

Visualization Analysis & Design

Full-Day Tutorial

Session 3

Tamara Munzner

Department of Computer Science
University of British Columbia

*Sanger Institute / European Bioinformatics Institute
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<http://www.cs.ubc.ca/~tmm/talks.html#minicourse14>

Outline

- **Visualization Analysis Framework**
Session 1 9:30-10:45am
 - Introduction: Definitions
 - Analysis: What, Why, How
 - Marks and Channels
- **Idiom Design Choices, Part 2**
Session 3 1:15pm-2:45pm
 - **Manipulate: Change, Select, Navigate**
 - Facet: Juxtapose, Partition, Superimpose
 - Reduce: Filter, Aggregate, Embed
- **Idiom Design Choices**
Session 2 11:00am-12:15pm
 - Arrange Tables
 - Arrange Spatial Data
 - Arrange Networks and Trees
 - Map Color
- **Guidelines and Examples**
Session 4 3-4:30pm
 - Rules of Thumb
 - Validation
 - BioVis Analysis Example

Idiom design choices: Part I

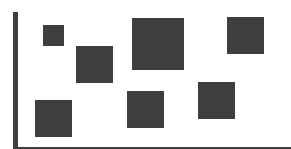
Encode

➔ Arrange

➔ Express



➔ Separate



➔ Order



➔ Align



➔ Use



➔ Map

from **categorical** and **ordered** attributes

➔ Color

➔ Hue



➔ Saturation



➔ Luminance



➔ Size, Angle, Curvature, ...

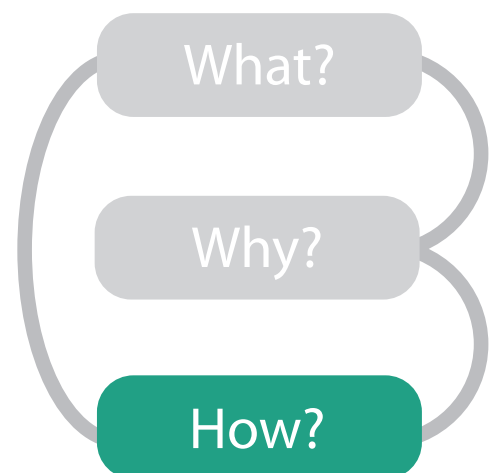


➔ Shape



➔ Motion

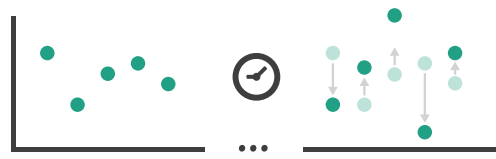
Direction, Rate, Frequency, ...



Idiom design choices: Part 2

Manipulate

→ Change



→ Select

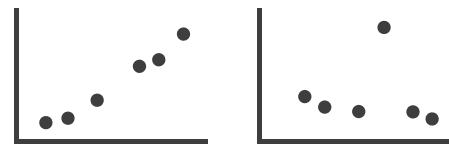


→ Navigate

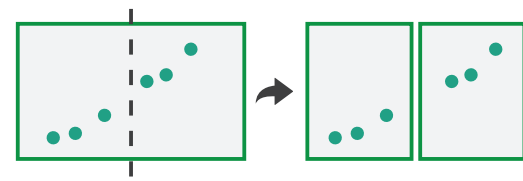


Facet

→ Juxtapose



→ Partition



→ Superimpose



Reduce

→ Filter



→ Aggregate

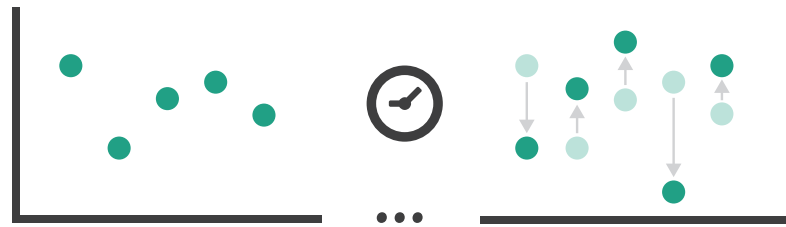


→ Embed



Manipulate

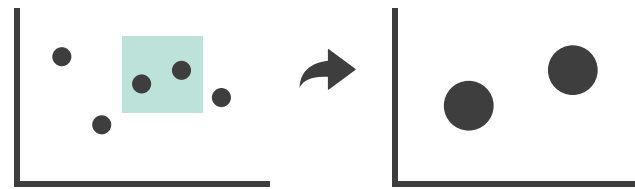
→ Change over Time



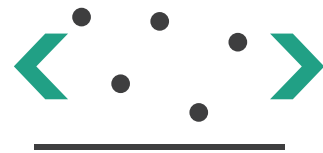
→ Navigate

→ Item Reduction

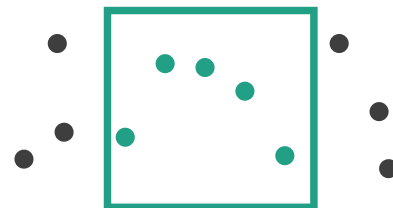
→ *Zoom*
Geometric or *Semantic*



→ *Pan/Translate*

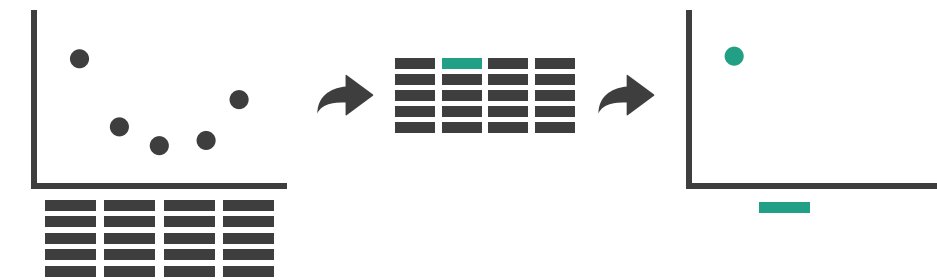


→ *Constrained*

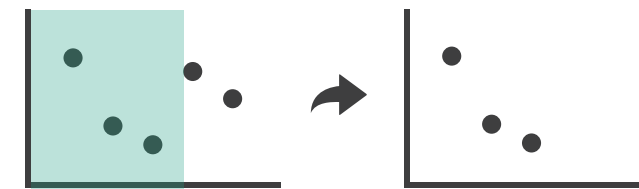


→ Attribute Reduction

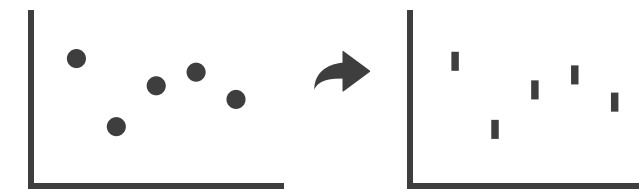
→ *Slice*



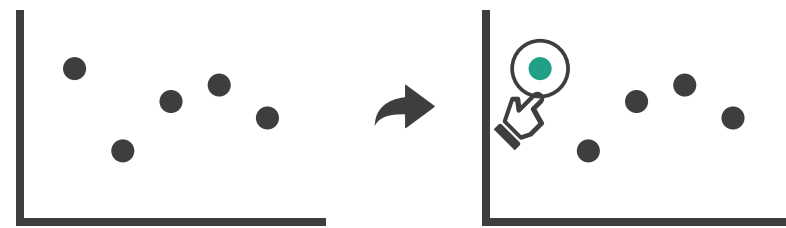
→ *Cut*



→ *Project*



→ Select

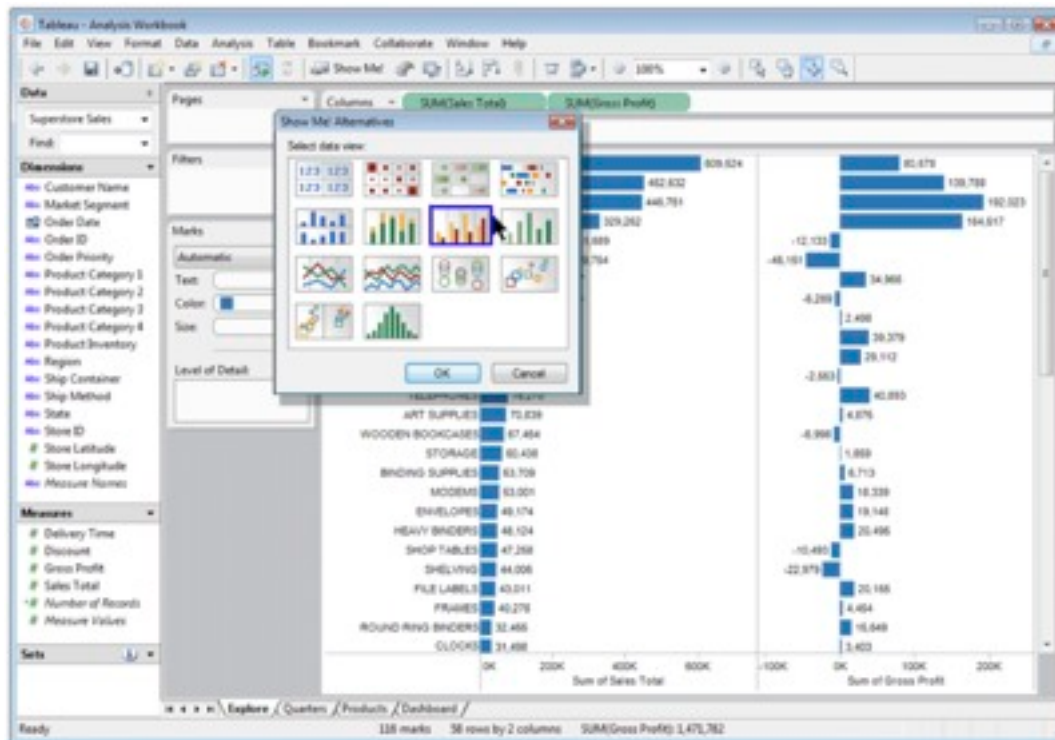
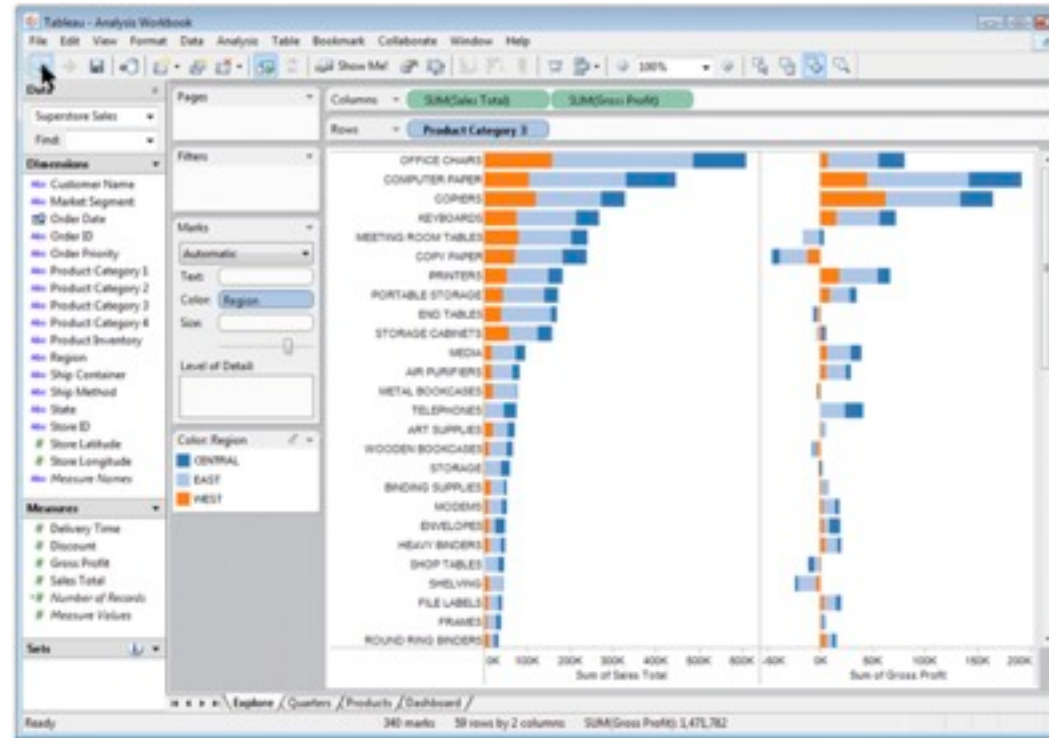
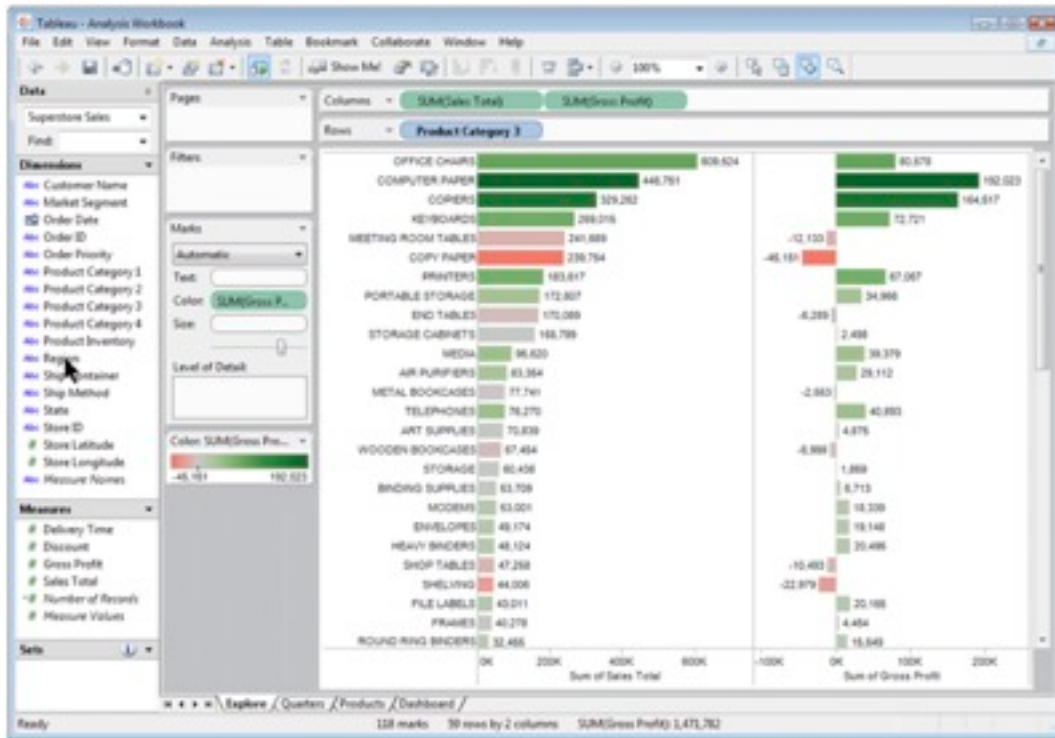


Change over time

- change any of the other choices
 - encoding itself
 - parameters
 - arrange: rearrange, reorder
 - aggregation level, what is filtered...
- why change?
 - one of four major strategies
 - change over time
 - facet data by partitioning into multiple views
 - reduce amount of data shown within view
 - embedding focus + context together
 - most obvious, powerful, flexible
 - interaction entails change

