Visualization Analysis & Design
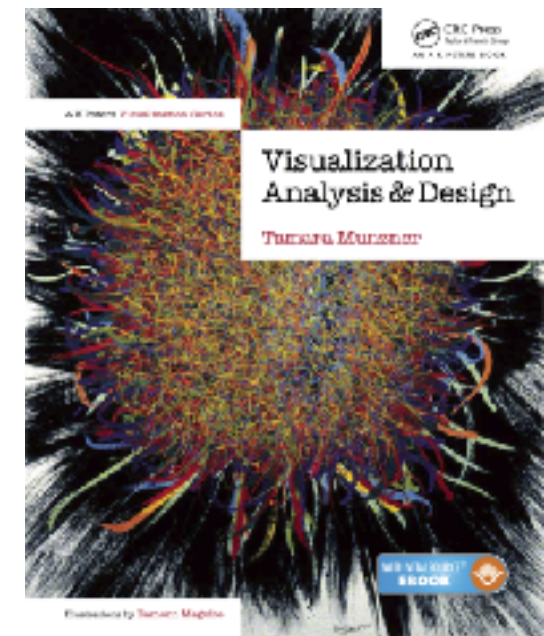
Interactive Views (Ch 11/12)

Tamara Munzner

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@tamaramunzner
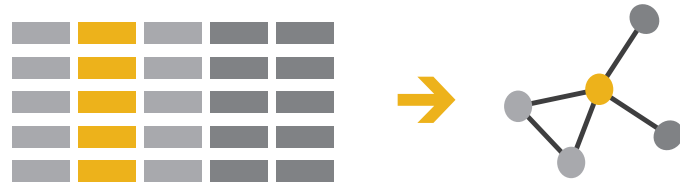
How to handle complexity: 1 previous strategy
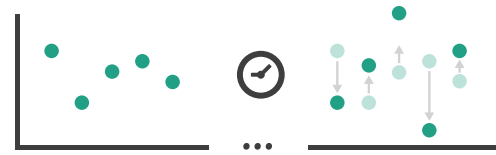
➔ *Derive*

• derive new data to show within view

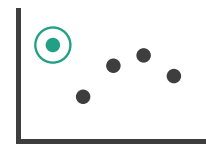# How to handle complexity: 1 previous strategy + 2 more

➔ *Derive*

- derive new data to show within view
- change view over time
- facet across multiple views

Manipulate

➔ **Change**

➔ **Select**

➔ **Navigate**
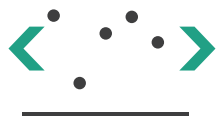
Facet

➔ **Juxtapose**
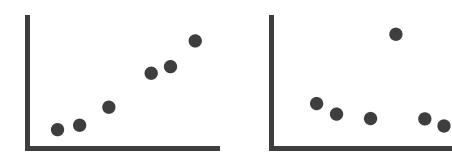
➔ **Partition**
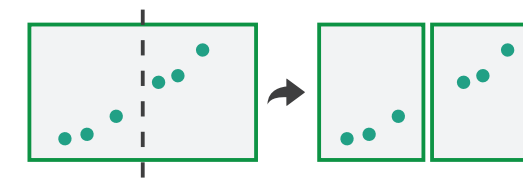
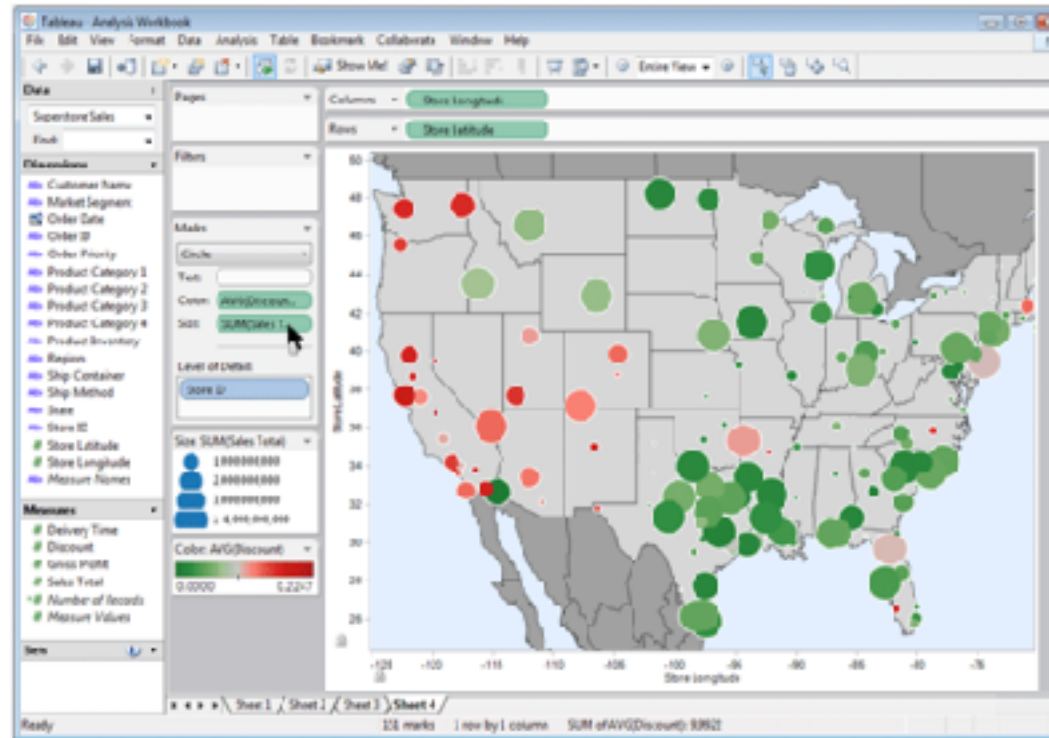➔ **Superimpose**
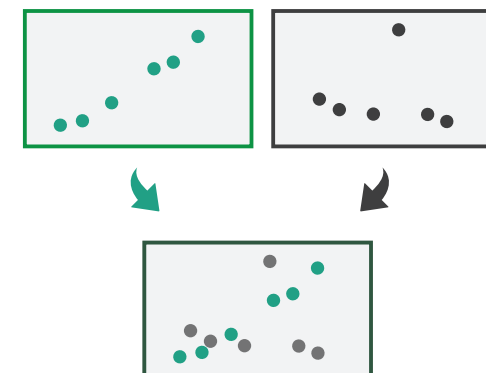
Manipulate View
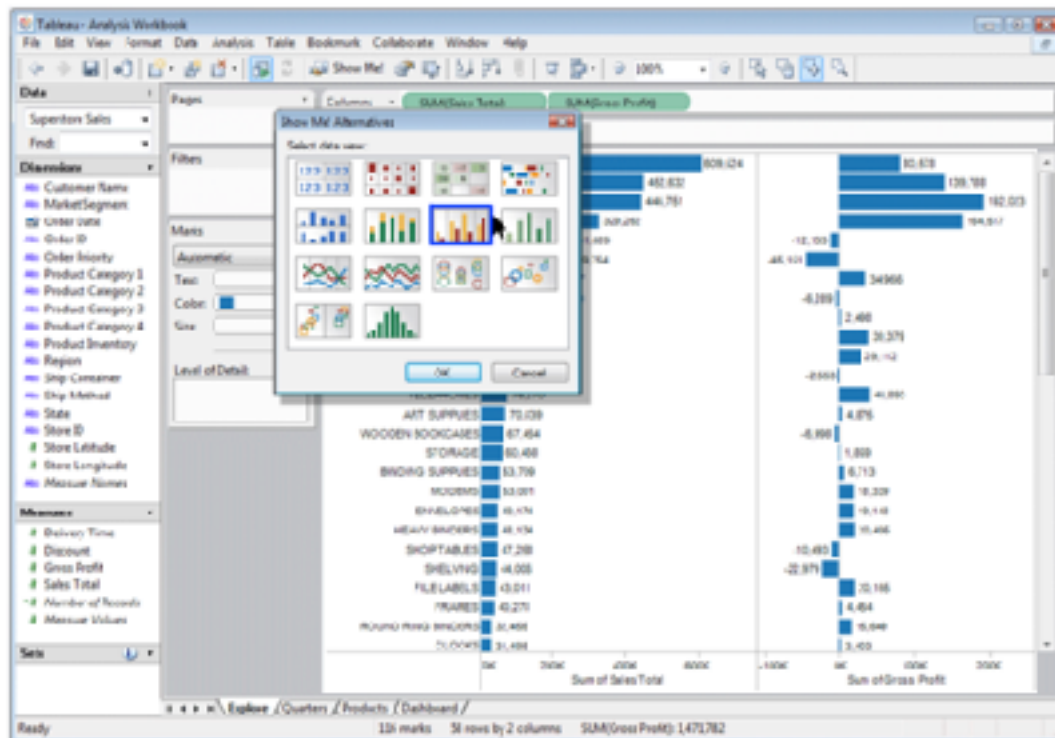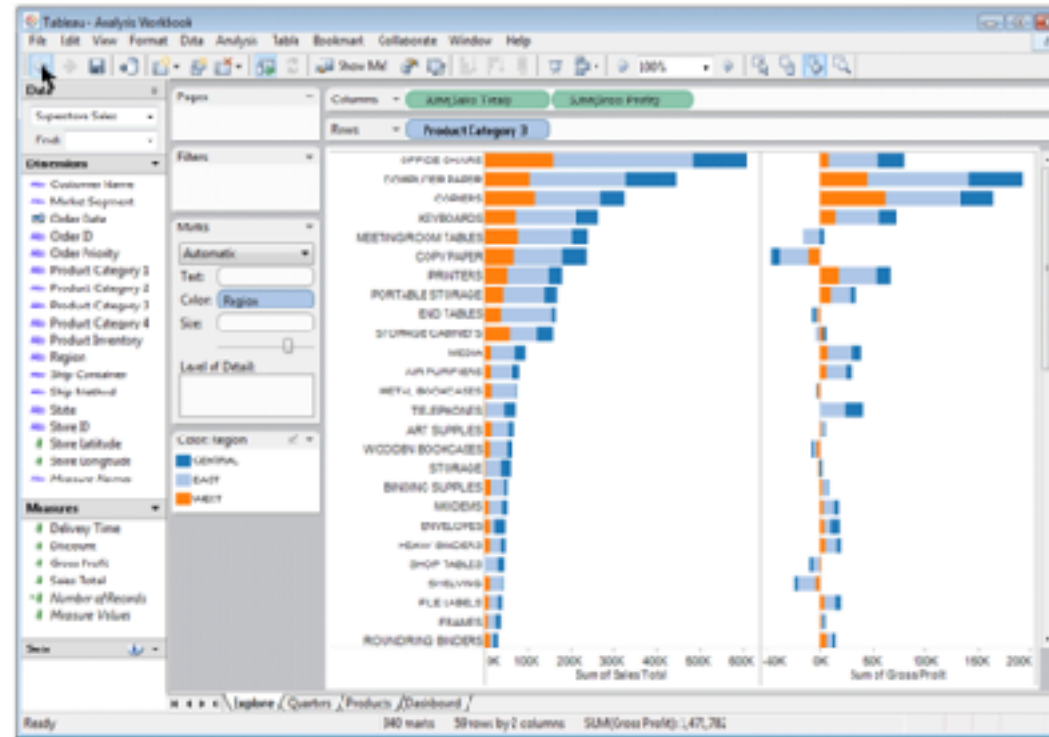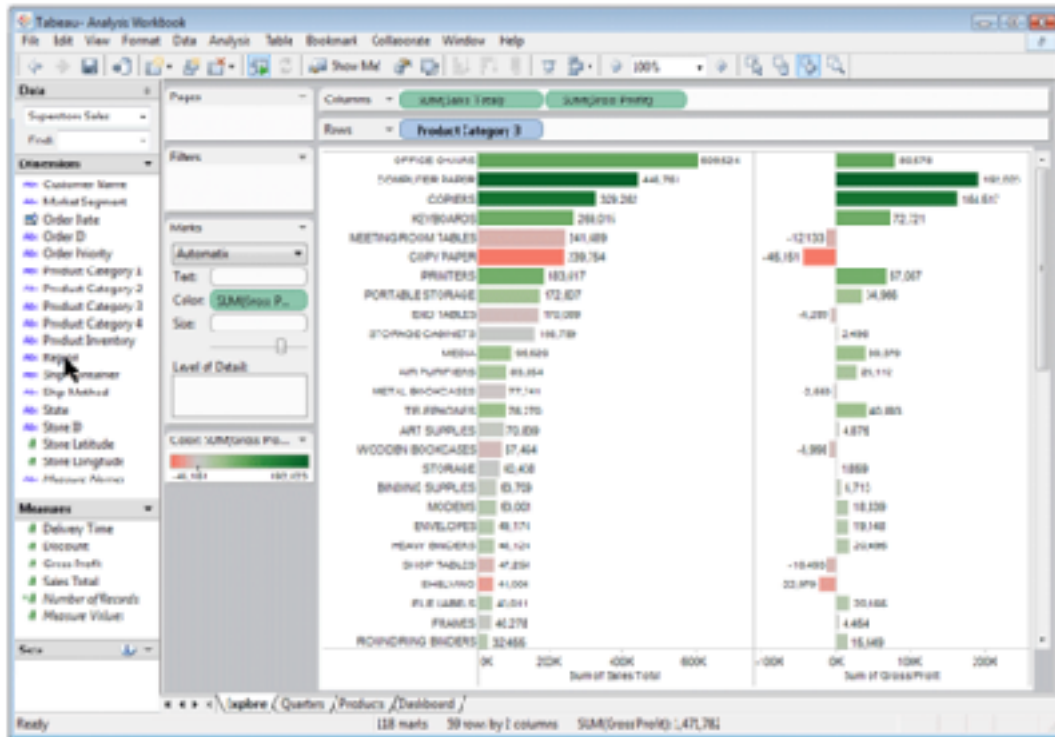
Manipulate

