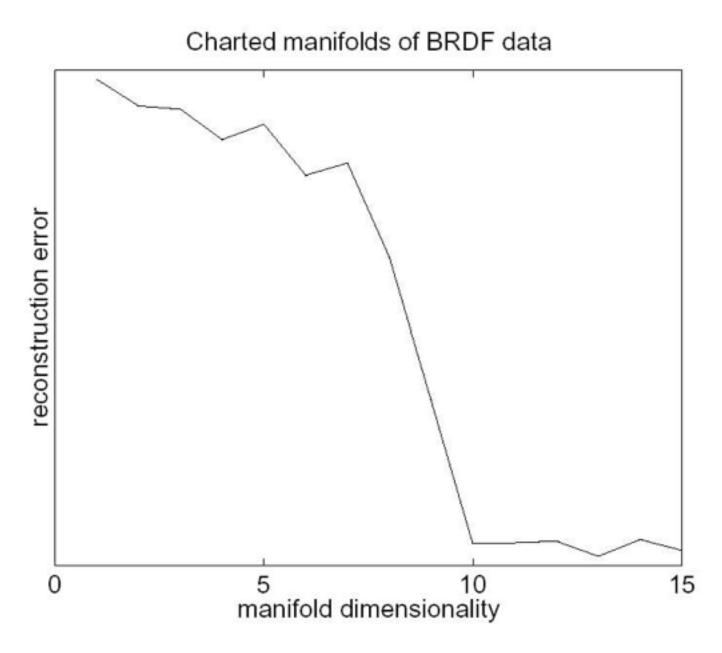




Nonlinear DR

- second try: charting (nonlinear DR technique)
 - -scree plot suggests 10-15 dims
 - note: dim estimate depends on technique used!



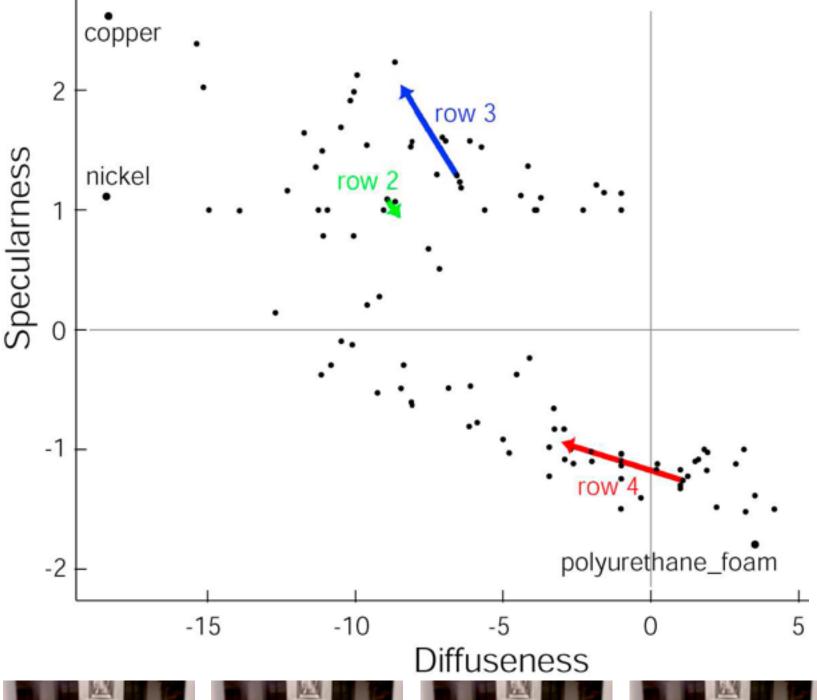


[Fig 10/11. Matusik et al. A Data-Driven Reflectance Model. SIGGRAPH 2003]

Finding semantics for synthetic dimensions

- look for meaning in scatterplots
 - synthetic dims created by algorithm but named by human analysts
 - points represent real-world images (spheres)
 - people inspect images corresponding to points to decide if axis could have meaningful name
- cross-check meaning
 - -arrows show simulated images (teapots) made from model
 - –check if those match dimension semantics

[Fig 12/16. Matusik et al. A Data-Driven Reflectance Model. SIGGRAPH 2003]