Idiom: Re-encode

System: Tableau

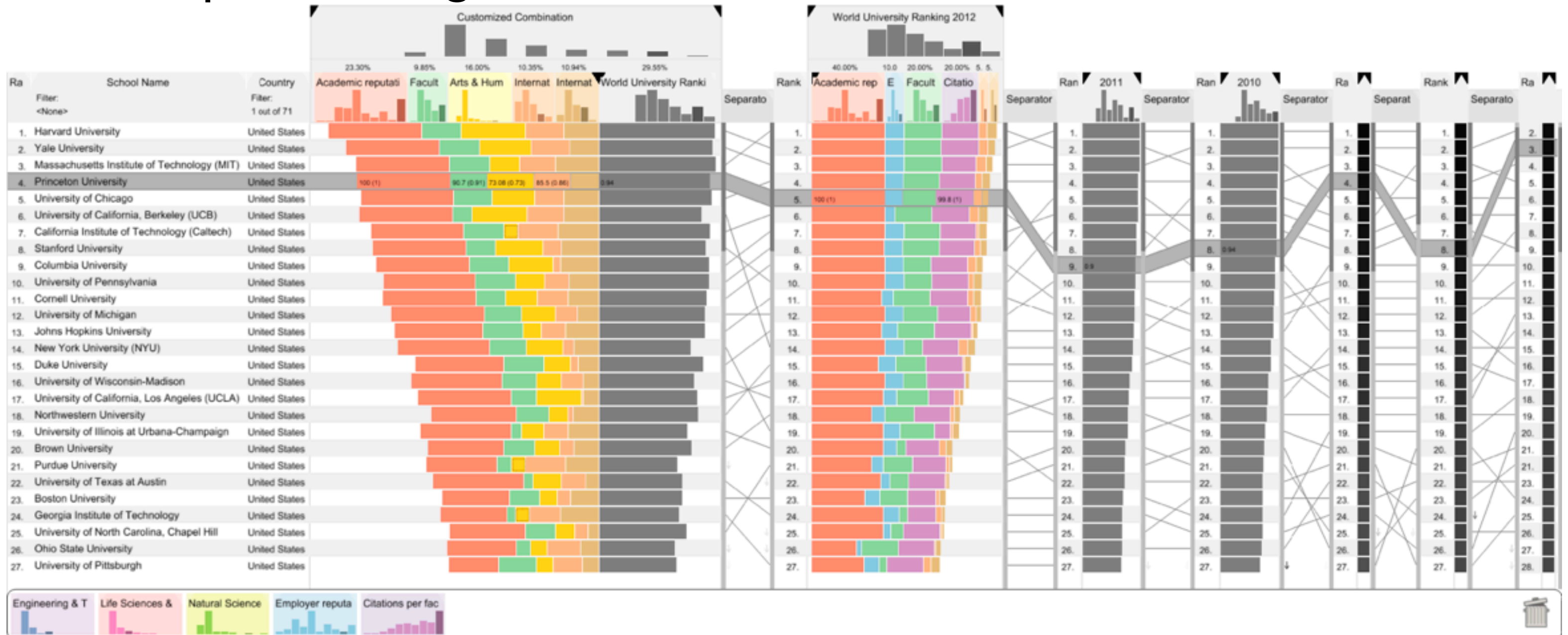


made using Tableau, <http://tableausoftware.com>

Idiom: Reorder

System: LineUp

- data: tables with many attributes
- task: compare rankings

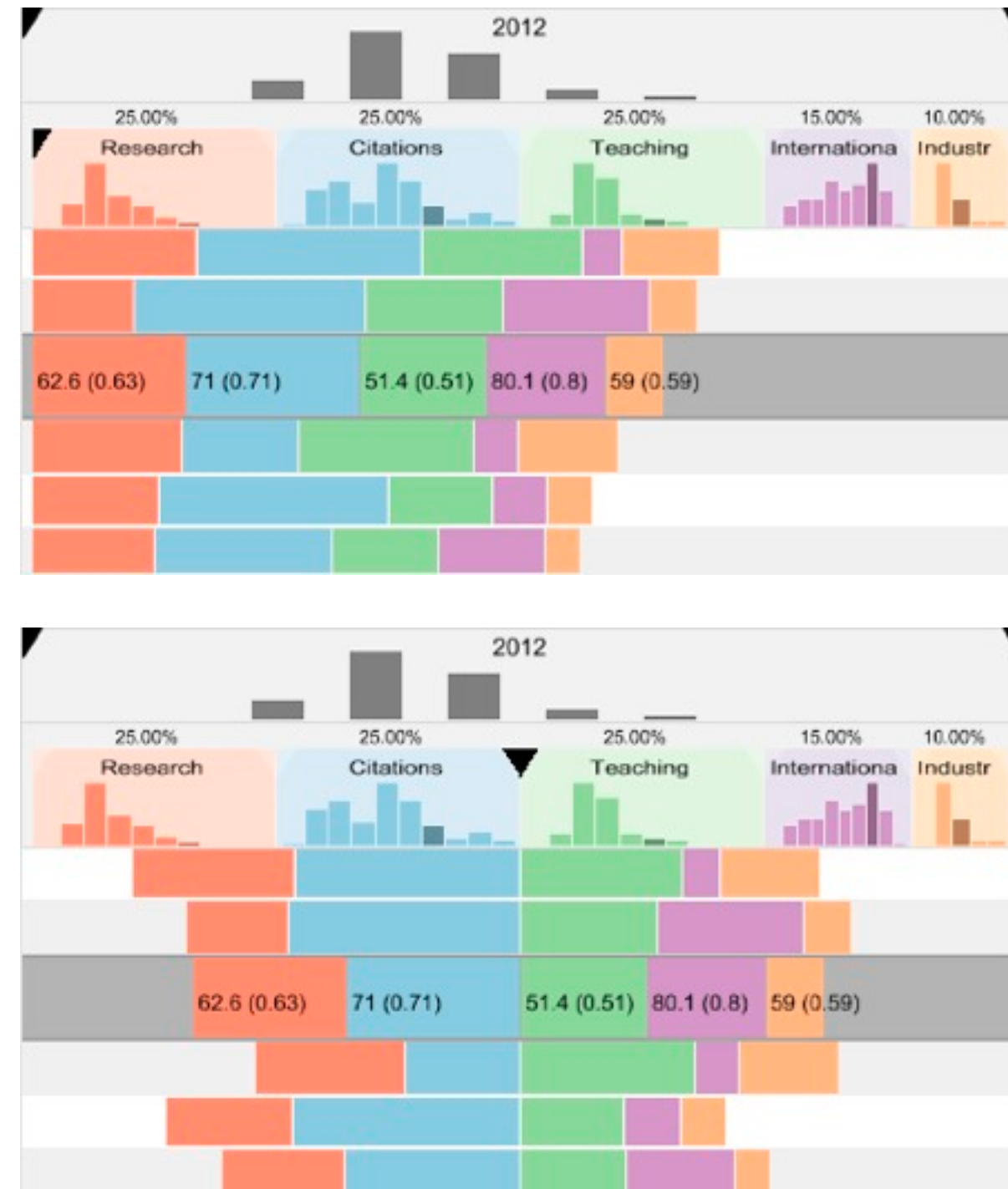


[LineUp: Visual Analysis of Multi-Attribute Rankings. Gratzl, Lex, Gehlenborg, Pfister, and Streit. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2013) 19:12 (2013), 2277–2286.]

Idiom: **Realign**

- stacked bars
 - easy to compare
 - first segment
 - total bar
- align to different segment
 - supports flexible comparison

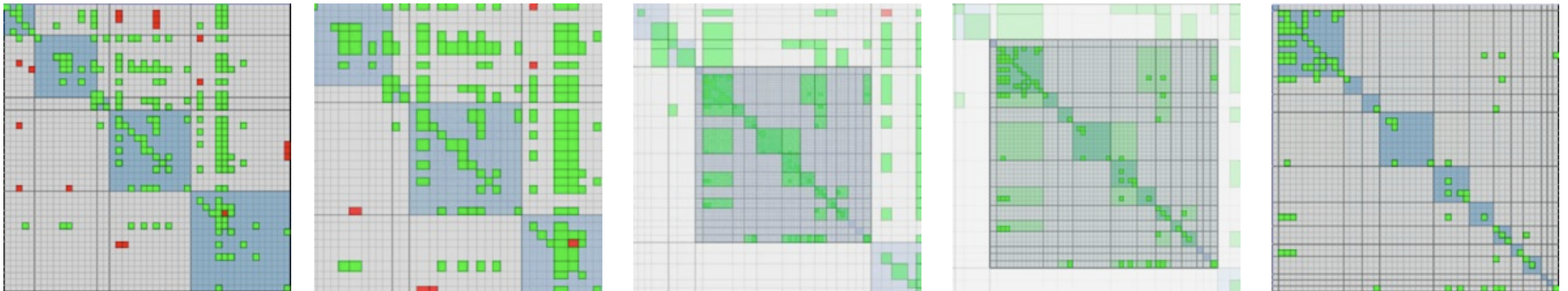
System: **LineUp**



[LineUp: Visual Analysis of Multi-Attribute Rankings. Gratzl, Lex, Gehlenborg, Pfister, and Streit. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2013) 19:12 (2013), 2277–2286.]

Idiom: **Animated transitions**

- smooth transition from one state to another
 - alternative to jump cuts
 - support for item tracking when amount of change is limited
- example: multilevel matrix views
 - scope of what is shown narrows down
 - middle block stretches to fill space, additional structure appears within
 - other blocks squish down to increasingly aggregated representations

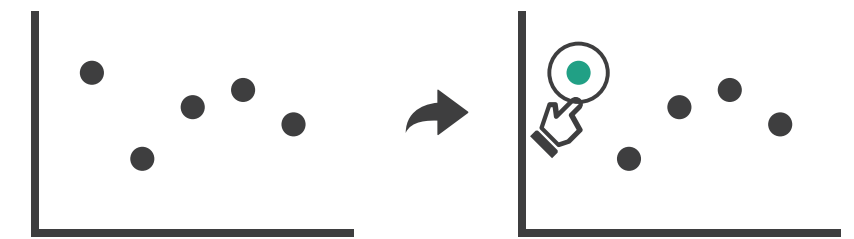


[Using Multilevel Call Matrices in Large Software Projects. van Ham. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 227–232, 2003.]

Select and highlight

- selection: basic operation for most interaction
- design choices
 - how many selection types?
 - click vs hover: heavyweight, lightweight
 - primary vs secondary: semantics (eg source/target)
- highlight: change visual encoding for selection targets
 - color
 - limitation: existing color coding hidden
 - other channels (eg motion)
 - add explicit connection marks between items

➔ Select



Navigate: Changing item visibility

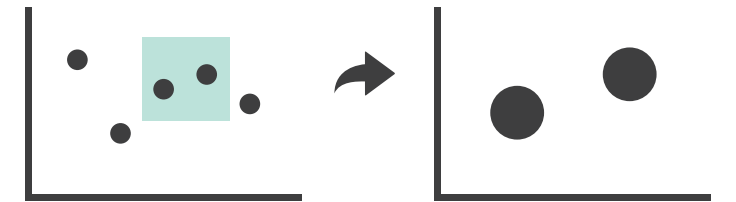
- change viewpoint
 - changes which items are visible within view
 - camera metaphor
 - zoom
 - geometric zoom: familiar semantics
 - semantic zoom: adapt object representation based on available pixels
 - » dramatic change, or more subtle one
 - pan/translate
 - rotate
 - especially in 3D
 - constrained navigation
 - often with animated transitions
 - often based on selection set

➔ Navigate

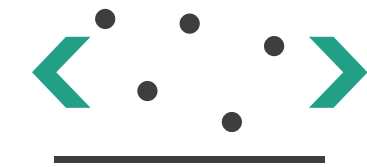
➔ Item Reduction

➔ Zoom

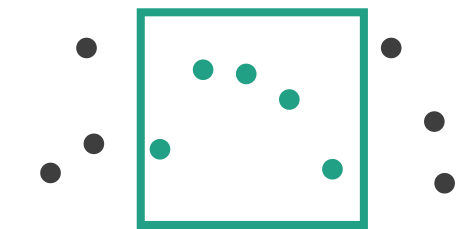
Geometric or *Semantic*



➔ Pan/Translate



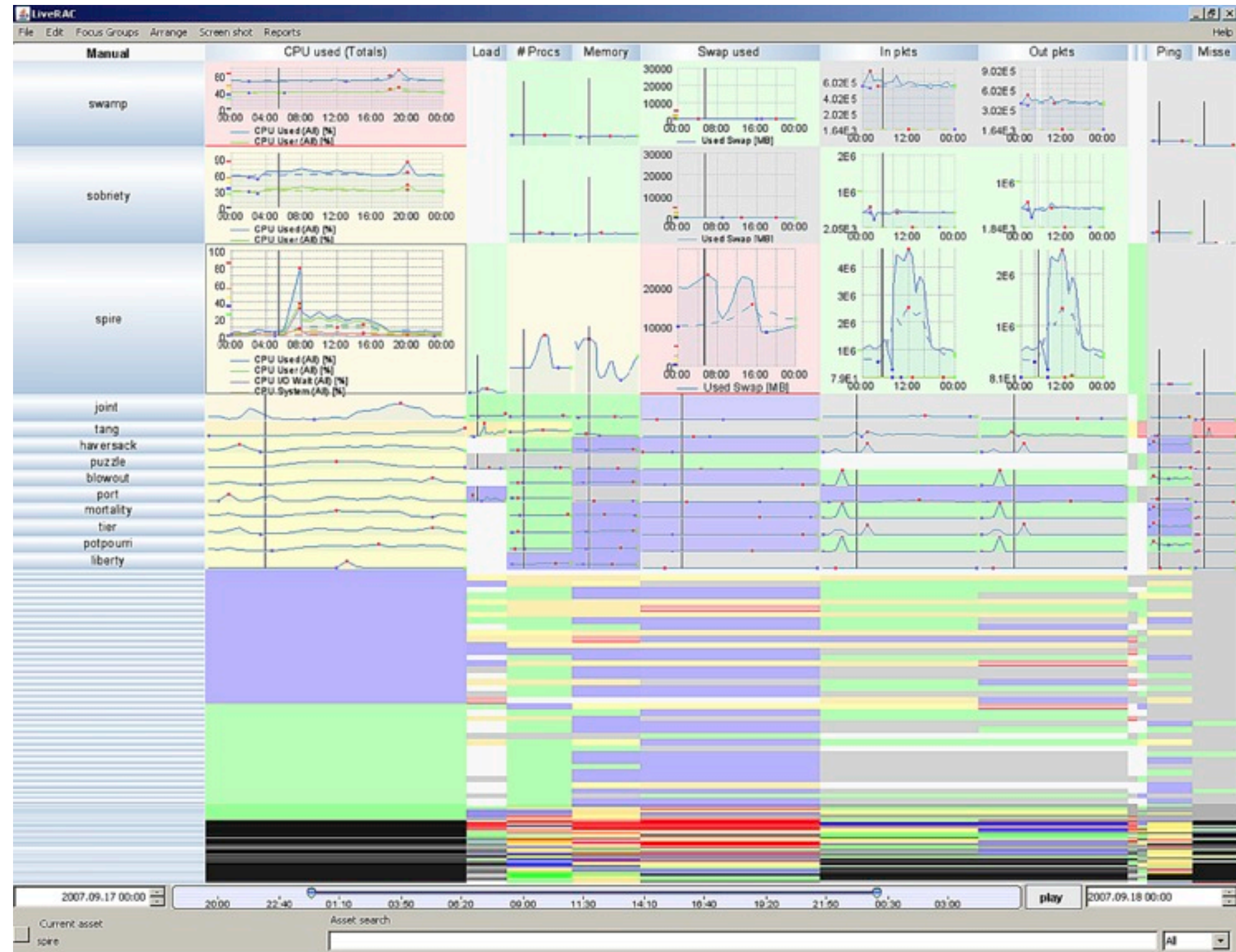
➔ Constrained



Idiom: Semantic zooming

System: LiveRAC

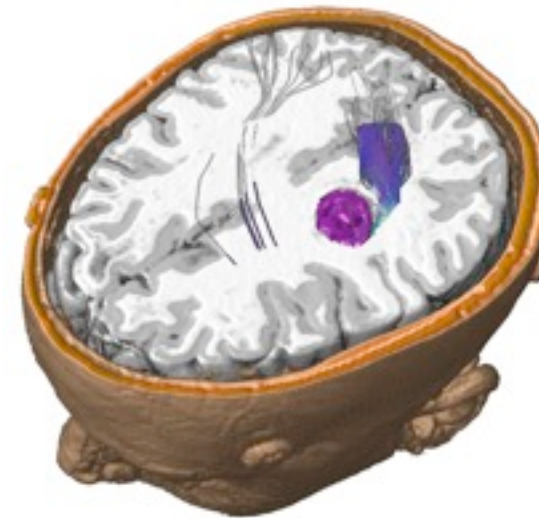
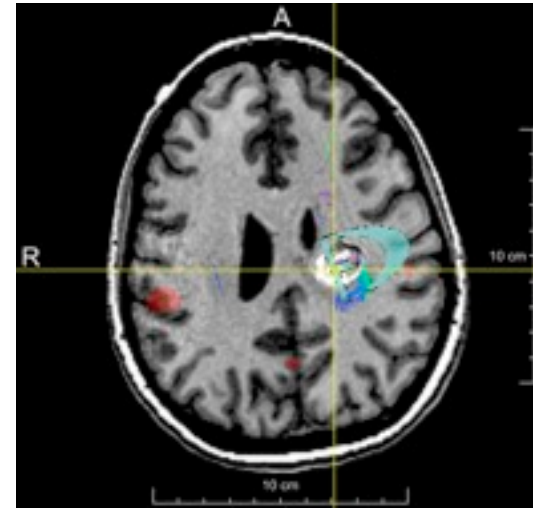
- visual encoding change
 - colored box
 - sparkline
 - simple line chart
 - full chart: axes and tickmarks



[LiveRAC - Interactive Visual Exploration of System Management Time-Series Data. McLachlan, Munzner, Koutsofios, and North. Proc. ACM Conf. Human Factors in Computing Systems (CHI), pp. 1483–1492, 2008.]

Navigate: Reducing attributes

- continuation of camera metaphor
 - slice
 - show only items matching specific value for given attribute: slicing plane
 - axis aligned, or arbitrary alignment
 - cut
 - show only items on far side of plane from camera
 - project
 - change mathematics of image creation
 - orthographic
 - perspective
 - many others: Mercator, cabinet, ...

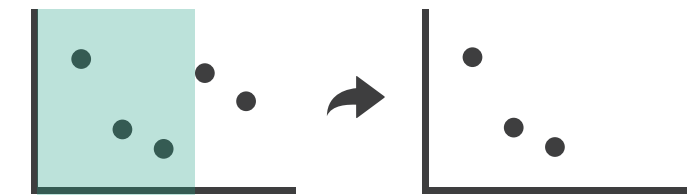


→ Attribute Reduction

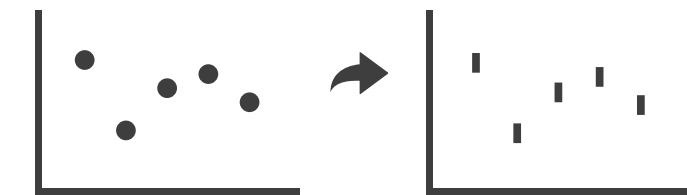
→ *Slice*



→ *Cut*



→ *Project*



Further reading

- Visualization Analysis and Design. Munzner. AK Peters / CRC Press, Oct 2014.
– *Chap 11: Manipulate View*
- *Animated Transitions in Statistical Data Graphics*. Heer and Robertson. IEEE Trans. on Visualization and Computer Graphics (Proc. InfoVis07) 13:6 (2007), 1240–1247.
- *Selection: 524,288 Ways to Say “This is Interesting”*. Wills. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 54–61, 1996.
- *Smooth and efficient zooming and panning*. van Wijk and Nuij. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 15–22, 2003.
- *Starting Simple - adding value to static visualisation through simple interaction*. Dix and Ellis. Proc. Advanced Visual Interfaces (AVI), pp. 124–134, 1998.