→ **Change over Time**

Change over time

- change any of the other choices
  - encoding itself
  - parameters
  - arrange: rearrange, reorder
  - aggregation level, what is filtered...

  - interaction entails change

- powerful & flexible

Idiom: **Re-encode**

made with Tableau, http://tableausoftware.com
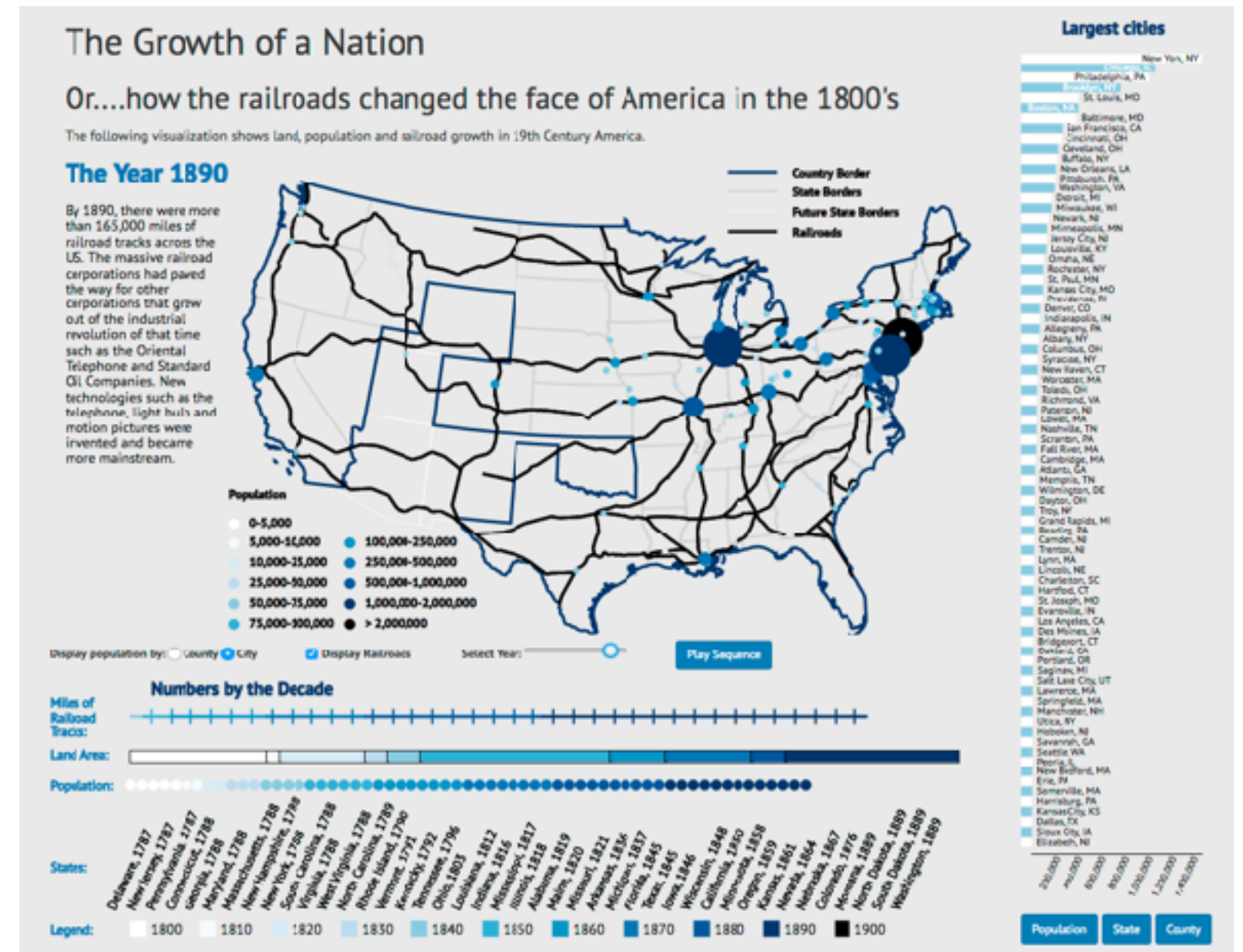
Idiom: **Change parameters**