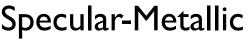


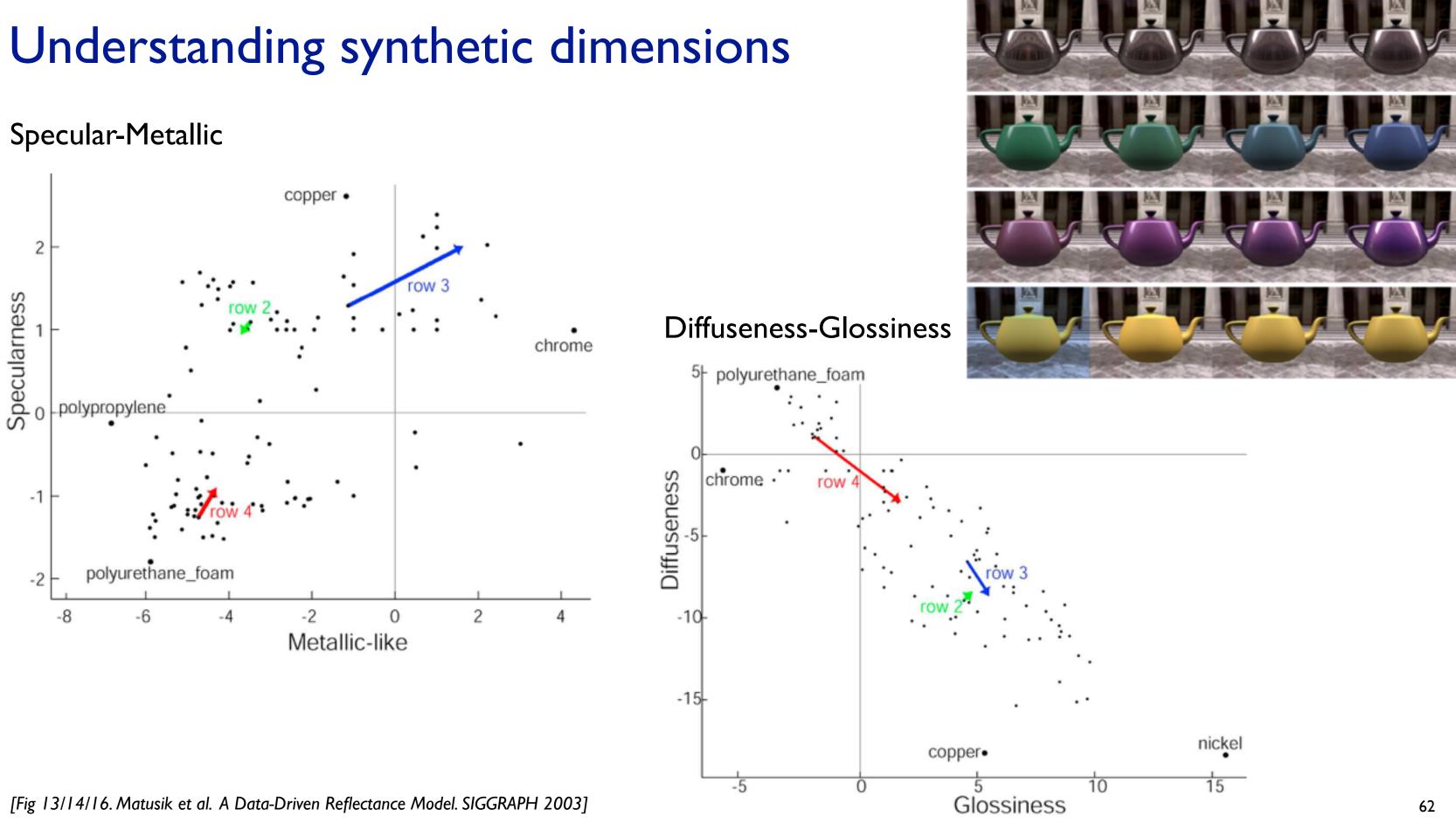
row 4











Further reading

 Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014.

-Chap 13: Reduce Items and Attributes

- Hierarchical Aggregation for Information Visualization: Overview, Techniques and Design Guidelines. Elmqvist and Fekete. IEEE Transactions on Visualization and Computer Graphics 16:3 (2010), 439–454.
- A Review of Overview+Detail, Zooming, and Focus+Context Interfaces. Cockburn, Karlson, and Bederson. ACM Computing Surveys 41:1 (2008), 1–31.
- A Guide to Visual Multi-Level Interface Design From Synthesis of Empirical Study Evidence. Lam and Munzner. Synthesis Lectures on Visualization Series, Morgan Claypool, 2010.