Outline

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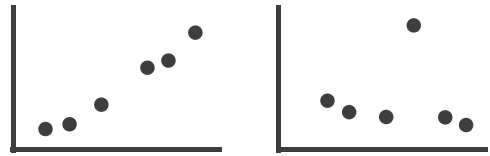
- **Guidelines and Examples**

Session 4 3-4:30pm

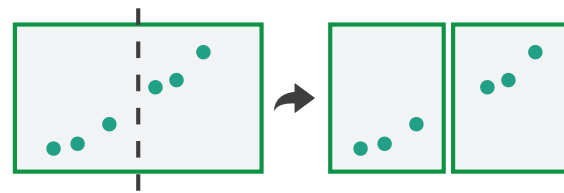
- Rules of Thumb
- Validation
- BioVis Analysis Example

Facet

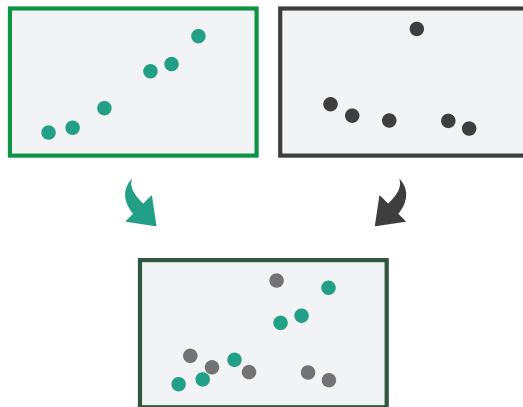
→ Juxtapose



→ Partition



→ Superimpose



Juxtapose and coordinate views

→ Share Encoding: Same/Different

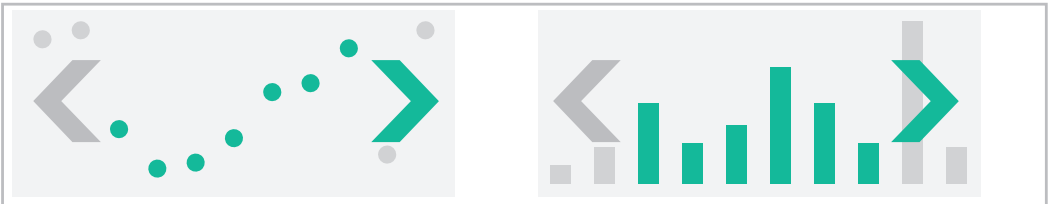
→ *Linked Highlighting*



→ Share Data: All/Subset/None



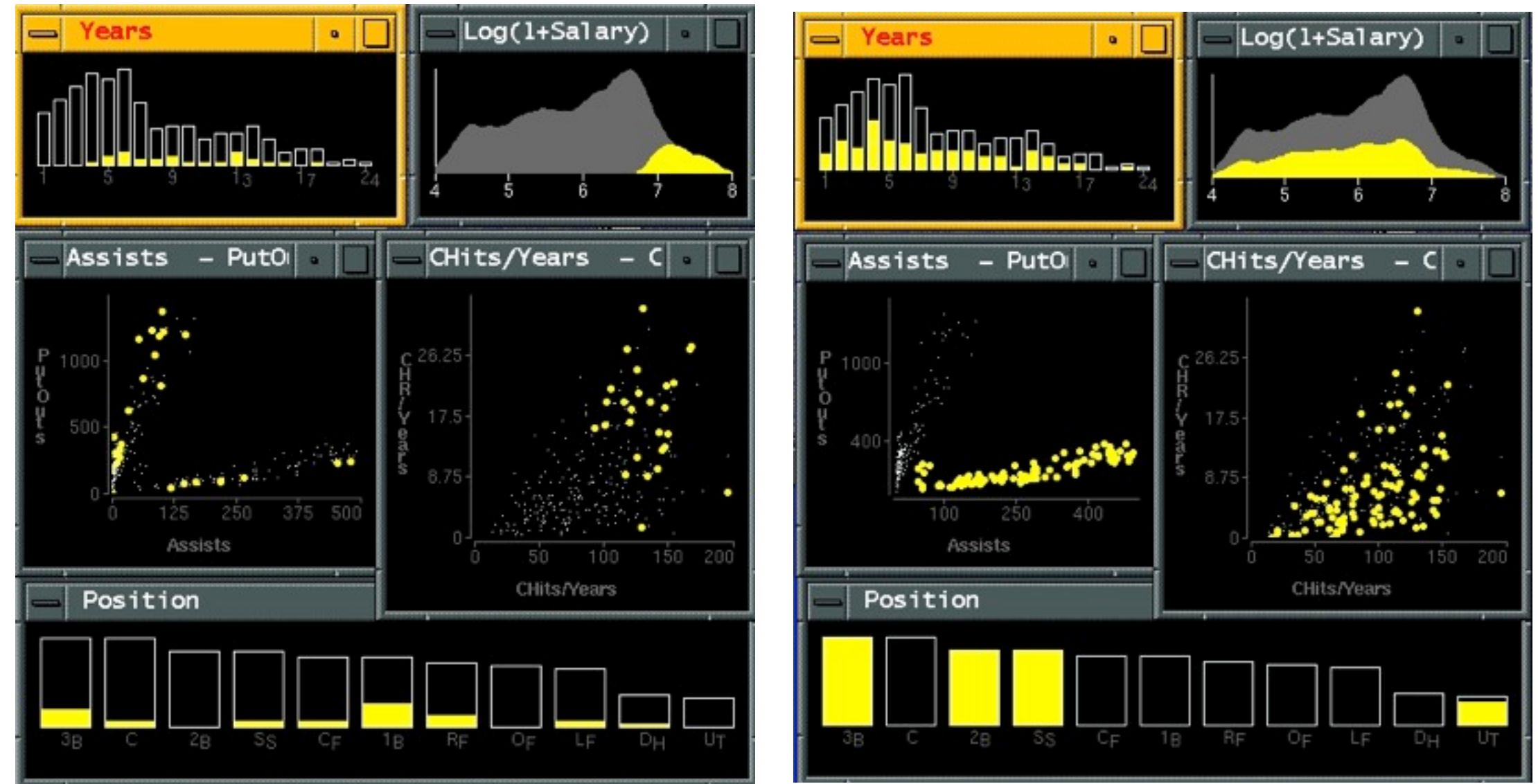
→ Share Navigation



Idiom: **Linked highlighting**

System: **EDV**

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



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

Idiom: **bird's-eye maps**

System: **Google Maps**

- encoding: same
- data: subset shared
- navigation: shared
 - bidirectional linking

- differences
 - viewpoint
 - (size)

- **overview-detail**

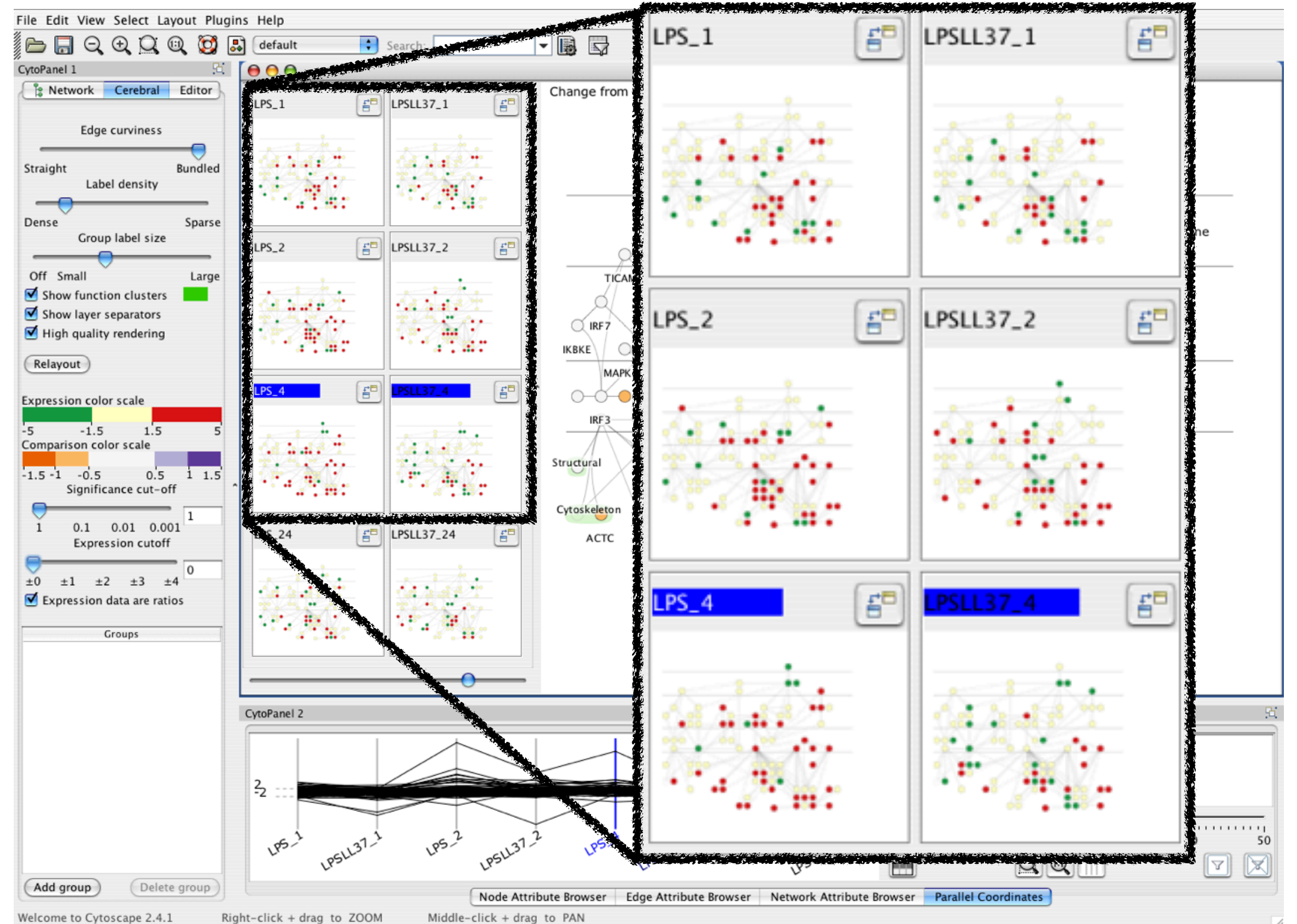


[A Review of Overview+Detail, Zooming, and Focus+Context Interfaces. Cockburn, Karlson, and Bederson. *ACM Computing Surveys* 41:1 (2008), 1–31.]

Idiom: **Small multiples**

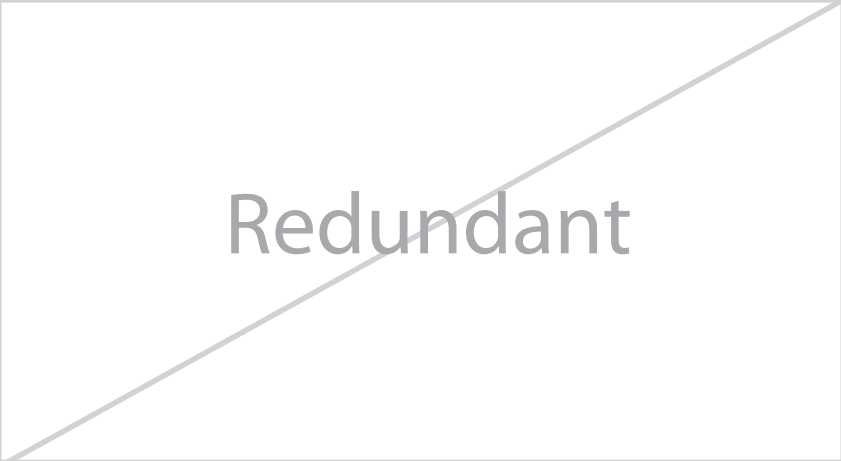
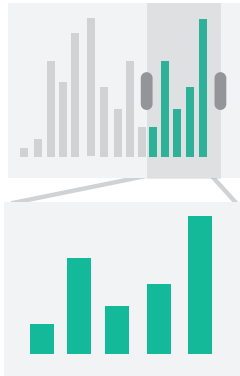
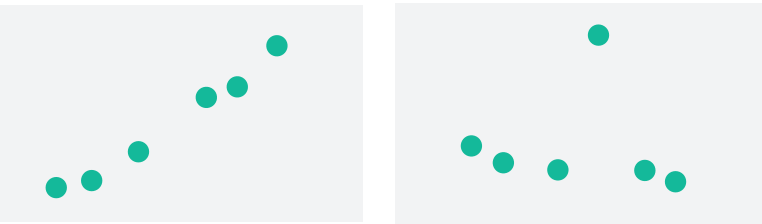



System: **Cerebral**

- 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.]

Coordinate views: Design choice interaction

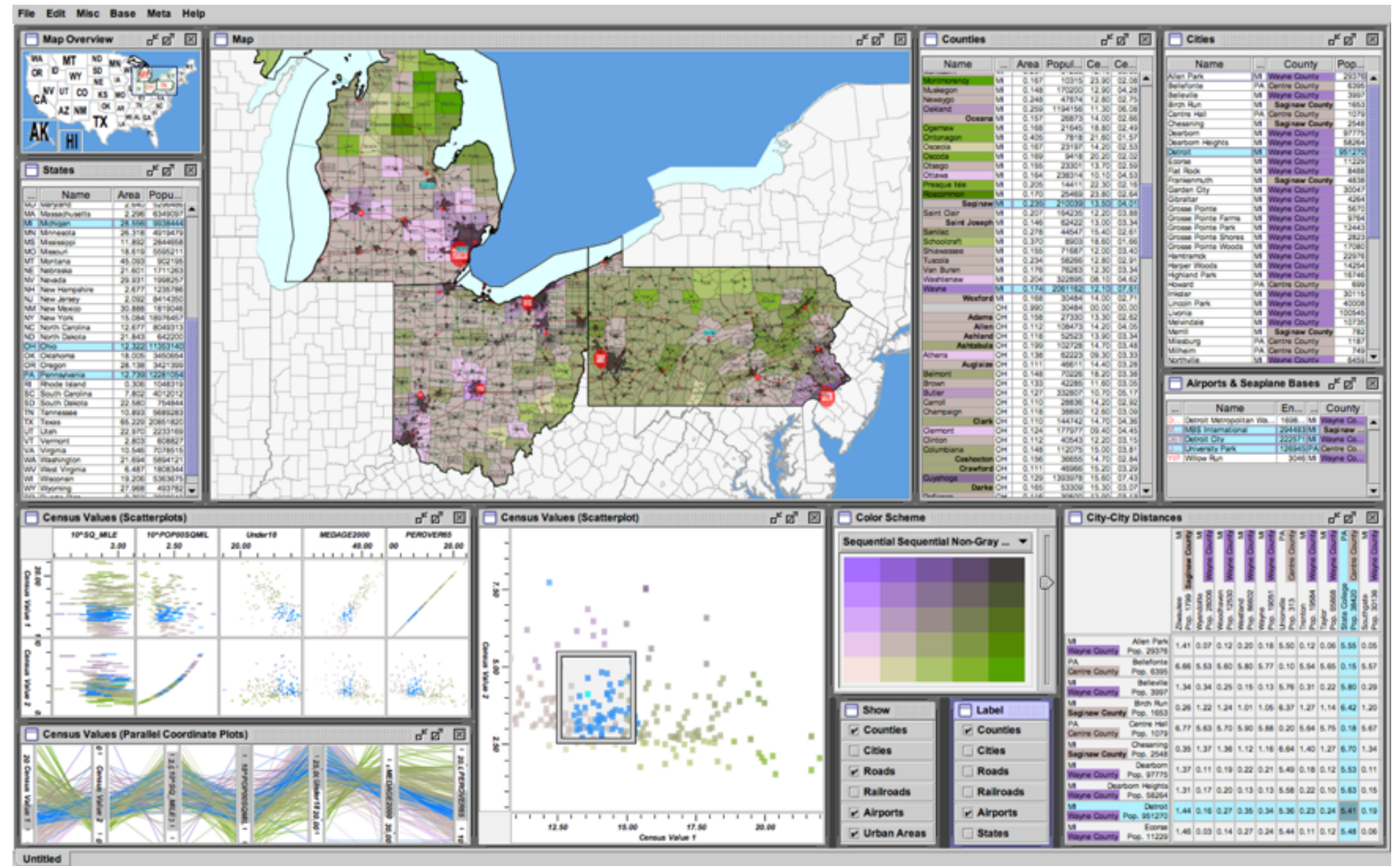
		Data		
		All	Subset	None
Encoding	Same	<p>Redundant</p> 	 <p>Overview/ Detail</p>	 <p>Small Multiples</p>
	Different	 <p>Multiform</p>	 <p>Multiform, Overview/ Detail</p>	<p>No Linkage</p> 

Juxtapose design choices

- design choices
 - view count
 - few vs many
 - how many is too many? open research question
 - view visibility
 - always side by side vs temporary popups
 - view arrangement
 - user managed vs system arranges/aligns
- why juxtapose views?
 - benefits: eyes vs memory
 - lower cognitive load to move eyes between 2 views than remembering previous state with 1
 - costs: display area
 - 2 views side by side each have only half the area of 1 view

System: Improvise

- investigate power of multiple views
 - pushing limits on view count, interaction complexity
 - reorderable lists
 - easy lookup
 - useful when linked to other encodings

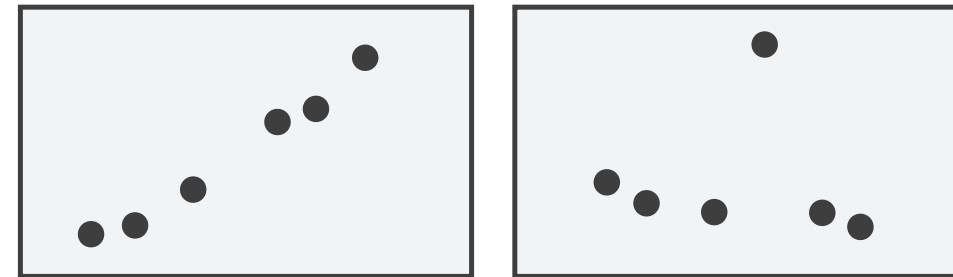


[Building Highly-Coordinated Visualizations In Improvise. Weaver. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 159–166, 2004.]

Partition into views

- how to divide data between views
 - encodes association between items using spatial proximity
 - major implications for what patterns are visible
 - split according to attributes
- design choices
 - how many splits
 - all the way down: one mark per region?
 - stop earlier, for more complex structure within region?
 - order in which attribs used to split
 - how many views

➔ Partition into Side-by-Side Views



Views and glyphs

- **view**

- contiguous region in which visually encoded data is shown on the display

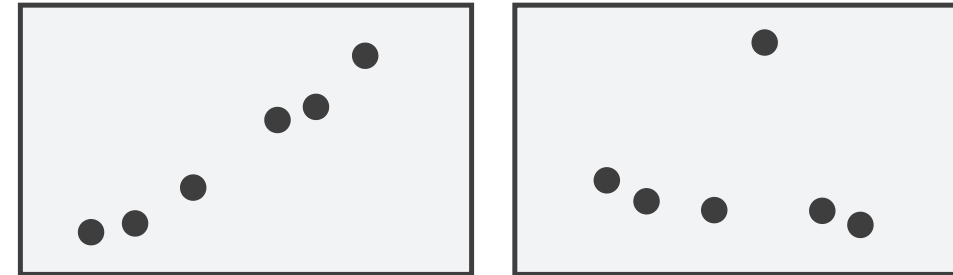
- **glyph**

- object with internal structure that arises from multiple marks

- no strict dividing line

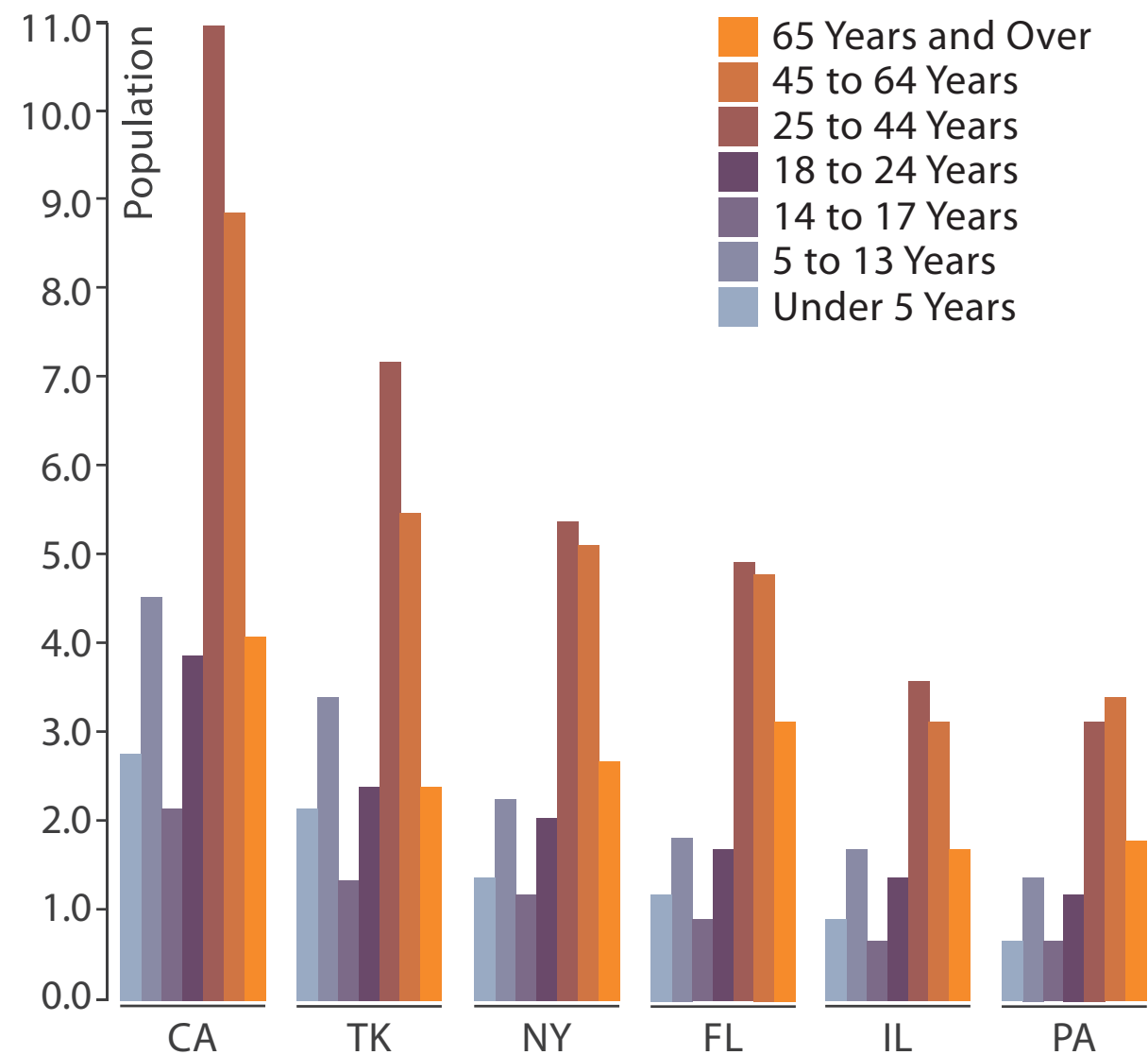
- view: big/detailed
- glyph: small/iconic