- widgets and controls
  - sliders, buttons, radio buttons, checkboxes, dropdowns/comboboxes

- pros
  - clear affordances, self-documenting (with labels)

- cons
  - uses screen space

- design choices
  - separated vs interleaved
    - controls & canvas

[Growth of a Nation](http://laurenwood.github.io/)
made with D3

Idiom: **Change order/arrangement**

- what: simple table

- how: data-driven reordering

- why: find extreme values, trends
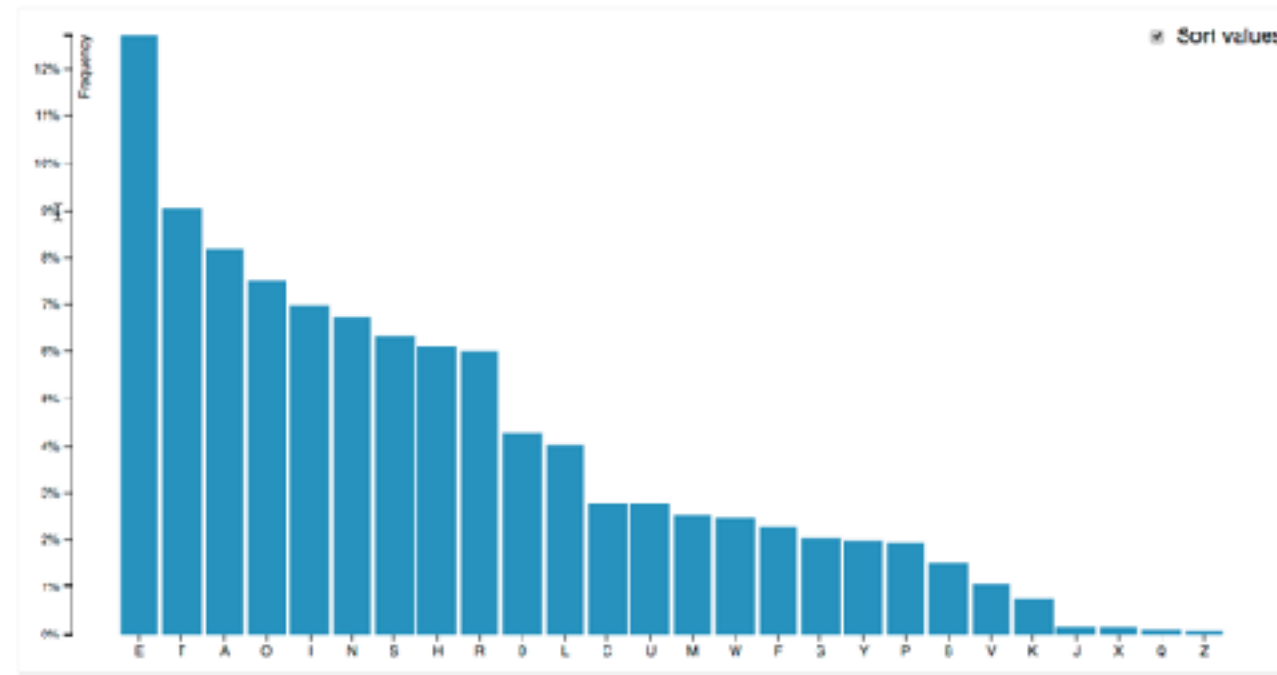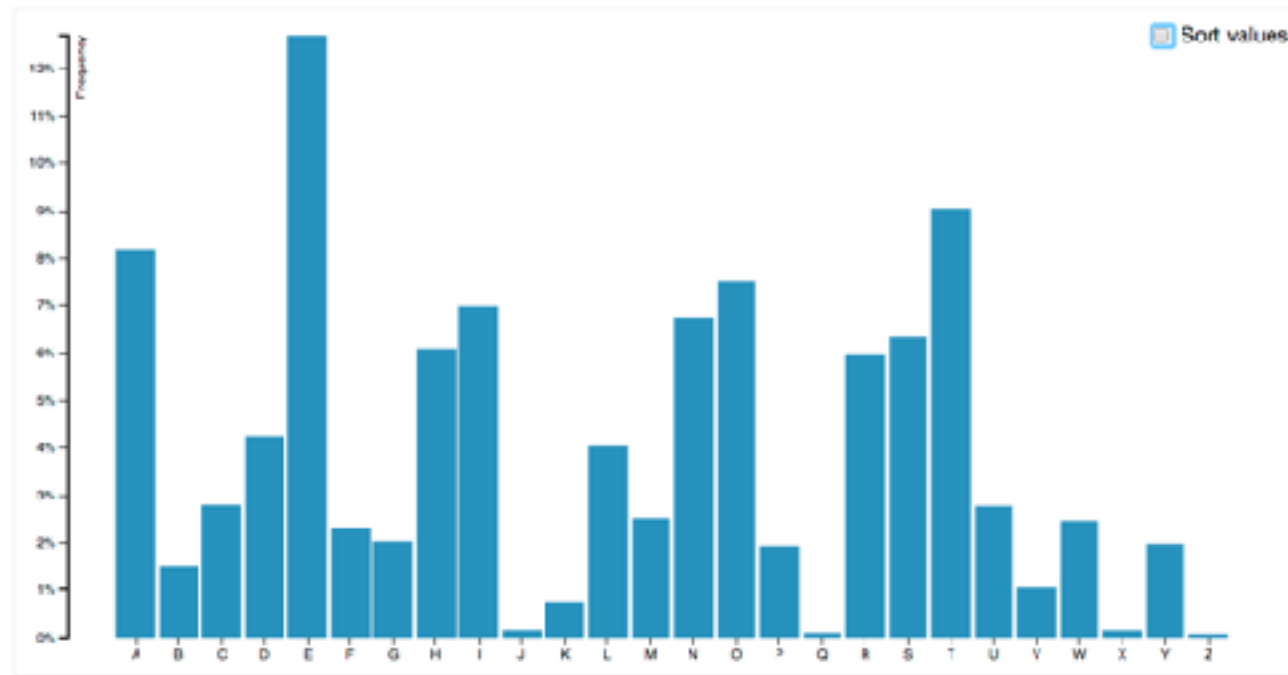
[Sortable Bar Chart] https://observablehq.com/@d3/sortable-bar-chart

made with D3

Idiom: **Reorder**

- what: table with many attributes

- how: data-driven reordering by selecting column

- why: find correlations between attributes

[http://carlmanaster.github.io/datastripes/]

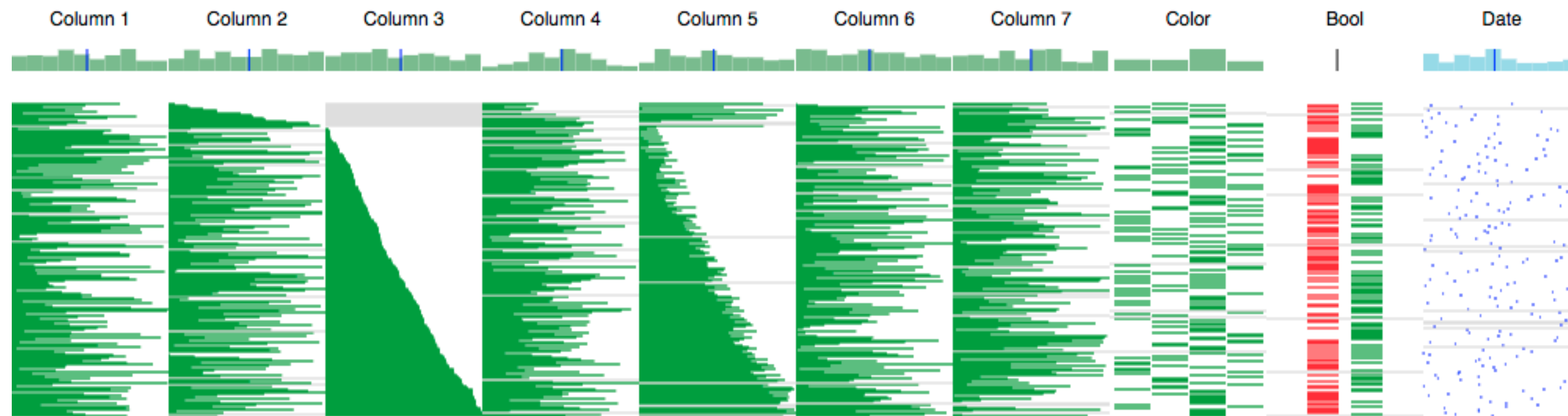*made with D3*

- stacked bars
  - easy to compare
    - first segment
    - total bar

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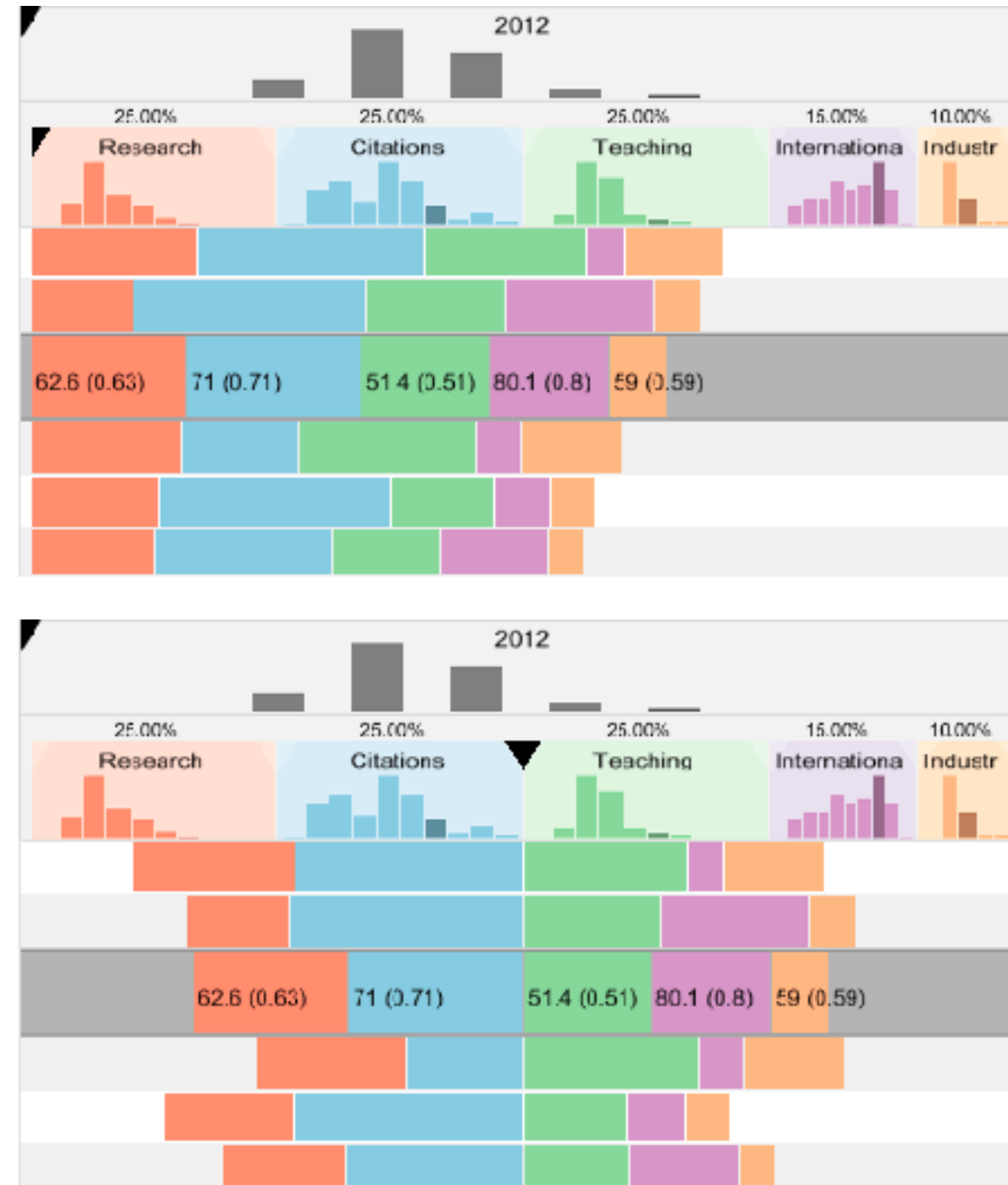
[LineUp: Visual Analysis of Multi-Attribute Rankings. Gratzl, Lex, Gehlenborg, Pfister, and Streit. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2013) 19:12 (2013), 2277–2286.]

Idiom: **Animated transitions - visual encoding change**

- smooth transition from one state to another
  - alternative to jump cuts, supports item tracking
    - best case for animation
  - staging to reduce cognitive load
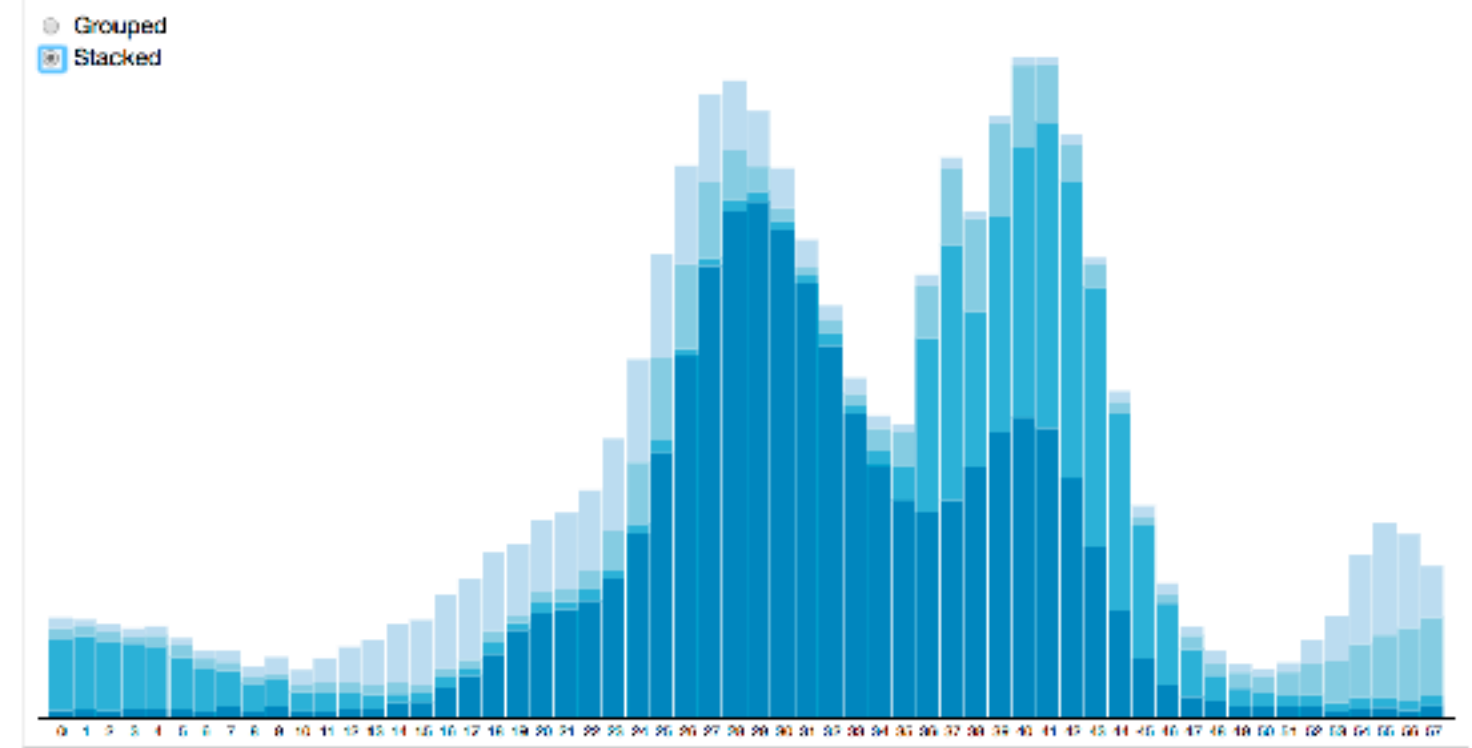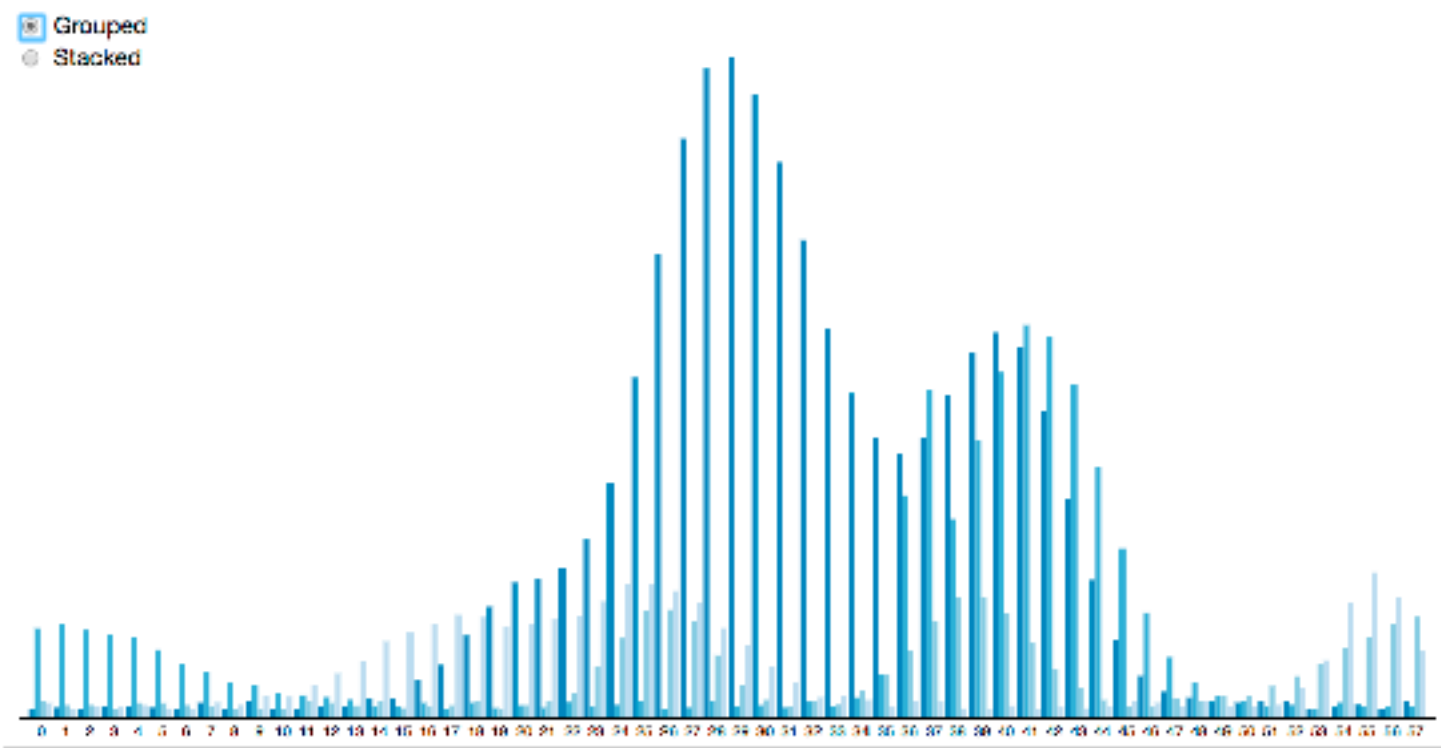
[Stacked to Grouped Bars] https://observablehq.com/@d3/stacked-to-grouped-bars