➔ Partition into Side-by-Side Views

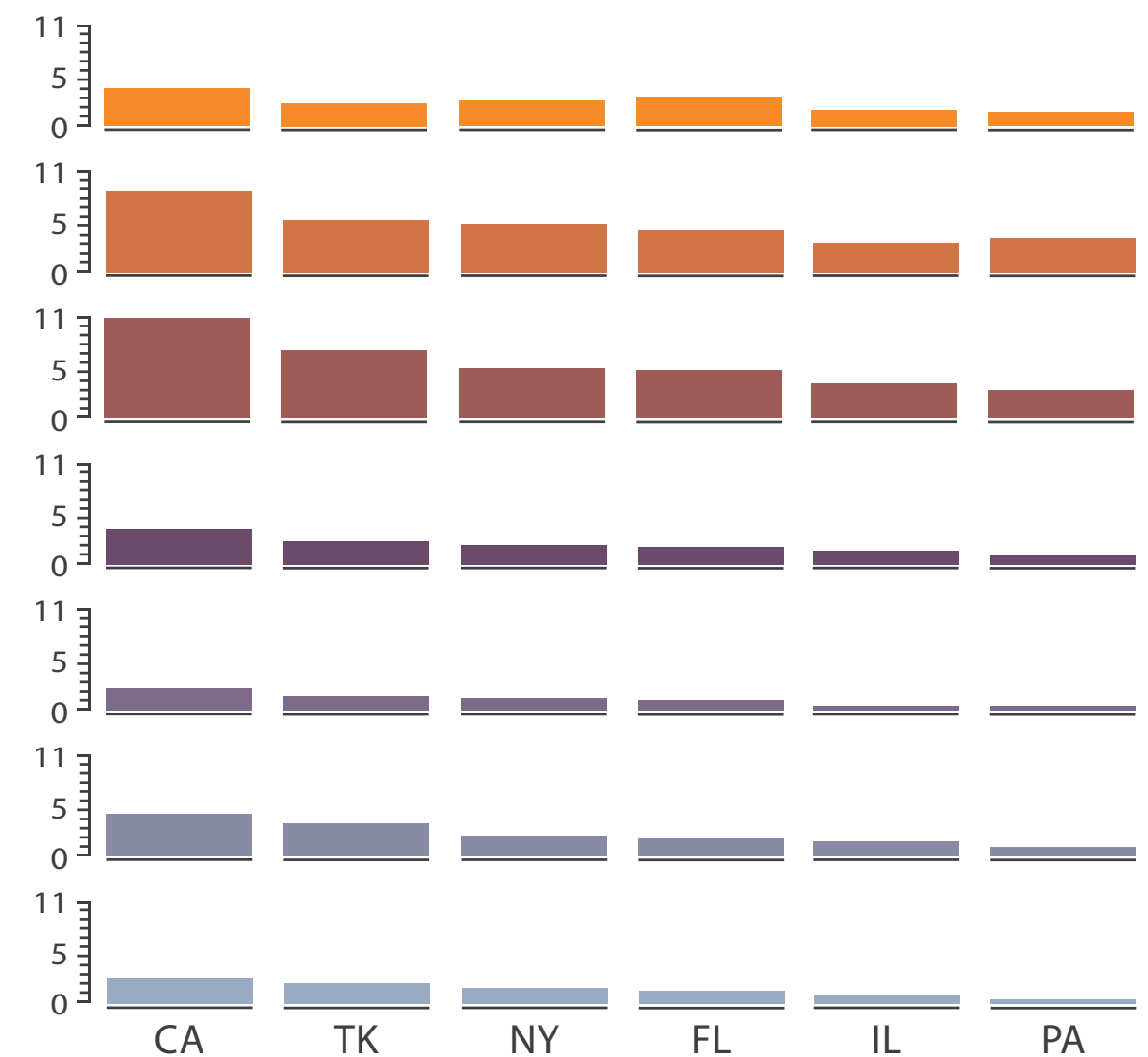


Partitioning: List alignment

- 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



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



Partitioning: Recursive subdivision

System: **HIVE**

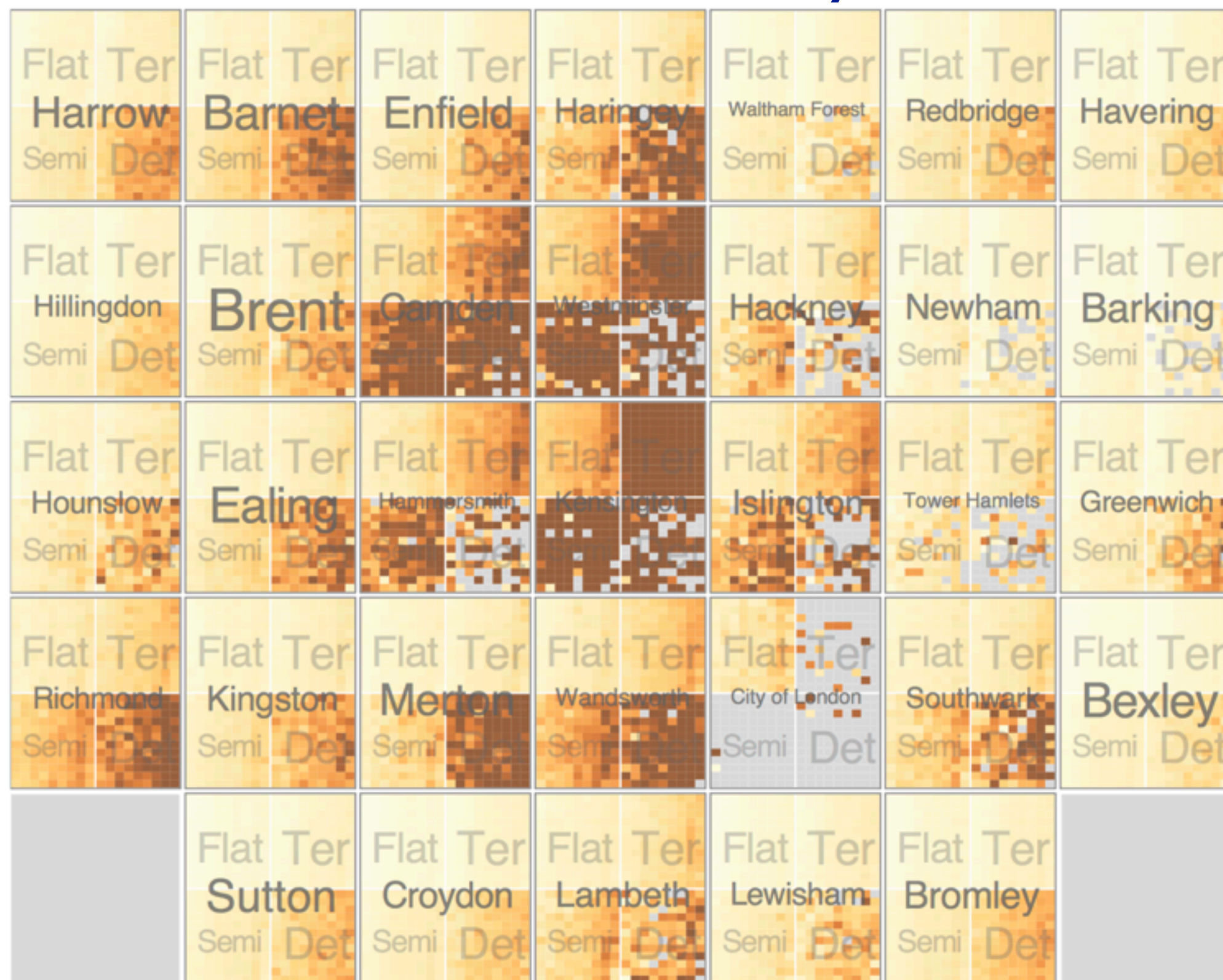
- split by type
- then by neighborhood
- then time
 - years as rows
 - months as columns



Partitioning: Recursive subdivision

System: **HIVE**

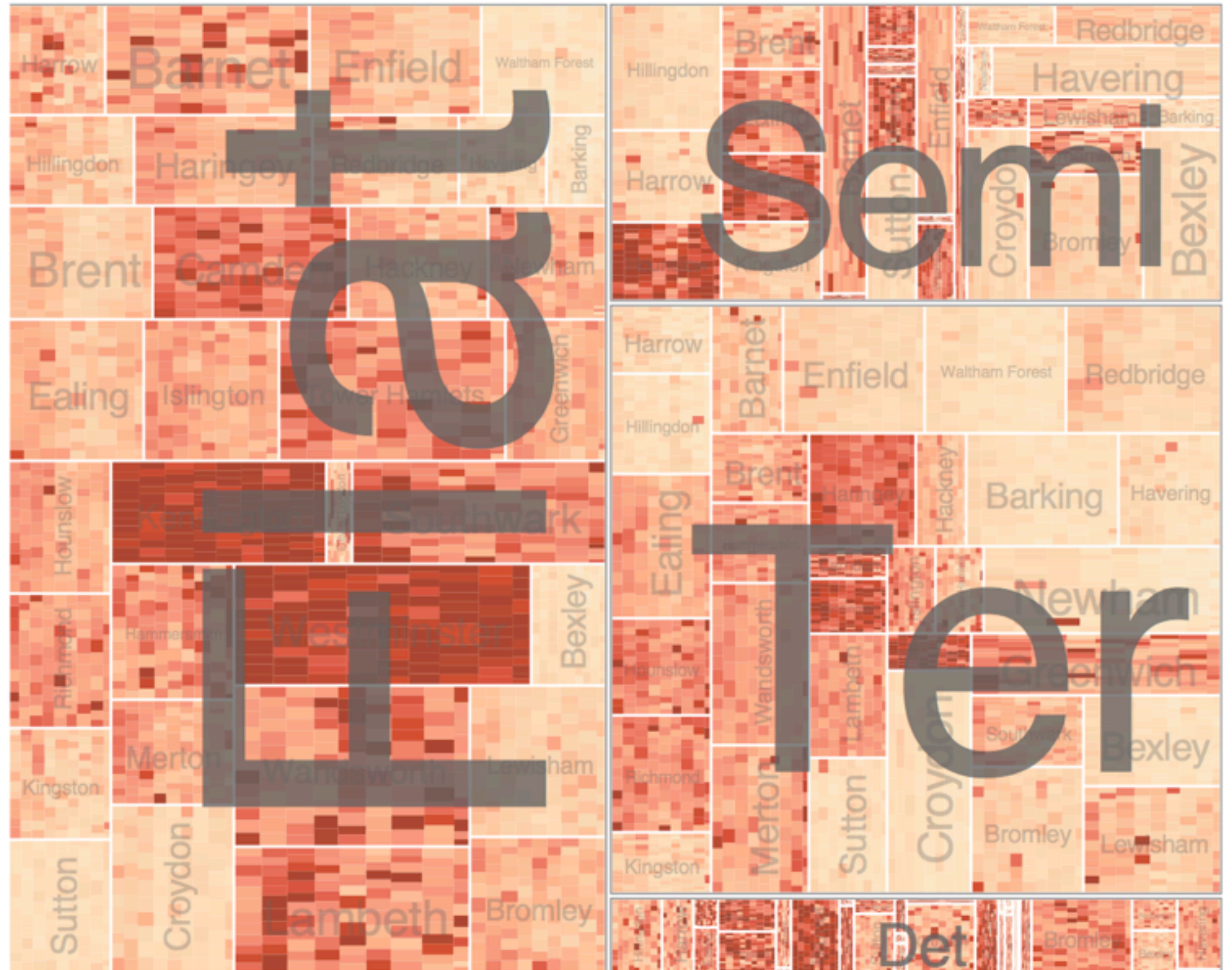
- switch order of splits
 - neighborhood then type
- very different patterns



Partitioning: Recursive subdivision

System: **HIVE**

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

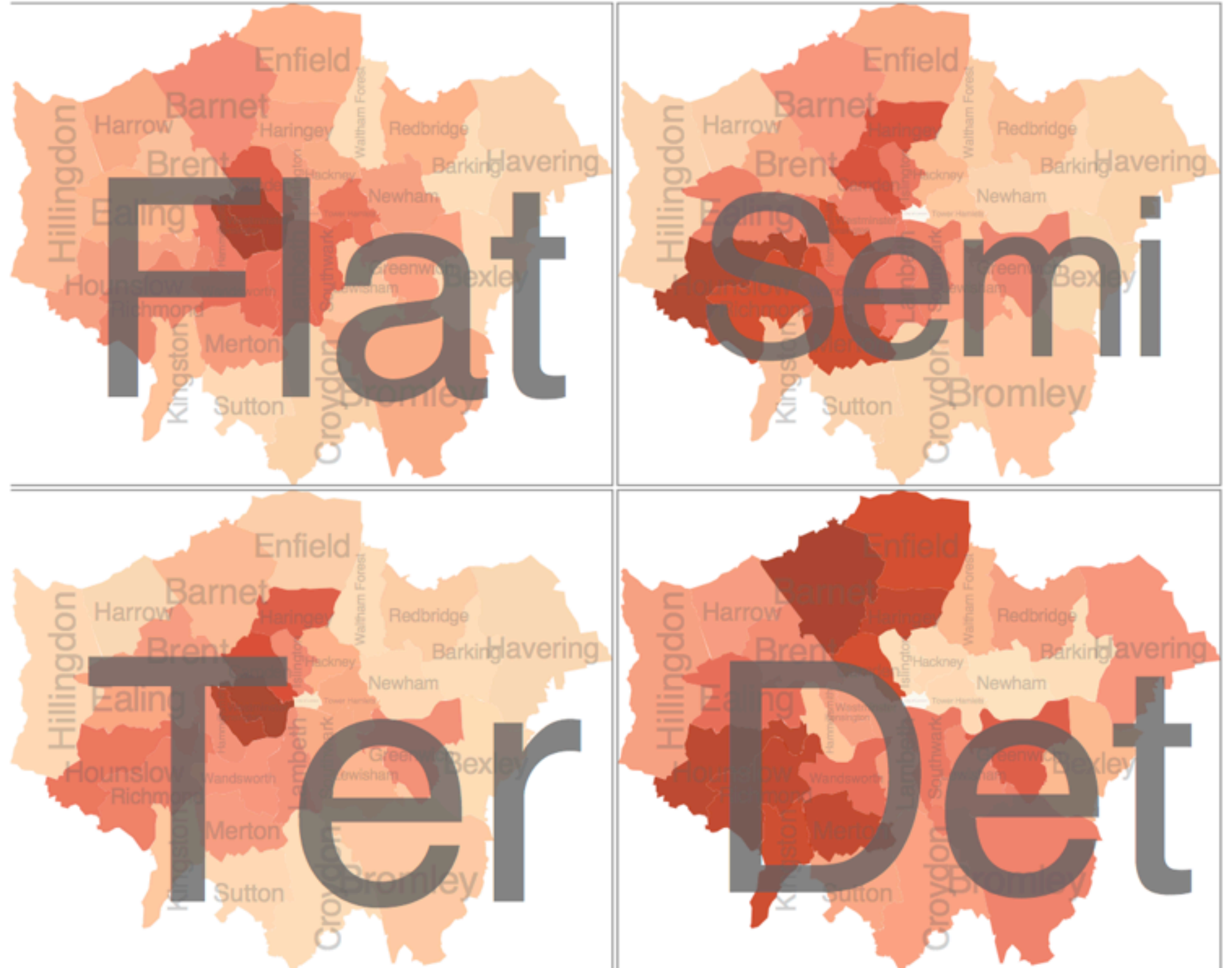


[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. *IEEE Transactions on Visualization and Computer Graphics* (Proc. InfoVis 2009) 15:6 (2009), 977–984.]