Idiom: **Animated transition - tree detail**

- animated transition
  - network drilldown/rollup

Manipulate

→ **Change over Time**

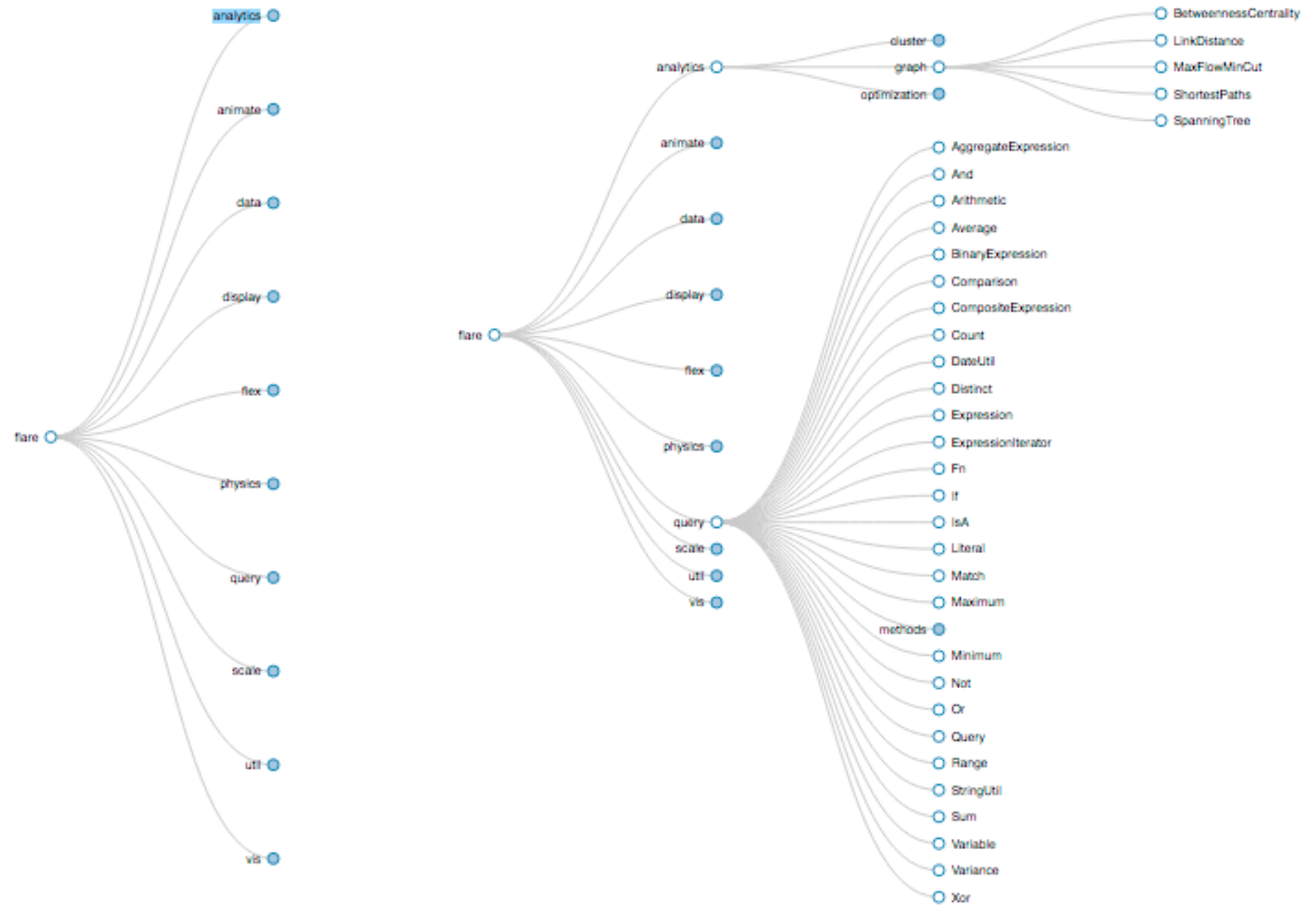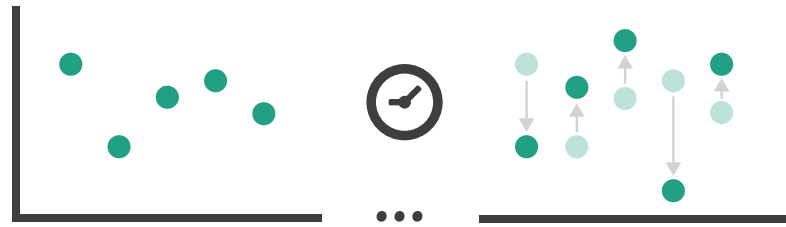→ **Select**
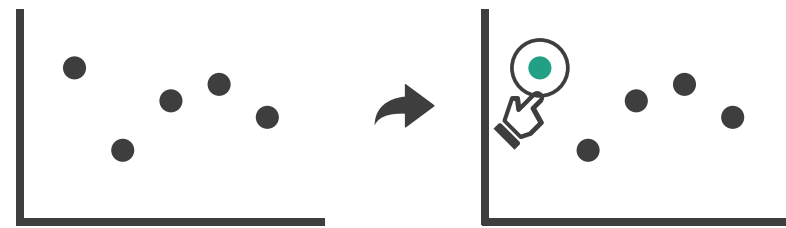
Interaction technology

- what do you design for?
  - mouse & keyboard on desktop?
    - large screens, hover, multiple clicks
  - touch interaction on mobile?
    - small screens, no hover, just tap

  - gestures from video / sensors?
    - ergonomic reality vs movie bombast

  - eye tracking?
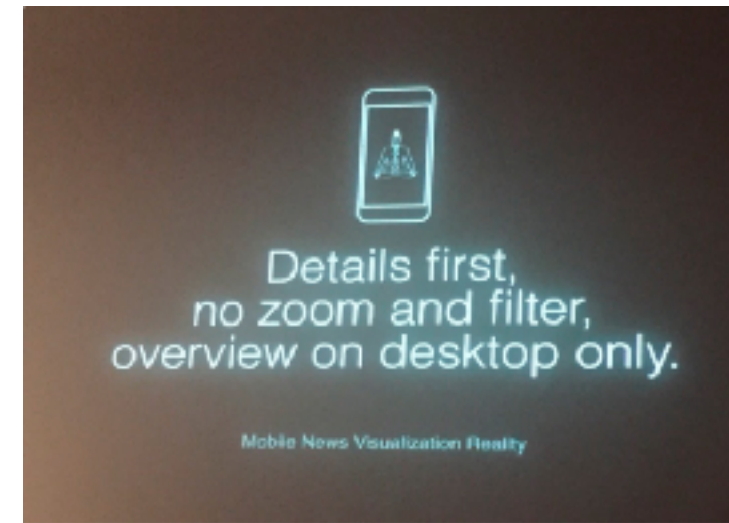
Data visualization and the news - Gregor Aisch (37 min)
vimeo.com/182590214