Partitioning: Recursive subdivision

System: **HIVE**

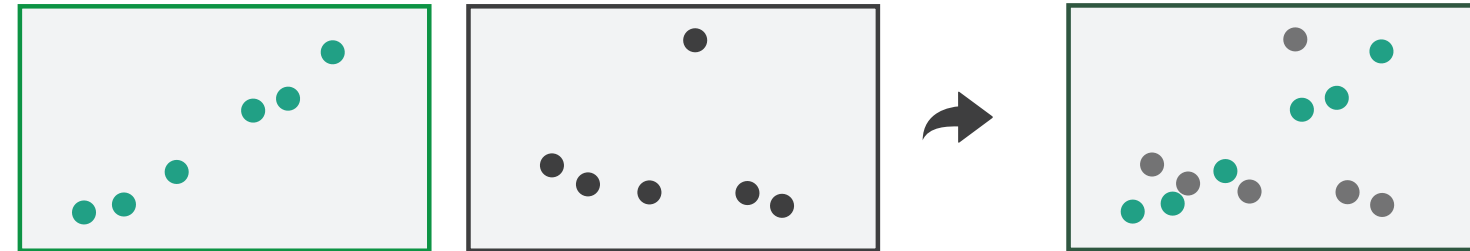
- different encoding for second-level regions
 - choropleth maps



Superimpose layers

- **layer**: set of objects spread out over region
 - each set is visually distinguishable group
 - extent: whole view
- design choices
 - how many layers?
 - how are layers distinguished?
 - small static set or dynamic from many possible?
 - how partitioned?
 - heavyweight with attribs vs lightweight with selection
- distinguishable layers
 - encode with different, nonoverlapping channels
 - two layers achievable, three with careful design

➔ Superimpose Layers



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

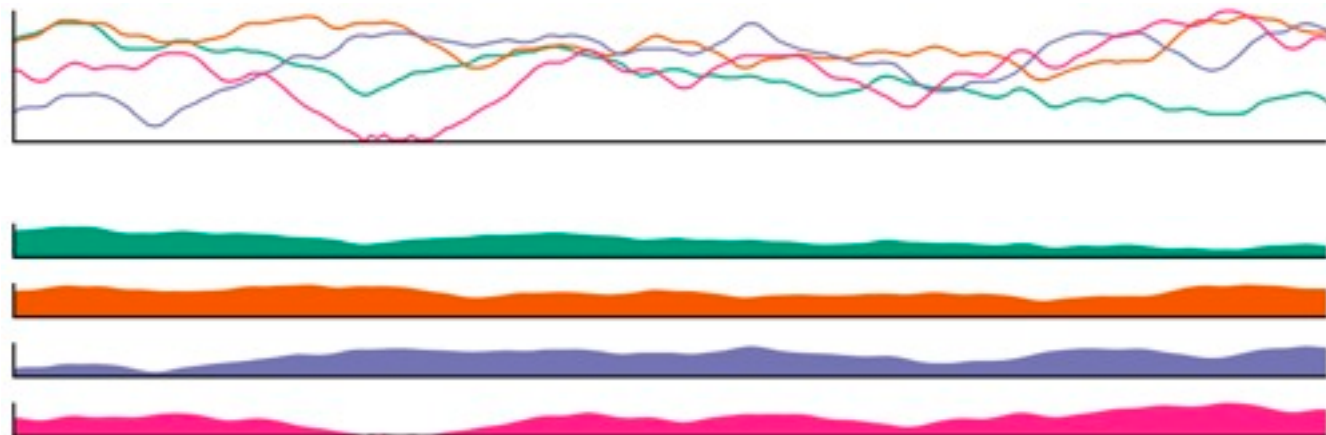


[Get it right in black and white. Stone. 2010.

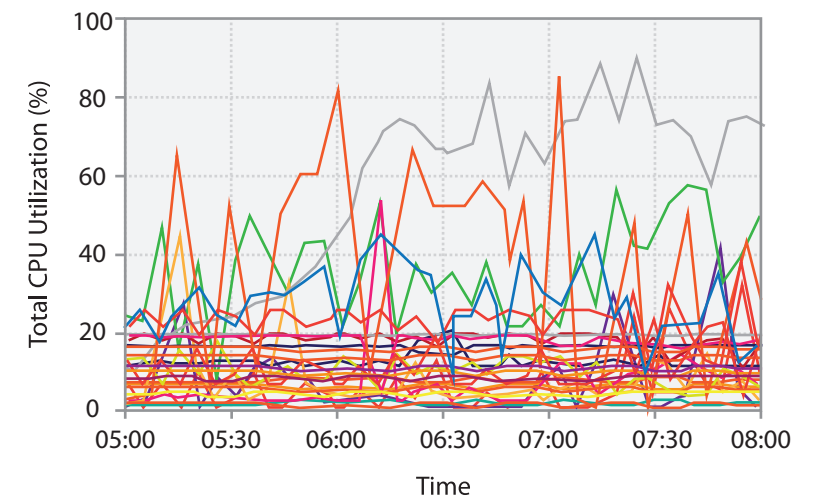
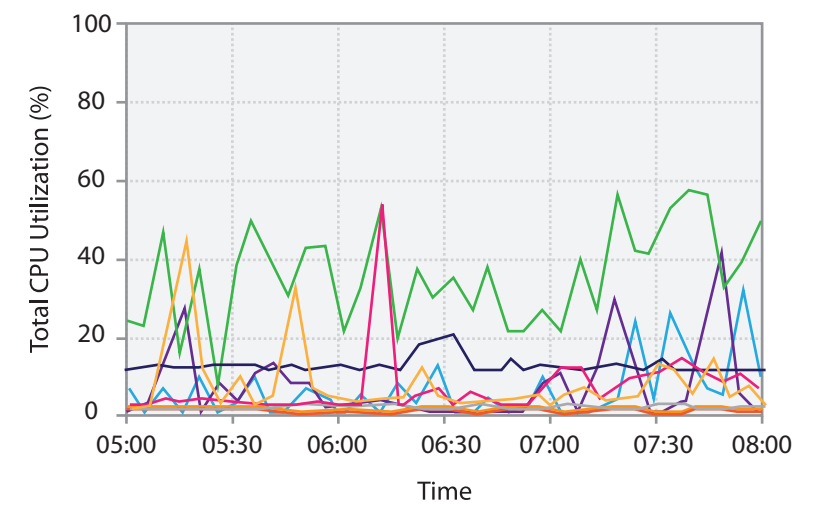
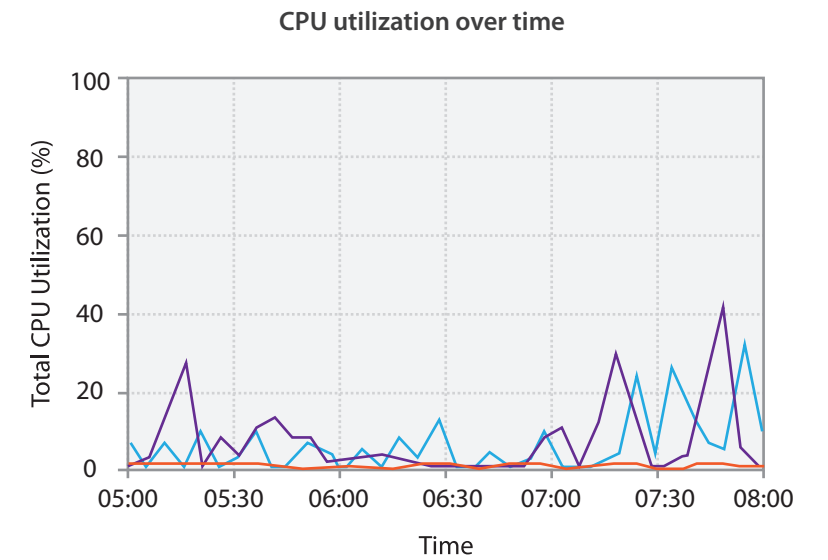
<http://www.stonesc.com/wordpress/2010/03/get-it-right-in-black-and-white>]

Superimposing limits

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



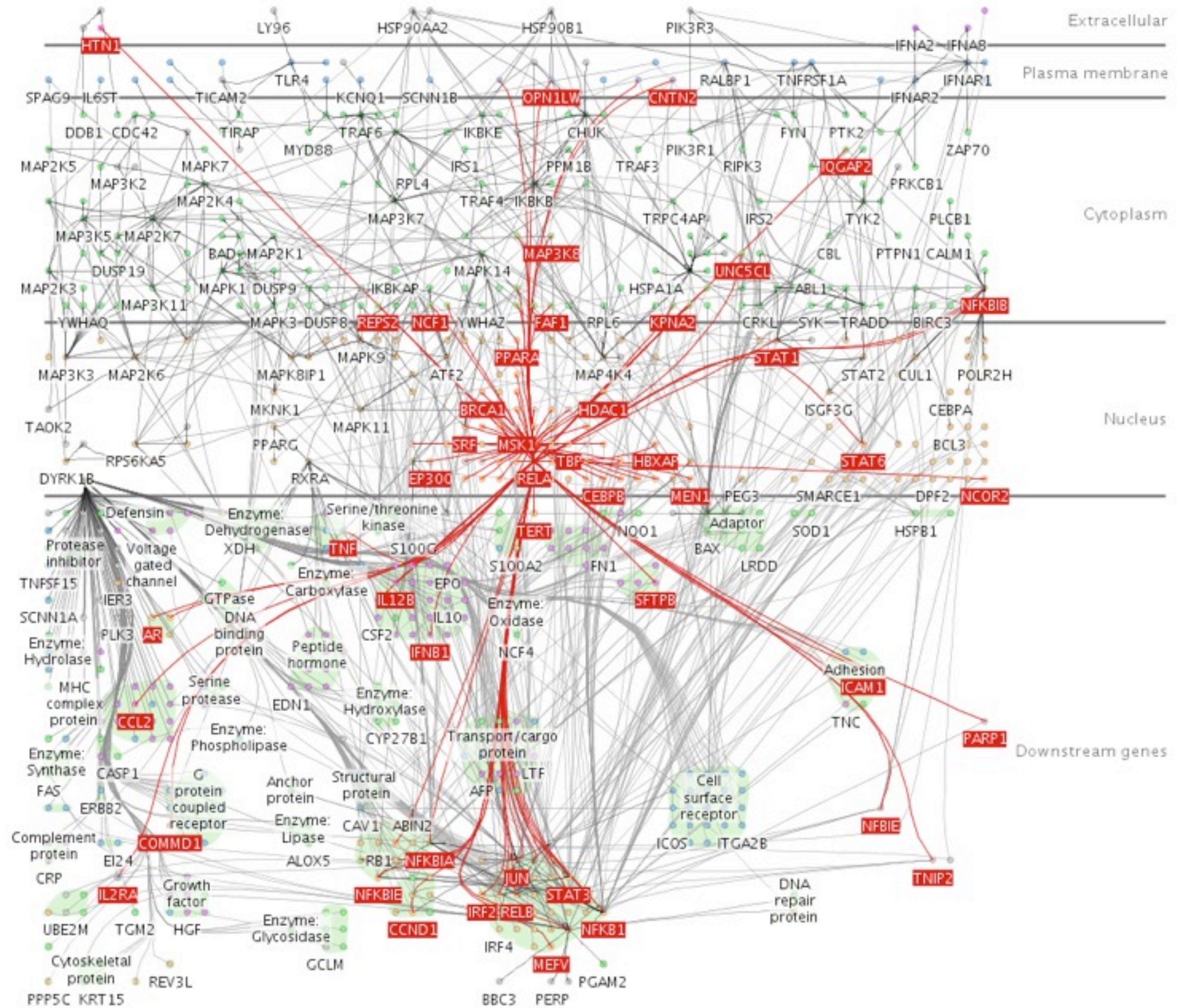
[Graphical Perception of Multiple Time Series. Javed, McDonnell, and Elmqvist. IEEE Transactions on Visualization and Computer Graphics (Proc. IEEE InfoVis 2010) 16:6 (2010), 927–934.]



Dynamic visual layering

System: Cerebral

- interactive, from selection
 - lightweight: click
 - very lightweight: hover
- ex: 1-hop neighbors



[Cerebral: a Cytoscape plugin for layout of and interaction with biological networks using subcellular localization annotation. Barsky, Gardy, Hancock, and Munzner. *Bioinformatics* 23:8 (2007), 1040–1042.]

Further reading

- Visualization Analysis and Design. Munzner. AK Peters / CRC Press, Oct 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. (PacificVis), 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.

Outline

- **Visualization Analysis Framework**
Session 1 9:30-10:45am
 - Introduction: Definitions
 - Analysis: What, Why, How
 - Marks and Channels
- **Idiom Design Choices, Part 2**
Session 3 1:15pm-2:45pm
 - Manipulate: Change, Select, Navigate
 - Facet: Juxtapose, Partition, Superimpose
 - **Reduce: Filter, Aggregate, Embed**
- **Idiom Design Choices**
Session 2 11:00am-12:15pm
 - Arrange Tables
 - Arrange Spatial Data
 - Arrange Networks and Trees
 - Map Color
- **Guidelines and Examples**
Session 4 3-4:30pm
 - Rules of Thumb
 - Validation
 - BioVis Analysis Example

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

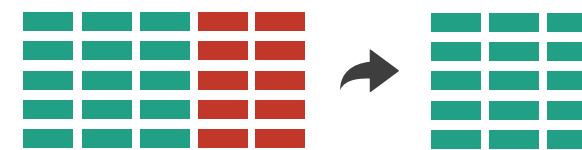
Reducing Items and Attributes

① Filter

→ Items

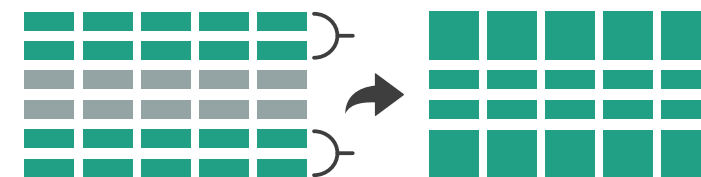


→ Attributes

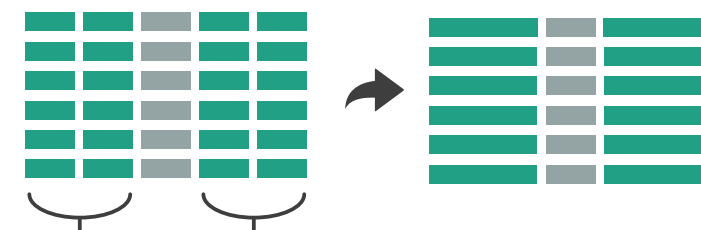


② Aggregate

→ Items



→ Attributes

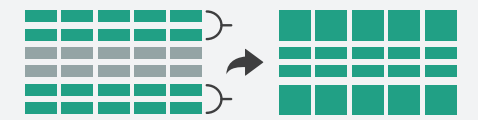


Reduce

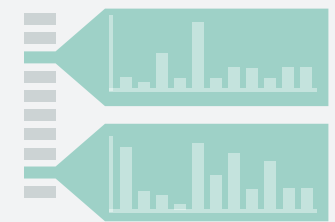
① Filter



② Aggregate



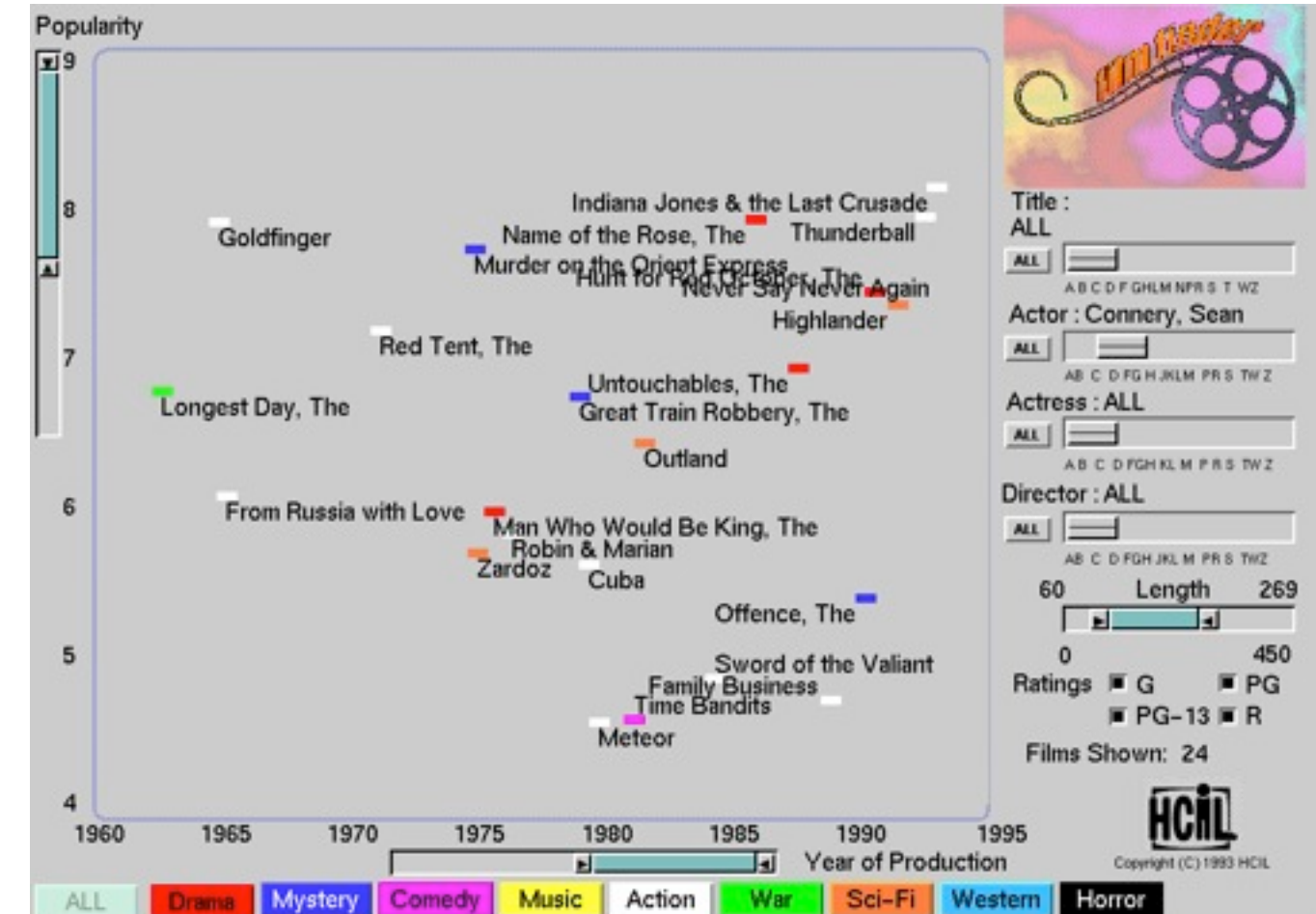
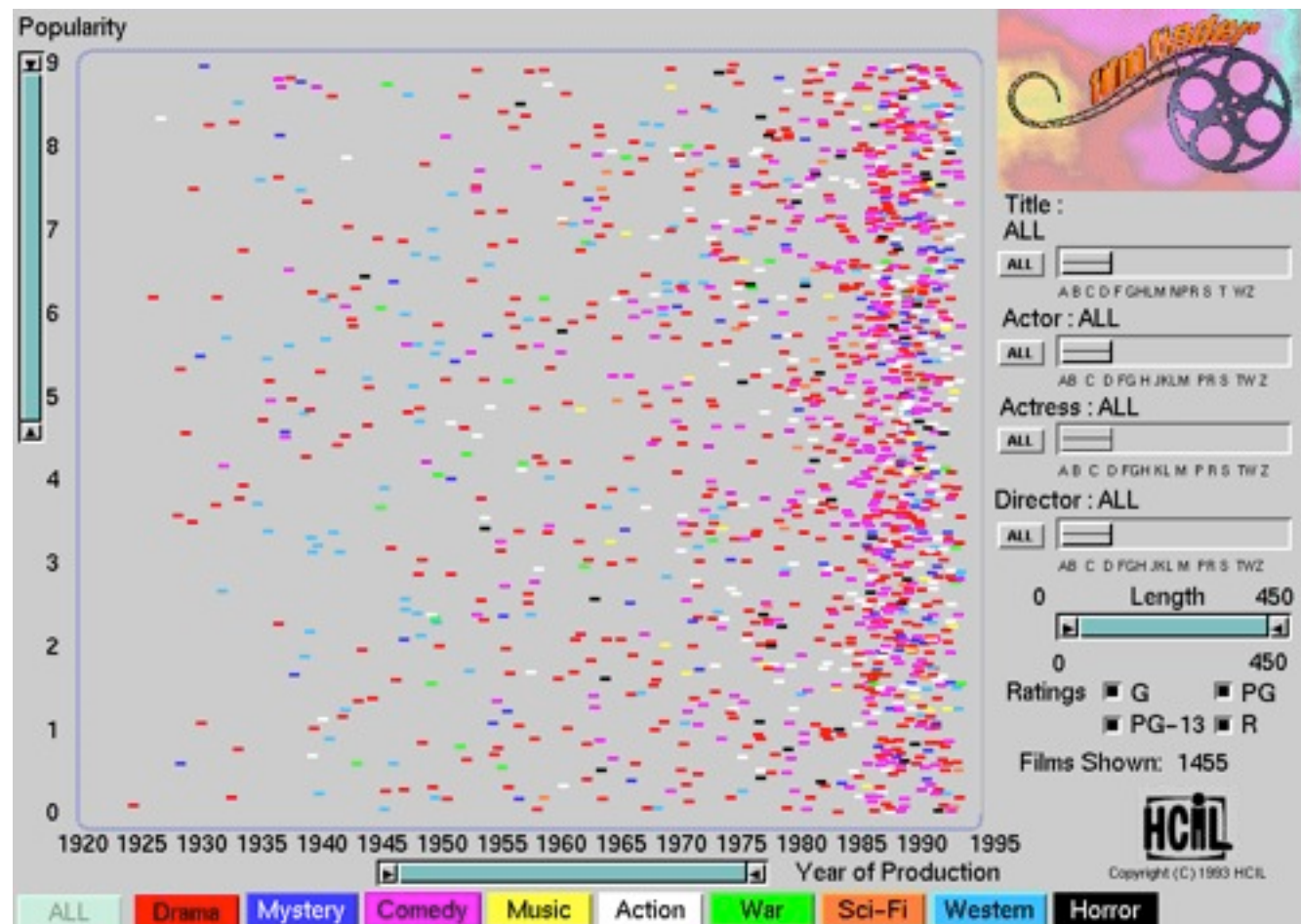
③ Embed