I Hate Tom Cruise - Alex Kauffmann (5 min)

www.youtube.com/watch?v=QXLfT9sFcbc

Selection

- selection: basic operation for most interaction

- design choices
  - how many selection types?
    - interaction modalities
   - click/tap (heavyweight) vs hover (lightweight but not available on most touchscreens)
      - multiple click types (shift-click, option-click, …)
      - proximity beyond click/hover (touching vs nearby vs distant)
    - application semantics
      - adding to selection set vs replacing selection
      - can selection be null?
        - ex: toggle so nothing selected if click on background
      - primary vs secondary (ex: source/target nodes in network)
   - group membership (add/delete items, name group, …)
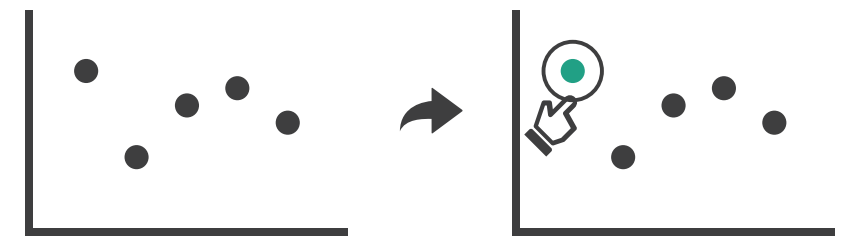
Highlighting

- highlight: change visual encoding for selection targets
  - visual feedback closely tied to but separable from selection (interaction)

- design choices: typical visual channels
  - change item color
    - but hides existing color coding
  - add outline mark
  - change size (ex: increase outline mark linewidth)
  - change shape (ex: from solid to dashed line for link mark)

- unusual channels: motion
  - motion: usually avoid for single view
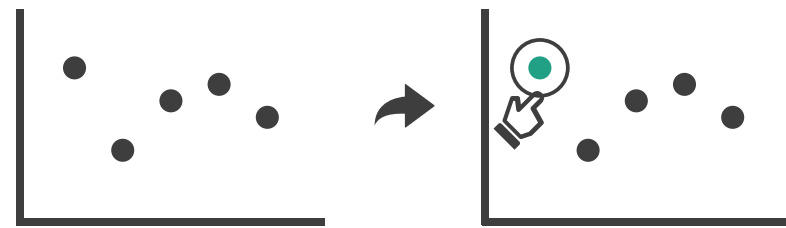   - with multiple views, could justify to draw attention to other views
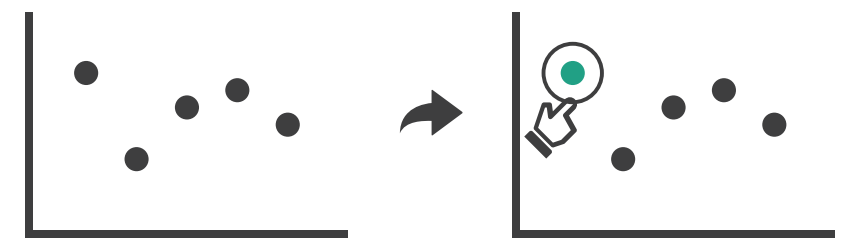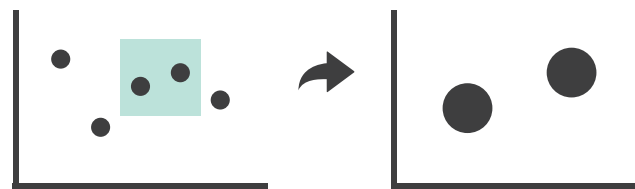
Manipulate

➔ **Change over Time**

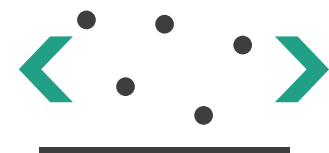
➔ **Select**

➔ **Navigate**
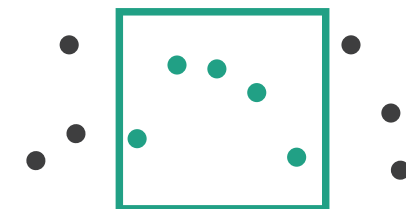
➔ Item Reduction

➔ *Zoom*
Geometric or *Semantic*

➔ *Pan/Translate*

➔ *Constrained*

Manipulate

Change over Time
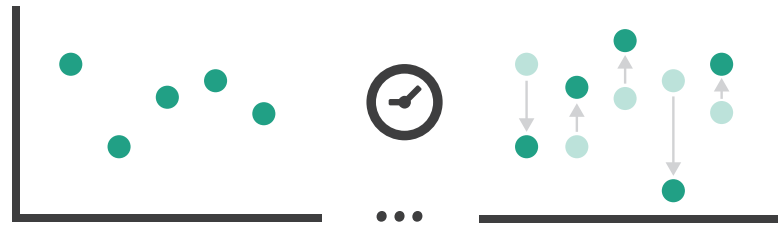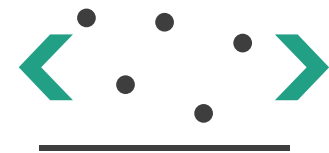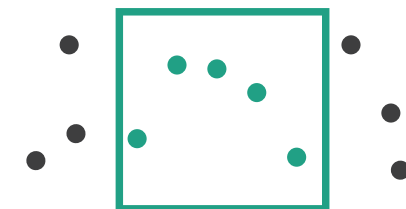
Select
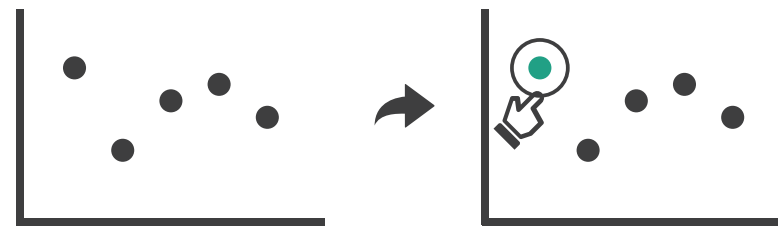
Navigate

➜ *Zoom*
  Geometric
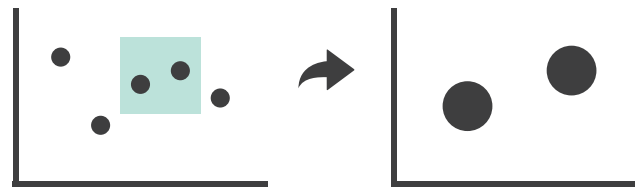
➜ *Pan/Translate*

➜ *Constrained*

Navigate: Changing viewpoint/visibility

- change viewpoint
  - changes which items are visible within view

- camera metaphor
  - pan/translate/scroll
    - move up/down/sideways

➔ **Navigate**

➔ *Pan/Translate*

Idiom: **Scrollytelling**

- how: navigate page by scrolling (panning down)

- pros:
  - familiar & intuitive, from standard web browsing
  - linear (only up & down) vs possible overload of click-based interface choices

- cons:
  - full-screen mode may lack affordances
  - scrolljacking, no direct access
  - unexpected behaviour
  - continuous control for discrete steps

[How to Scroll, Bostock](https://bost.ocks.org/mike/scroll/)

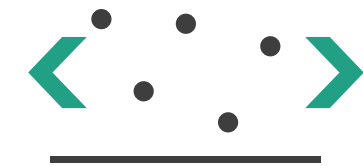https://eagereyes.org/blog/2016/the-scrollytelling-scourge

Navigate: Changing viewpoint/visibility

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- camera metaphor
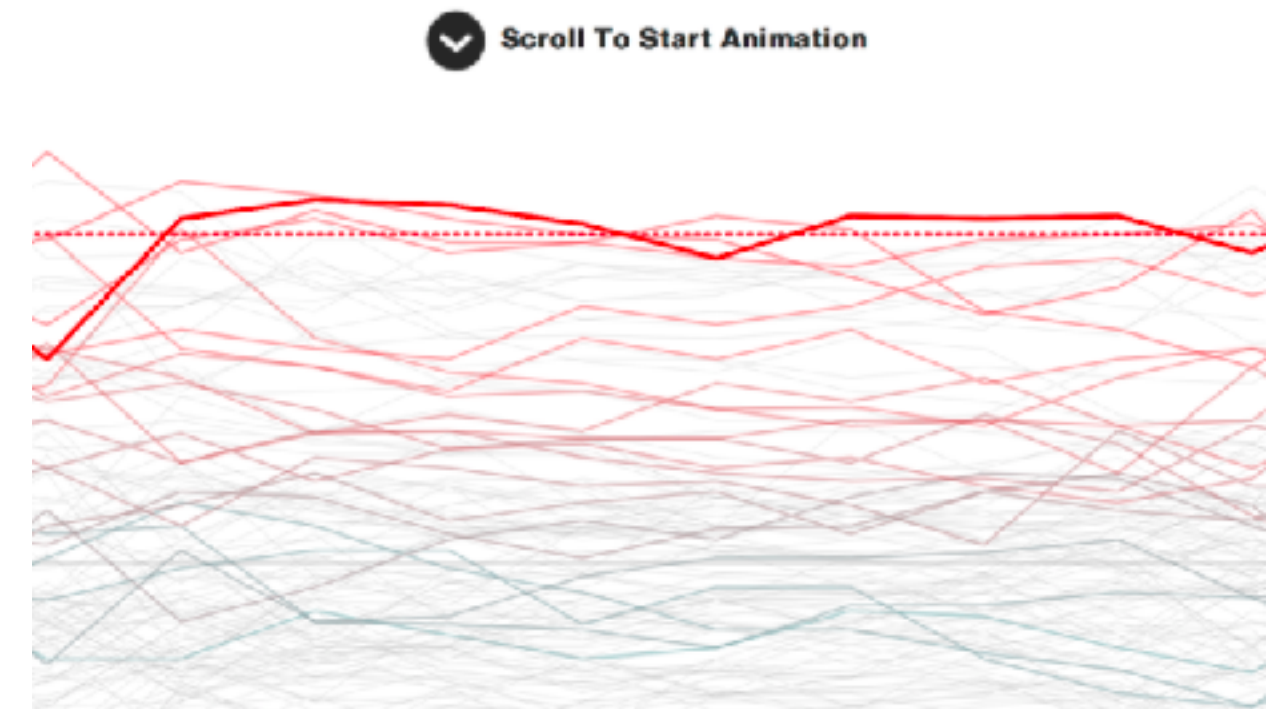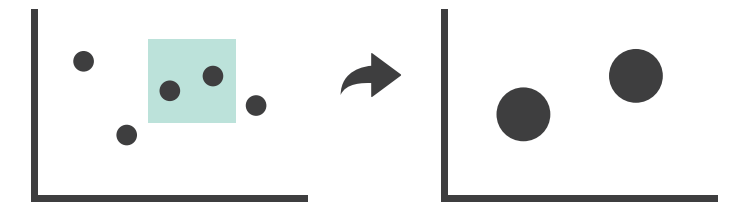 - pan/translate/scroll
    - move up/down/sideways
  - rotate/spin
    - typically in 3D
  - zoom in/out
    - enlarge/shrink world == move camera closer/further
    - geometric zoom: standard, like moving physical object