Idiom: dynamic filtering

System: FilmFinder

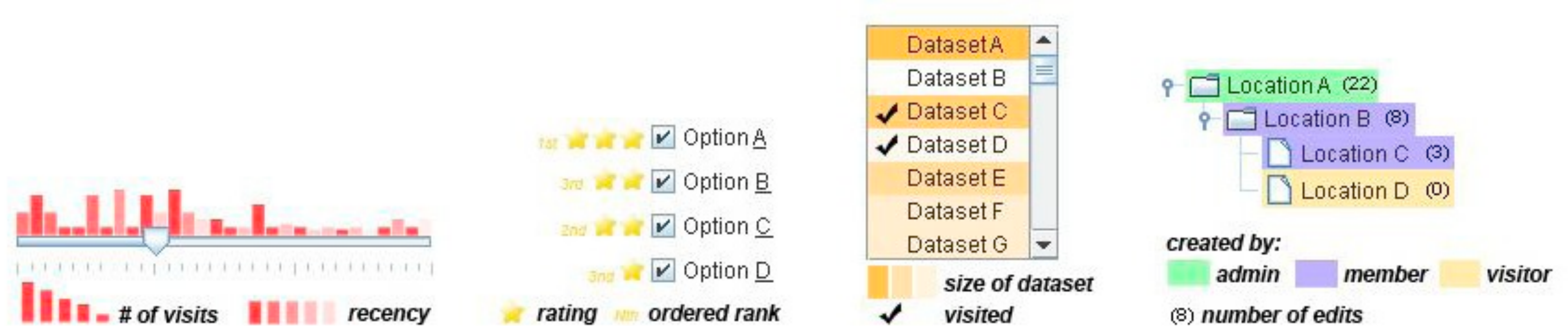
- item filtering
- browse through tightly coupled interaction
 - alternative to queries that might return far too many or too few



[Visual information seeking: Tight coupling of dynamic query filters with starfield displays. Ahlberg and Shneiderman. Proc. ACM Conf. on Human Factors in Computing Systems (CHI), pp. 313–317, 1994.]

Idiom: scented widgets

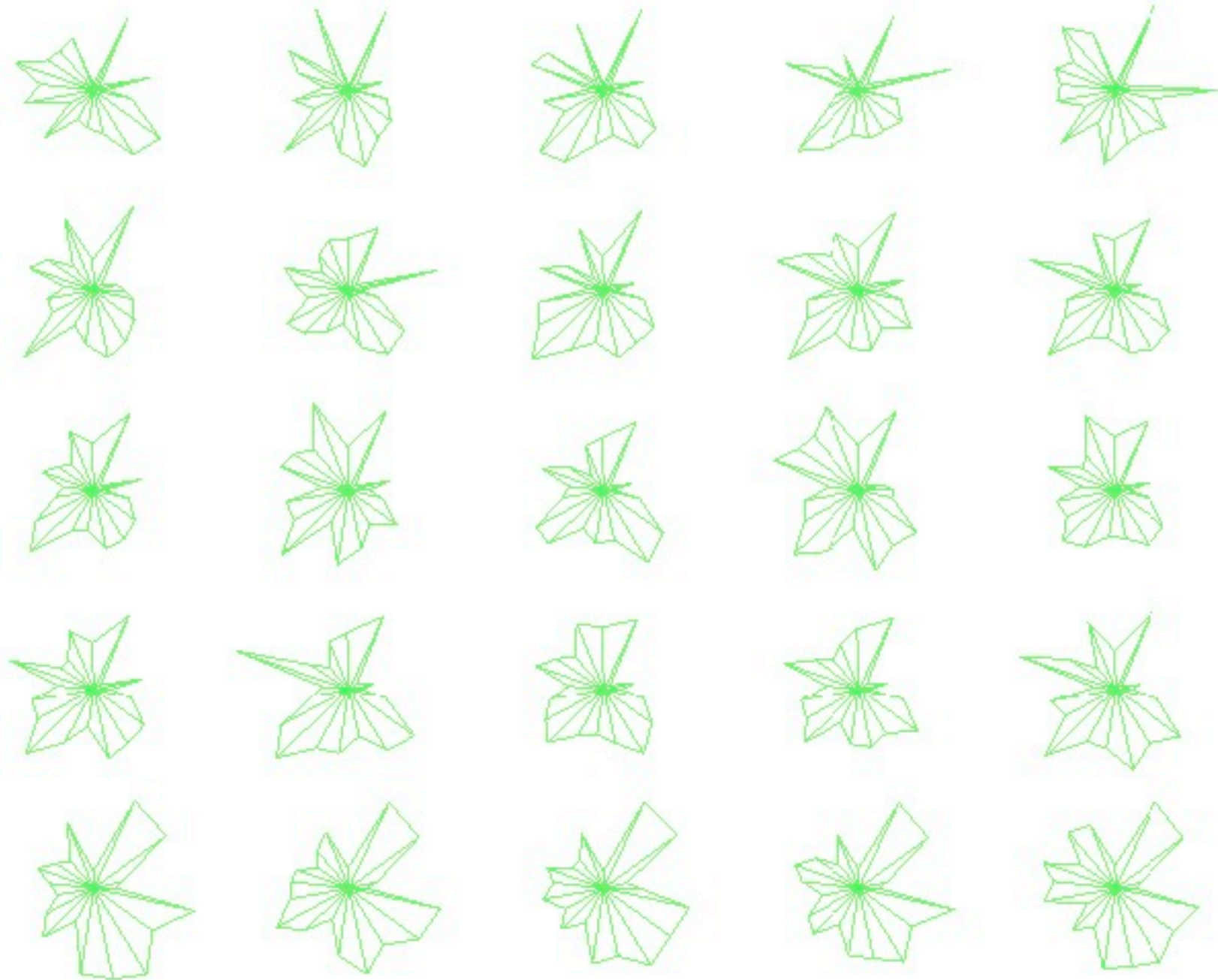
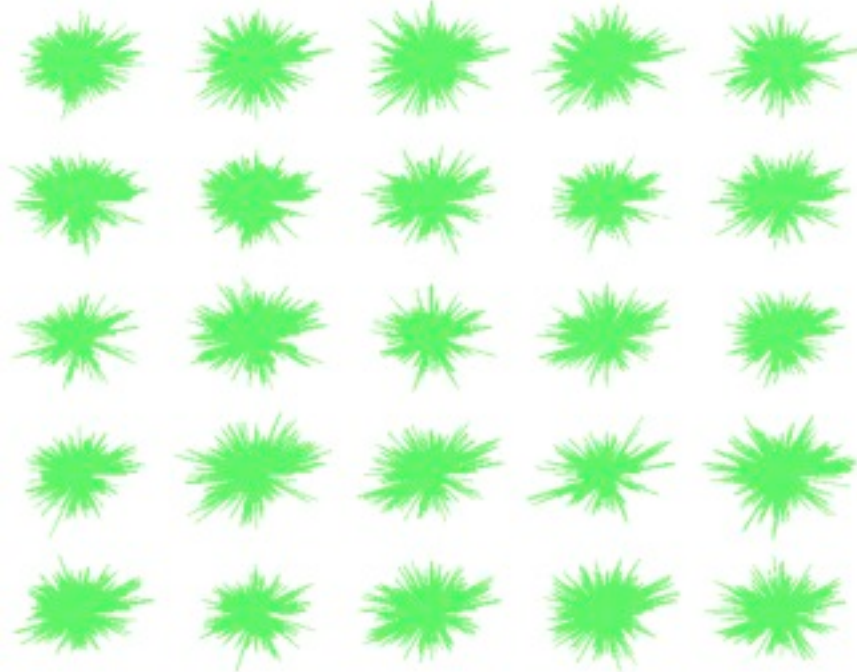
- augment widgets for filtering to show **information scent**
 - cues to show whether value in drilling down further vs looking elsewhere
- concise, in part of screen normally considered control panel



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

Idiom: **DOSFA**

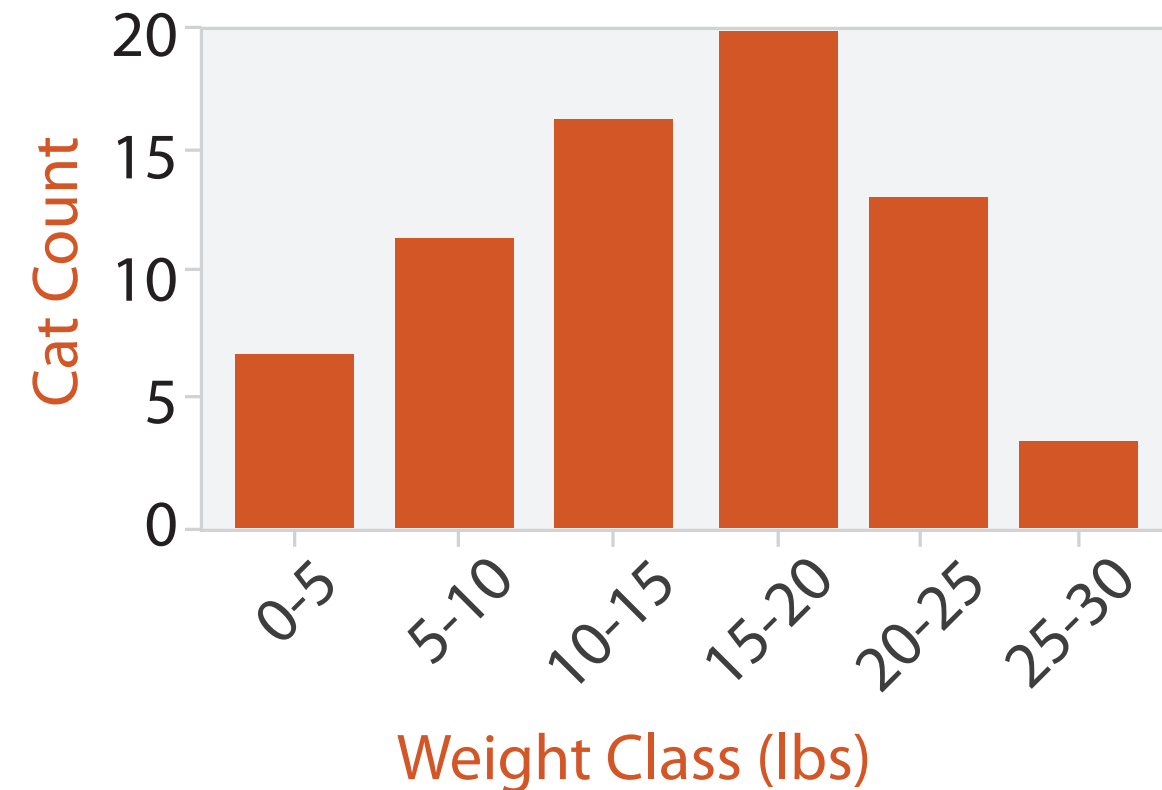
- attribute filtering
- encoding: star glyphs



[Interactive Hierarchical Dimension Ordering, Spacing and Filtering for Exploration Of High Dimensional Datasets. Yang, Peng, Ward, and. Rundensteiner. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 105–112, 2003.]