➔ **Navigate**

➔ *Zoom*
Geometric

➔ *Pan/Translate*
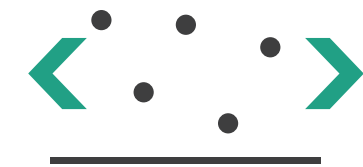
Navigate: Unconstrained vs constrained

- unconstrained navigation
  - easy to implement for designer
  - hard to control for user
    - easy to overshoot/undershoot

- constrained navigation
  - typically uses animated transitions
  - trajectory automatically computed based on selection
    - just click; selection ends up framed nicely in final viewport

➔ **Navigate**

➔ Item Reduction

➔ *Zoom*
Geometric or *Semantic*

➔ *Pan/Translate*

➔ *Constrained*

Idiom: **Animated transition + constrained navigation**
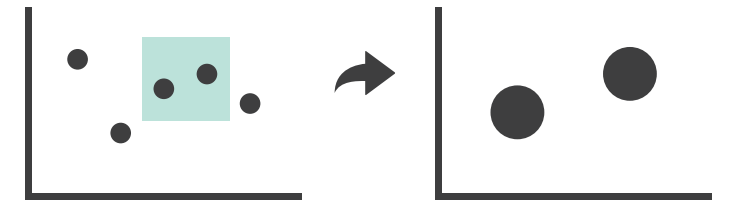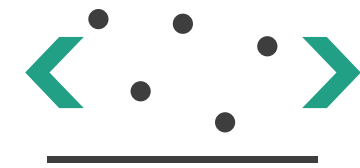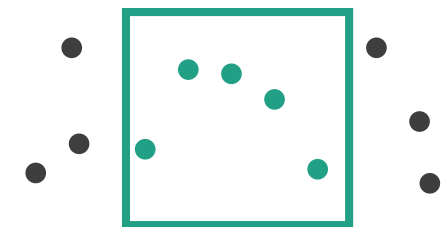
- example: geographic map
  - simple zoom, only viewport changes, shapes preserved

Zoom to Bounding Box

[Zoom to Bounding Box] https://observablehq.com/@d3/zoom-to-bounding-box

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 slide of plane from camera
  - project
    - change mathematics of image creation
      - orthographic
      - perspective
      - many others: Mercator, cabinet, ...
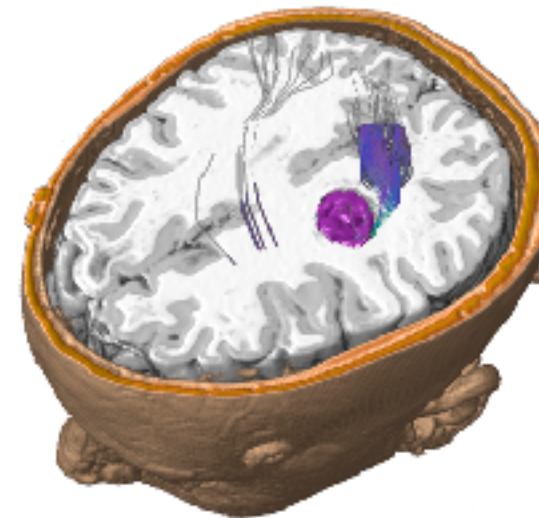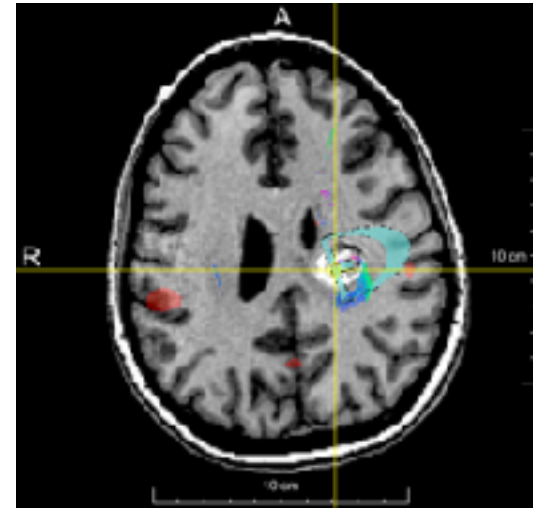
➜ Attribute Reduction

➜ *Slice*
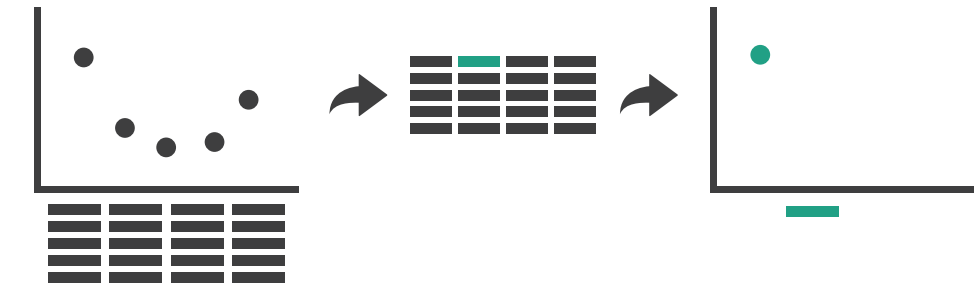
➜ *Cut*
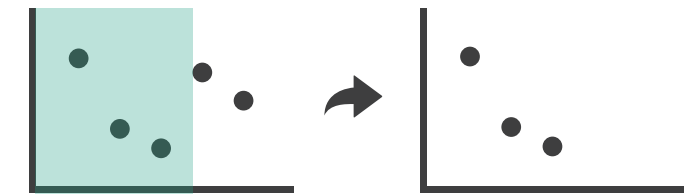
➜ *Project*
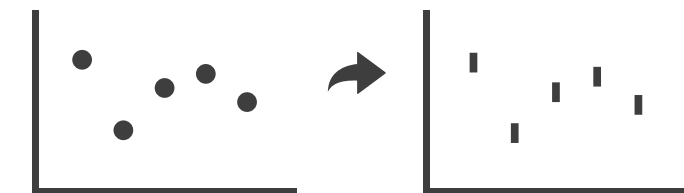
Interaction benefits

- interaction pros
  - major advantage of computer-based vs paper-based visualization
  - flexible, powerful, intuitive
    - exploratory data analysis: change as you go during analysis process
    - fluid task switching: different visual encodings support different tasks
  - animated transitions provide excellent support
    - empirical evidence that animated transitions help people stay oriented

Interaction limitations

- interaction has a time cost
  - sometimes minor, sometimes significant
  - degenerates to human-powered search in worst case
- remembering previous state imposes cognitive load
- controls may take screen real estate
  - or invisible functionality may be difficult to discover (lack of affordances)
- users may not interact as planned by designer
  - NYTimes logs show ~90% don't interact beyond scrollytelling - Aisch, 2016
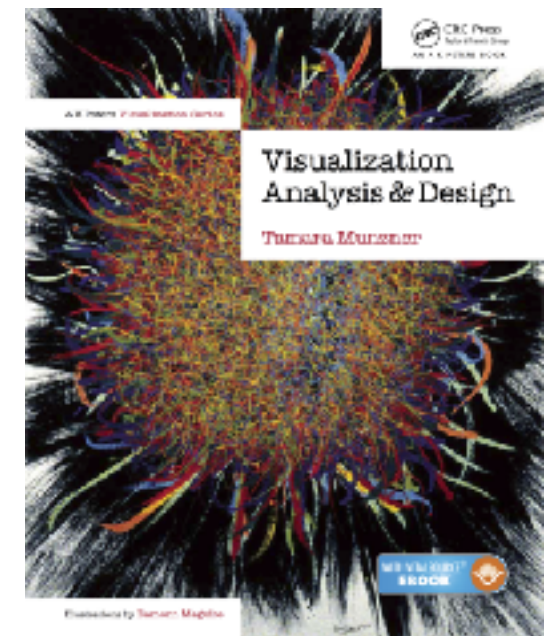
Visualization Analysis & Design