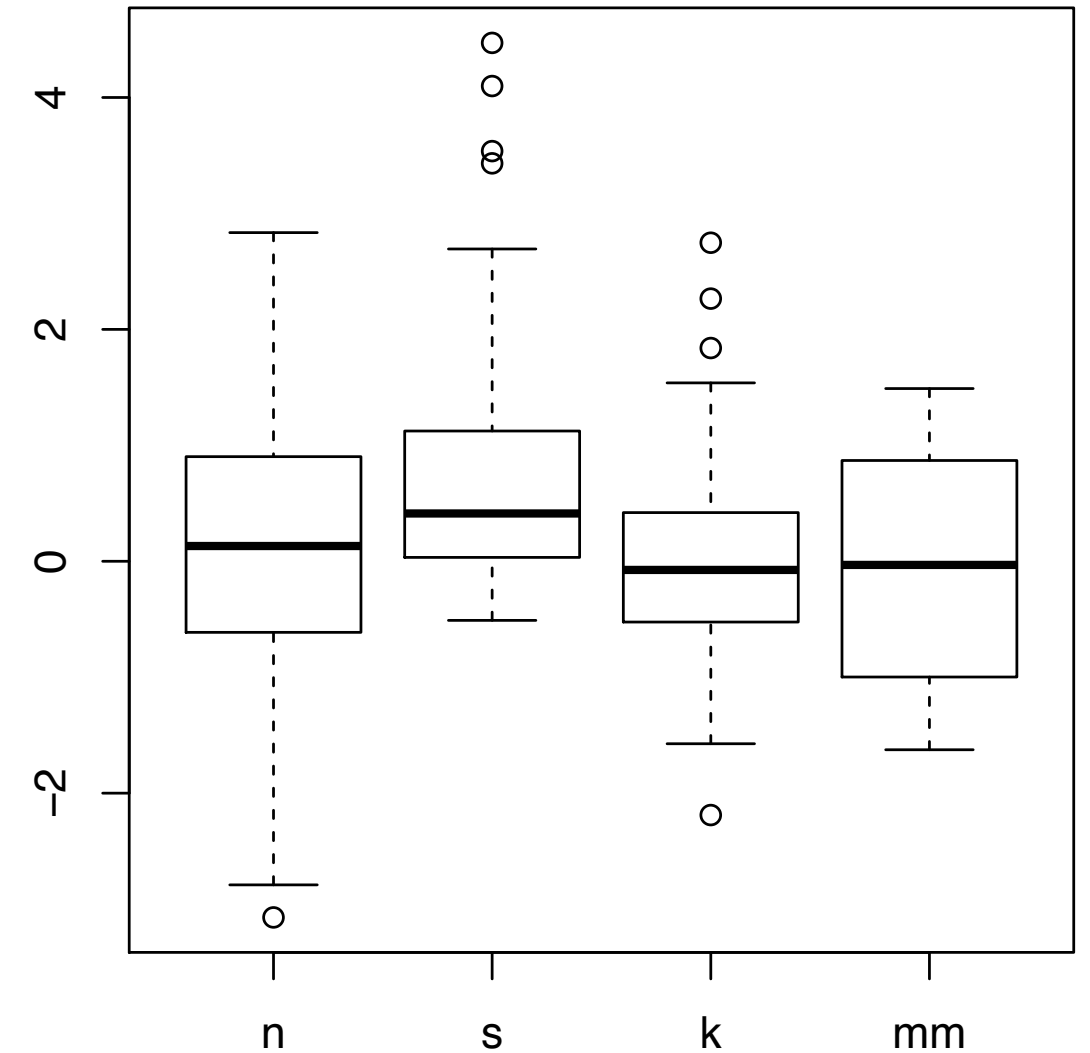
Idiom: **histogram**

- 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: **boxplot**

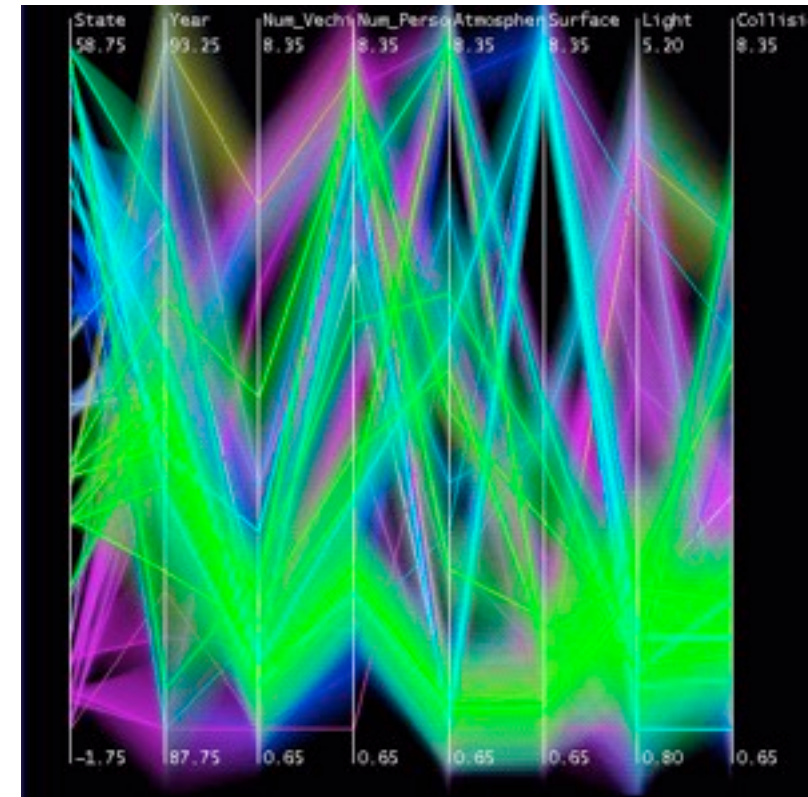
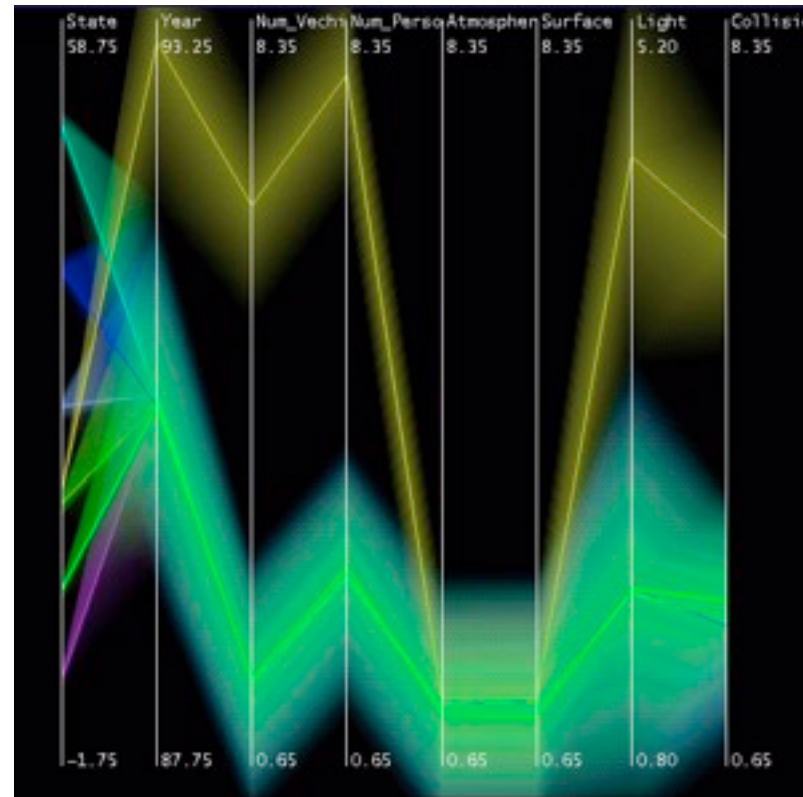
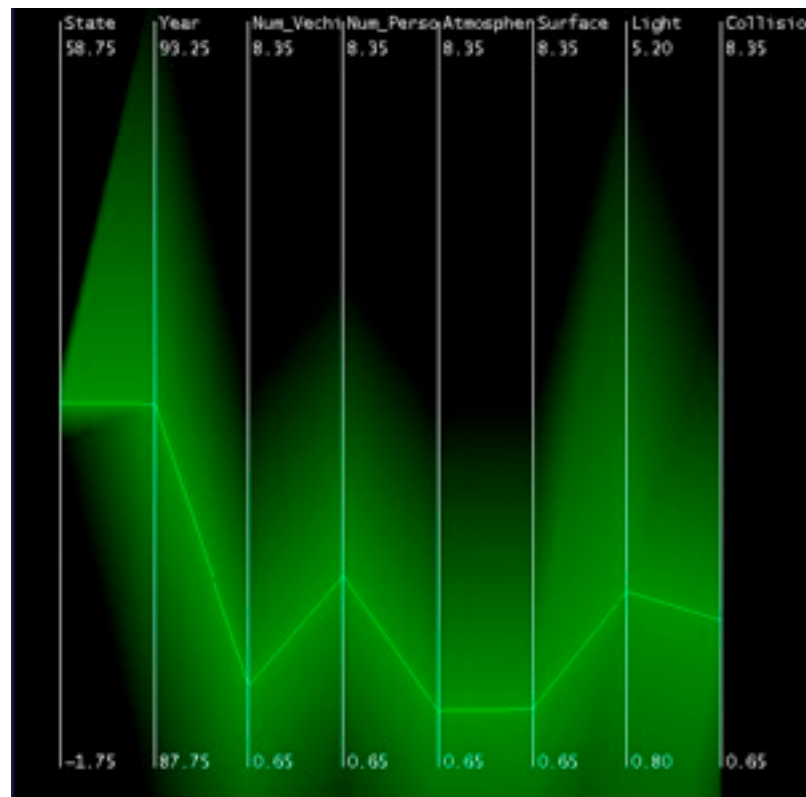
- static item aggregation
- task: find distribution
- data: table
- derived data
 - 5 quant attribs
 - median: central line
 - lower and upper quartile: boxes
 - lower upper fences: whiskers
 - values beyond which items are outliers
 - outliers beyond fence cutoffs explicitly shown



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

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



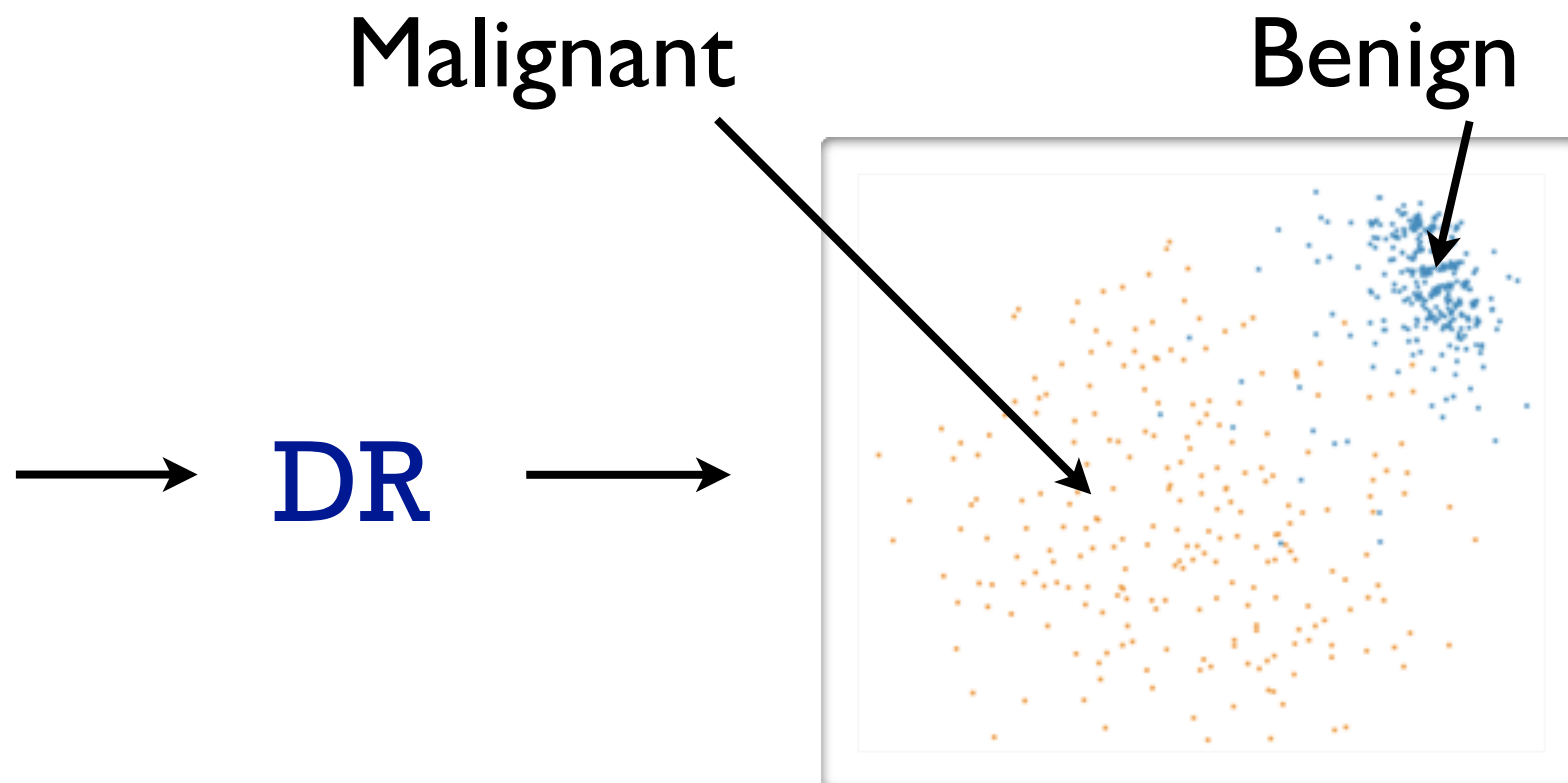
[Hierarchical Parallel Coordinates for Exploration of Large Datasets. Fua, Ward, and Rundensteiner. Proc. IEEE Visualization Conference (Vis '99), pp. 43– 50, 1999.]

Dimensionality reduction

- attribute aggregation
 - derive low-dimensional target space from high-dimensional measured space
 - 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

Tumor
Measurement Data

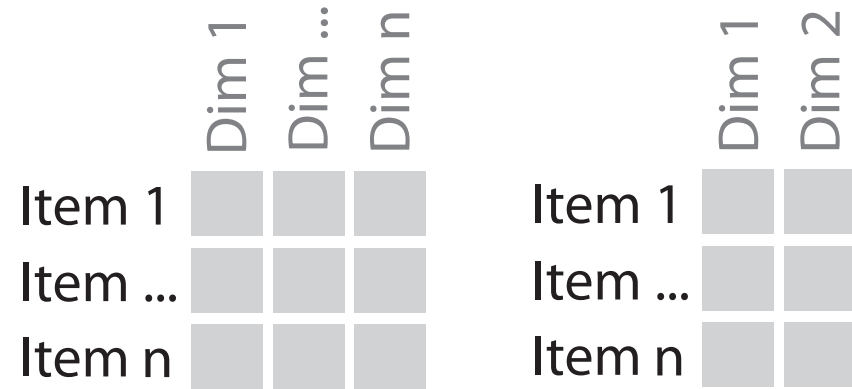
data: 9D measured space



derived data: 2D target space

Dimensionality reduction for documents

Task 1



In HD data → **Out** 2D data

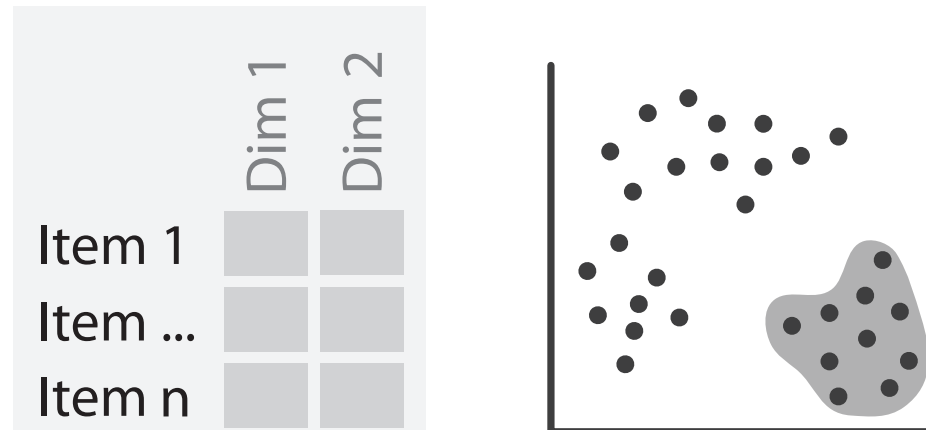
What?

Why?

- **In** High-dimensional data
- **Out** 2D data

- Produce
- Derive

Task 2



In 2D data → **Out** Scatterplot
Clusters & points

What?

Why?

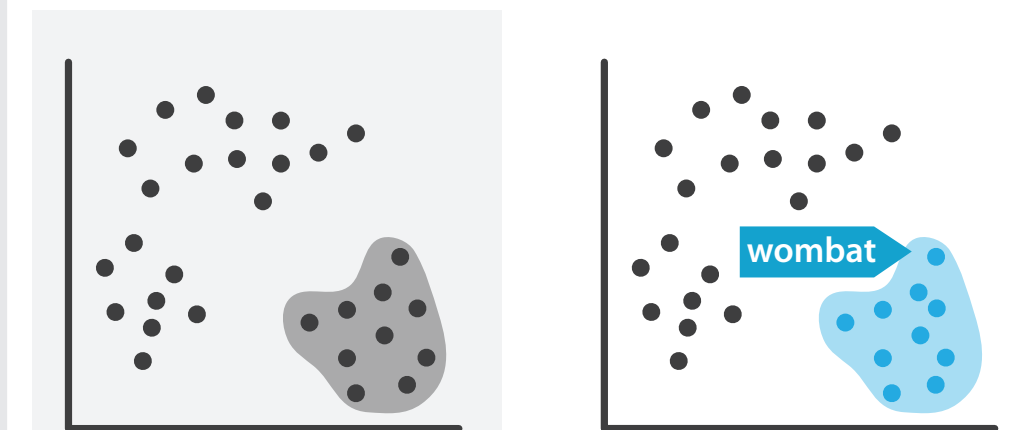
How?

- **In** 2D data
- **Out** Scatterplot
- **Out** Clusters & points

- Discover
- Explore
- Identify

- Encode
- Navigate
- Select

Task 3



In Scatterplot
Clusters & points → **Out** Labels for clusters

What?

Why?

- **In** Scatterplot
- **In** Clusters & points
- **Out** Labels for clusters

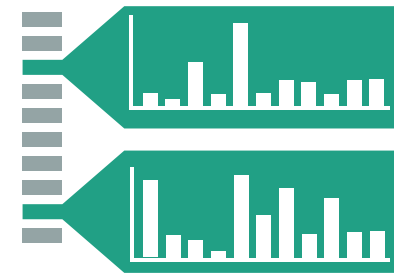
- Produce
- Annotate

Embed: Focus+Context

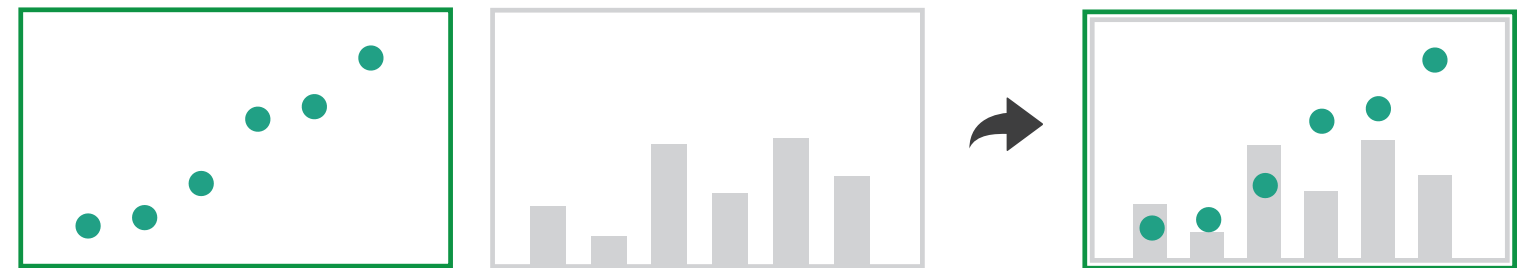
- combine information within single view
- elide
 - selectively filter and aggregate
- superimpose layer
 - local lens
- distortion design choices
 - region shape: radial, rectilinear, complex
 - how many regions: one, many
 - region extent: local, global
 - interaction metaphor

→ Embed

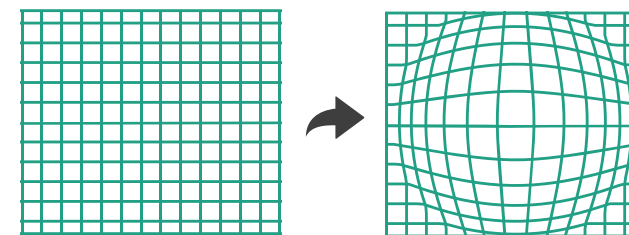
→ Elide Data



→ Superimpose Layer

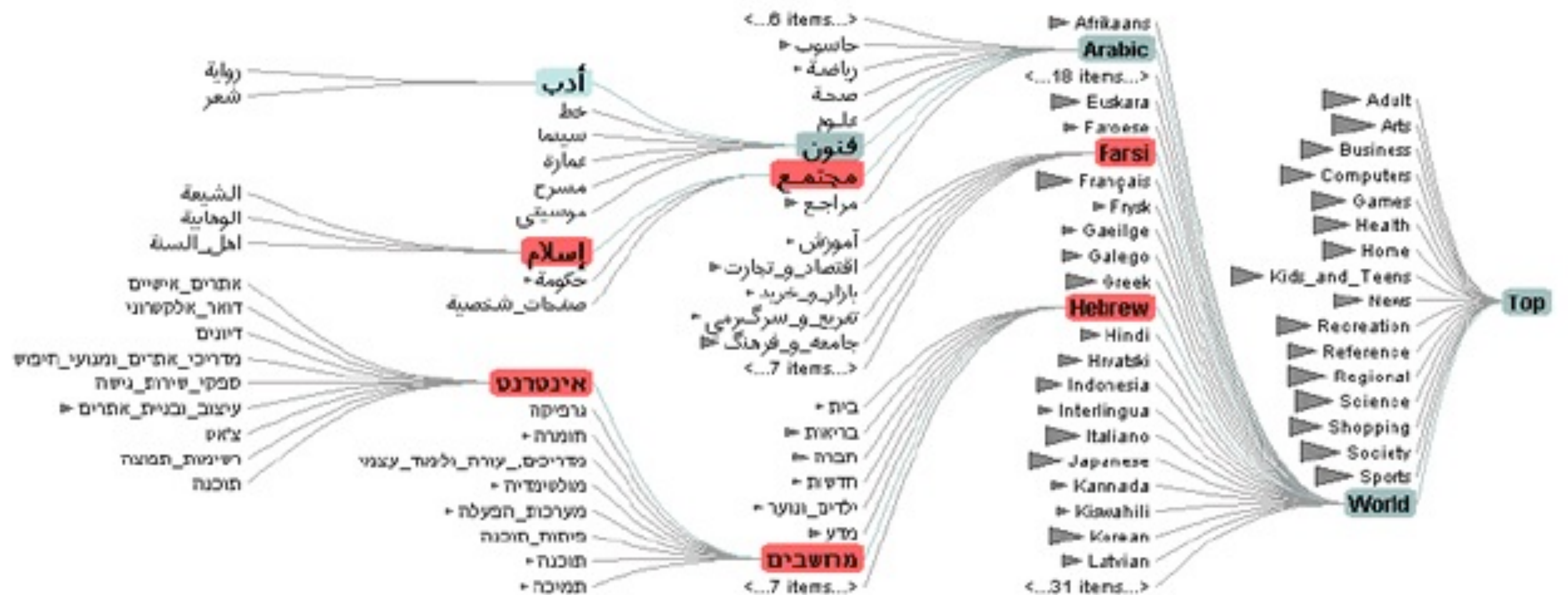


→ Distort Geometry



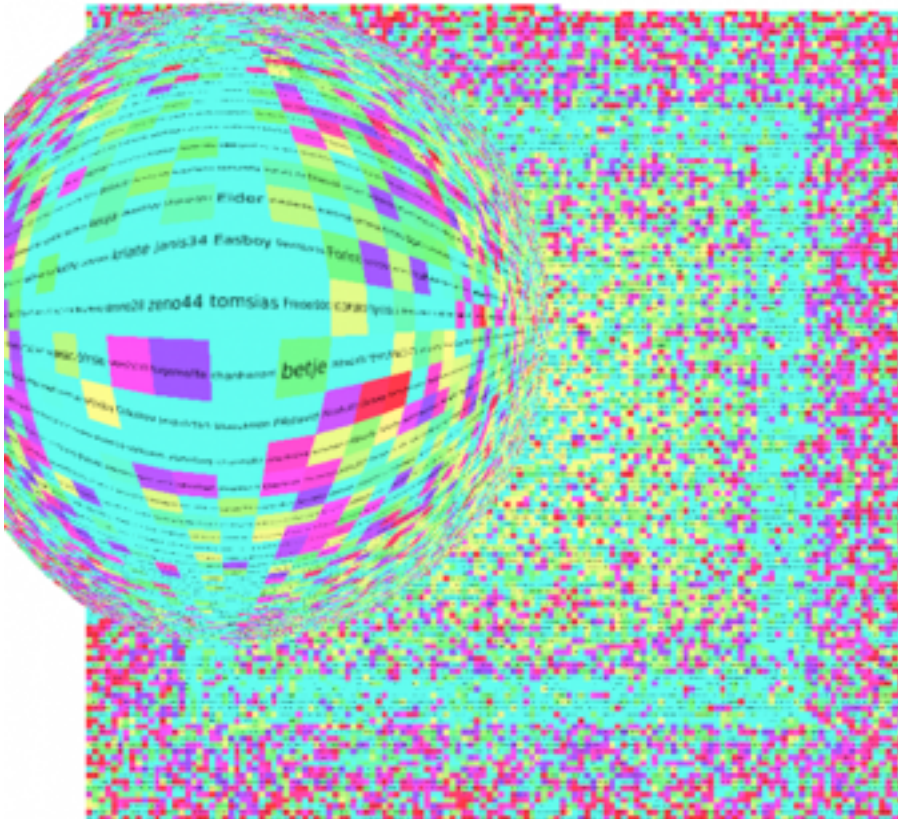
Idiom: DOI Trees Revisited

- elide
 - some items dynamically filtered out
 - some items dynamically aggregated together
 - some items shown in detail

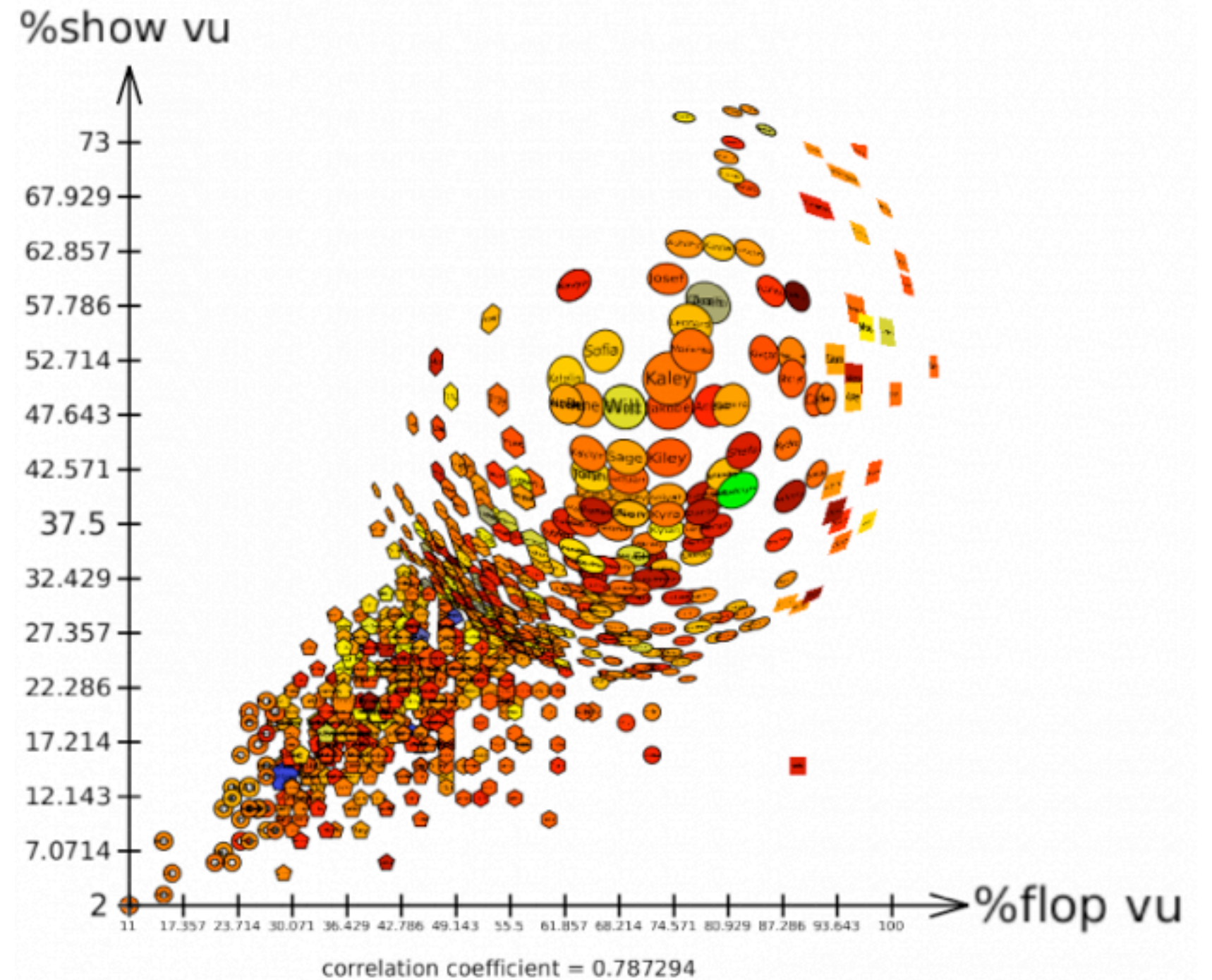


Idiom: **Fisheye Lens**

- distort geometry
 - shape: radial
 - focus: single extent
 - extent: local
 - metaphor: draggable lens



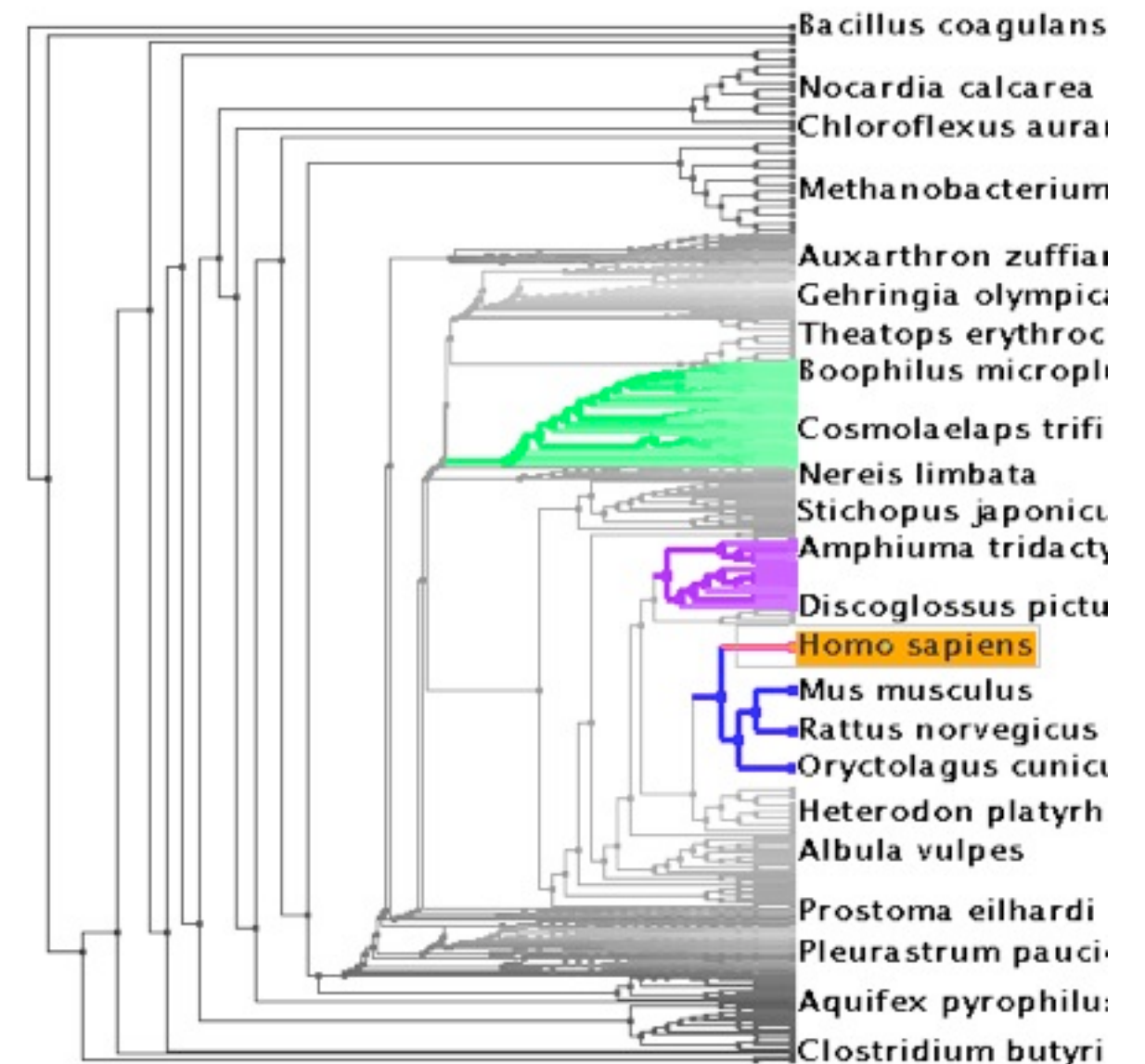
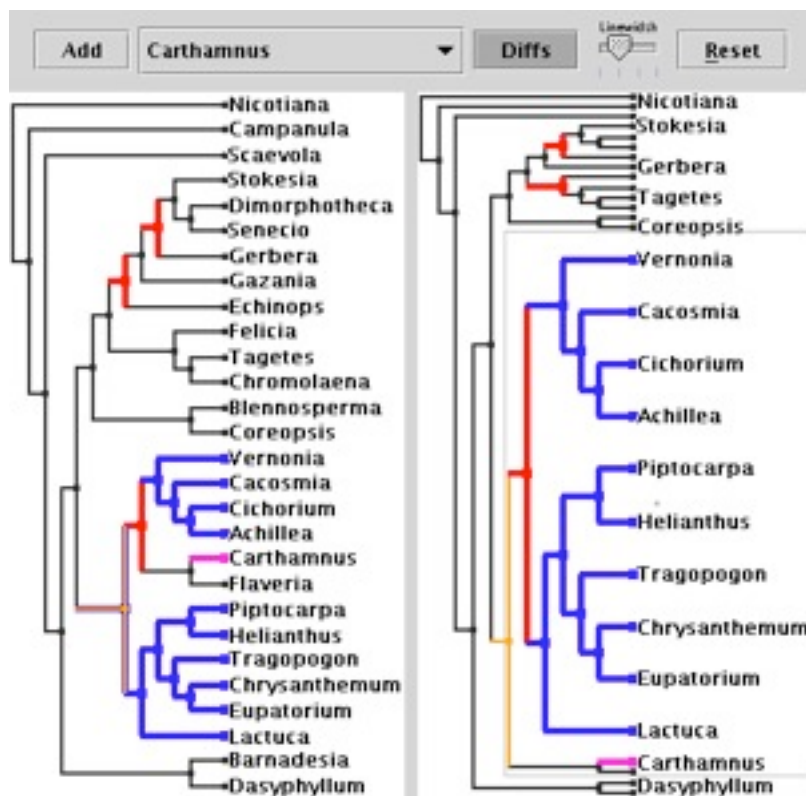
<http://tulip.labri.fr/TulipDrupal/?q=node/351>
<http://tulip.labri.fr/TulipDrupal/?q=node/371>



Idiom: Stretch and Squish Navigation

- distort geometry
 - shape: rectilinear
 - foci: multiple
 - impact: global
 - metaphor: stretch and squish, borders fixed

System: TreeJuxtaposer



[TreeJuxtaposer: Scalable Tree Comparison Using Focus+Context With Guaranteed Visibility. Munzner, Guimbretiere, Tasiran, Zhang, and Zhou. ACM Transactions on Graphics (Proc. SIGGRAPH) 22:3 (2003), 453– 462.]

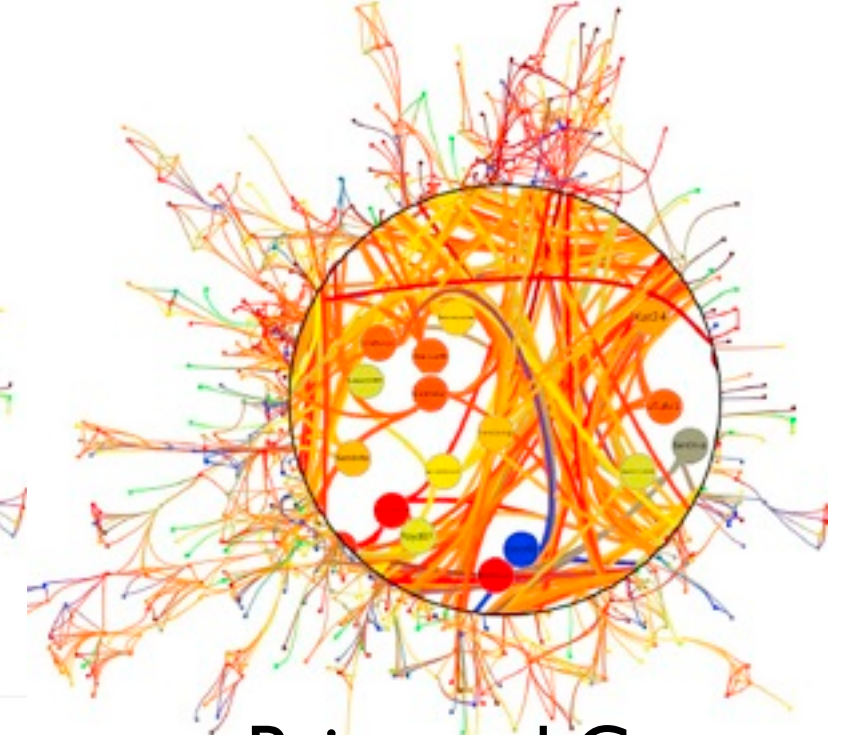
Distortion costs and benefits

- **benefits**
 - combine focus and context information in single view
- **costs**
 - length comparisons impaired
 - network/tree topology comparisons unaffected: connection, containment
 - effects of distortion unclear if original structure unfamiliar
 - object constancy/tracking maybe impaired

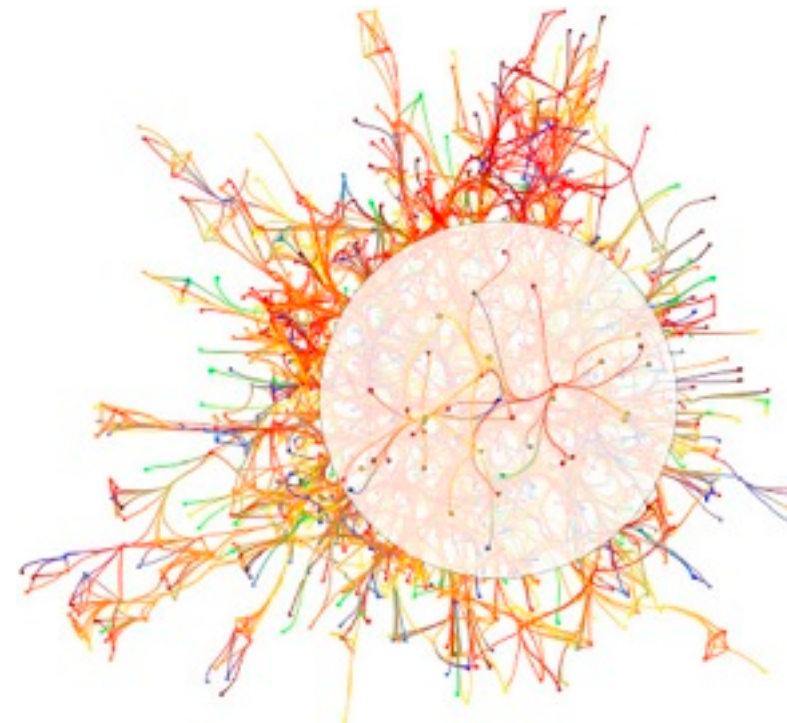
fisheye lens



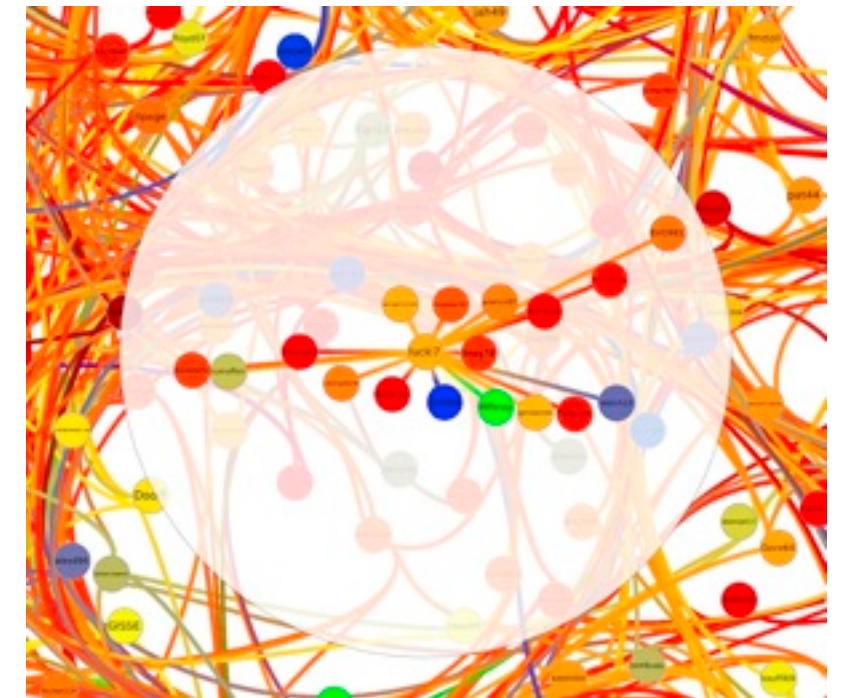
magnifying lens



neighborhood layering



Bring and Go



Further reading

- Visualization Analysis and Design. Munzner. AK Peters / CRC Press, Oct 2014.
– *Chap 14: Embed: Focus+Context*
- *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.
- *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 Fisheye Follow-up: Further Reflection on Focus + Context*. Furnas. Proc. ACM Conf. Human Factors in Computing Systems (CHI), pp. 999–1008, 2006.