Interactive Views (Ch 11/12) II

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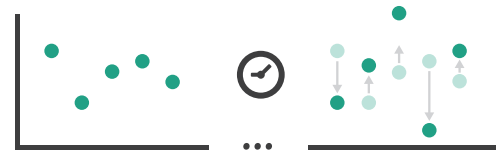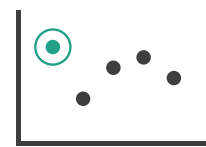# How to handle complexity: 1 previous strategy + 2 more

→ *Derive*

- derive new data to show within view
- change view over time
- facet across multiple views

Manipulate

→ **Change**

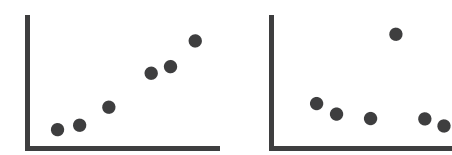
→ **Select**

→ **Navigate**

Facet

→ **Juxtapose**
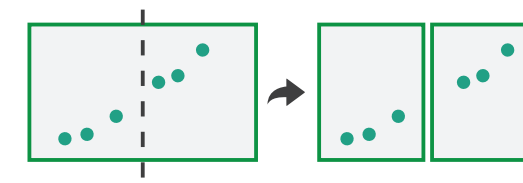
→ **Partition**

→ **Superimpose**

Multiple Views

Facet

→ **Juxtapose**
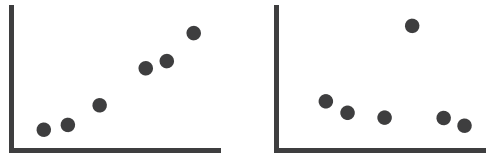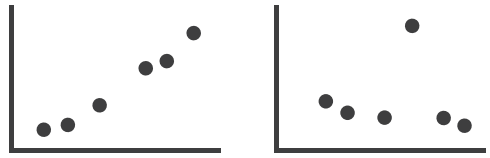

→ **Partition**

→ **Superimpose**

Facet

→ **Juxtapose**

→ **Partition**
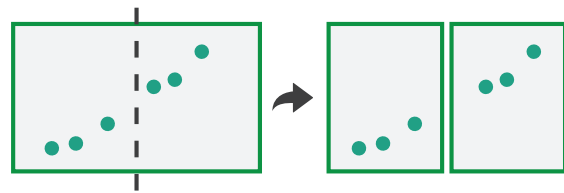
→ **Superimpose**
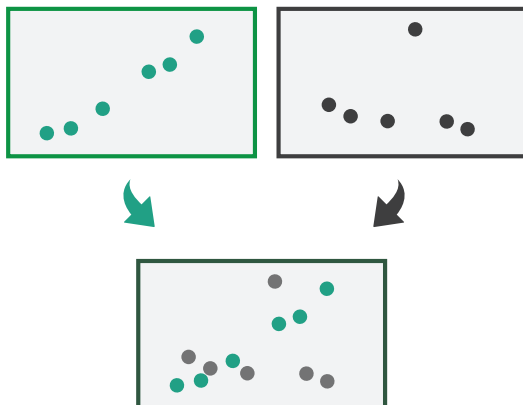
Juxtapose and coordinate views

➔ Share Encoding: Same/Different

  ➔ *Linked Highlighting*

➔ Share Data: All/Subset/None

➔ Share Navigation
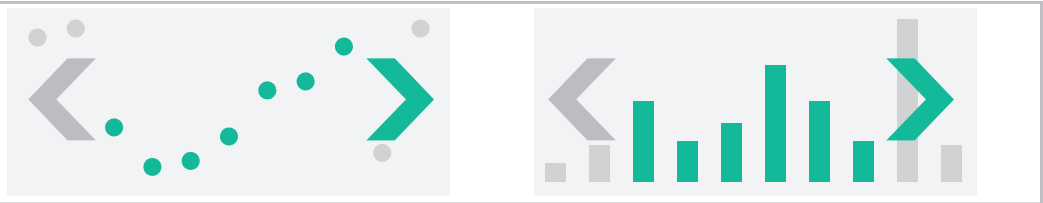
- see how regions contiguous in one view are distributed within another
  - powerful and pervasive interaction idiom

- encoding: different
  - *multiform*

- data: all shared
  - all **items** shared
  - different **attributes** across the views

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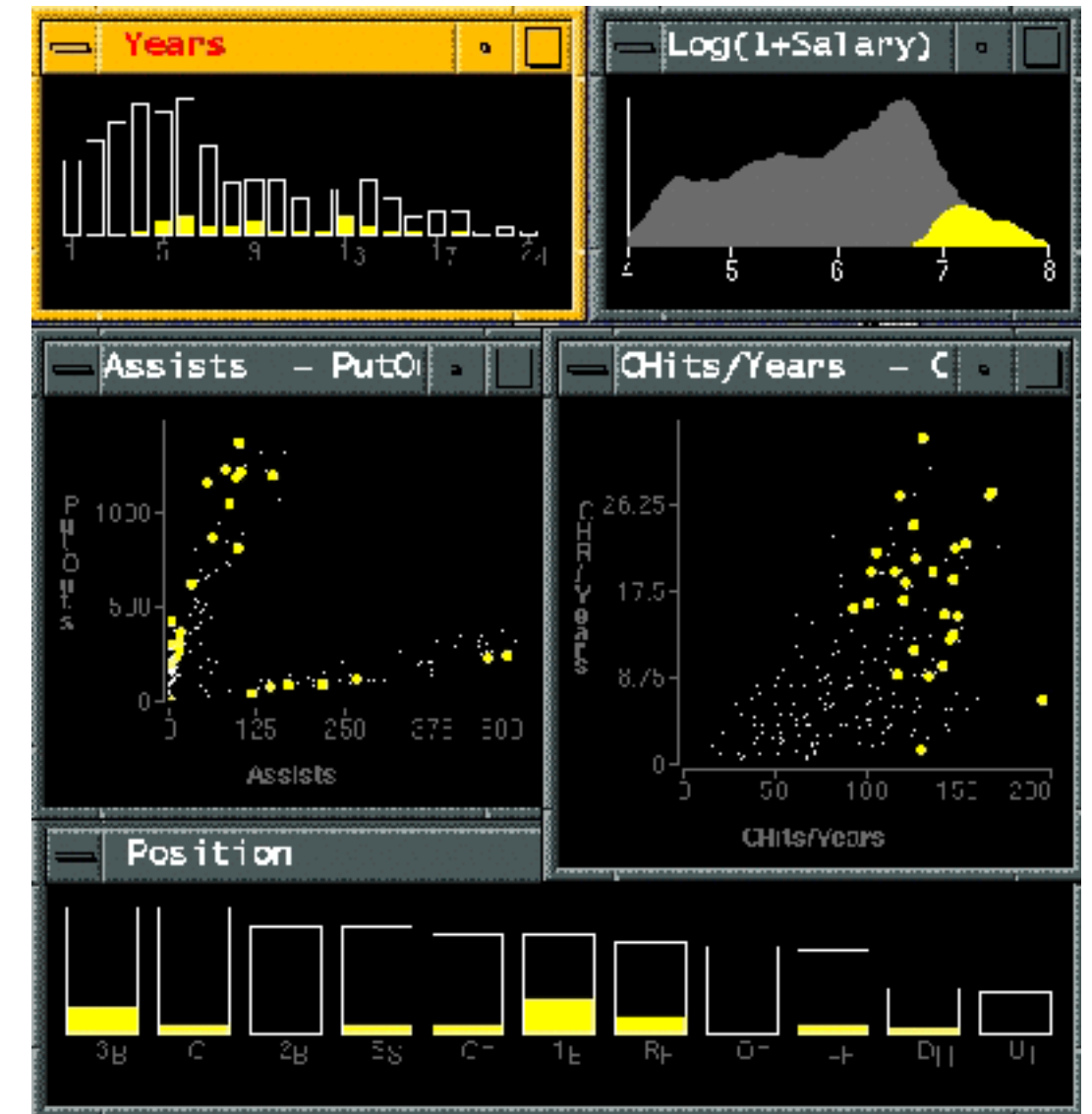
[Visual Exploration of Large Structured Datasets. Wills.
Proc. New Techniques and Trends in Statistics (NTTS), pp. 237–246. IOS Press, 1995.]

Linked views: Directionality

- unidirectional vs bidirectional linking
  - bidirectional almost always better!
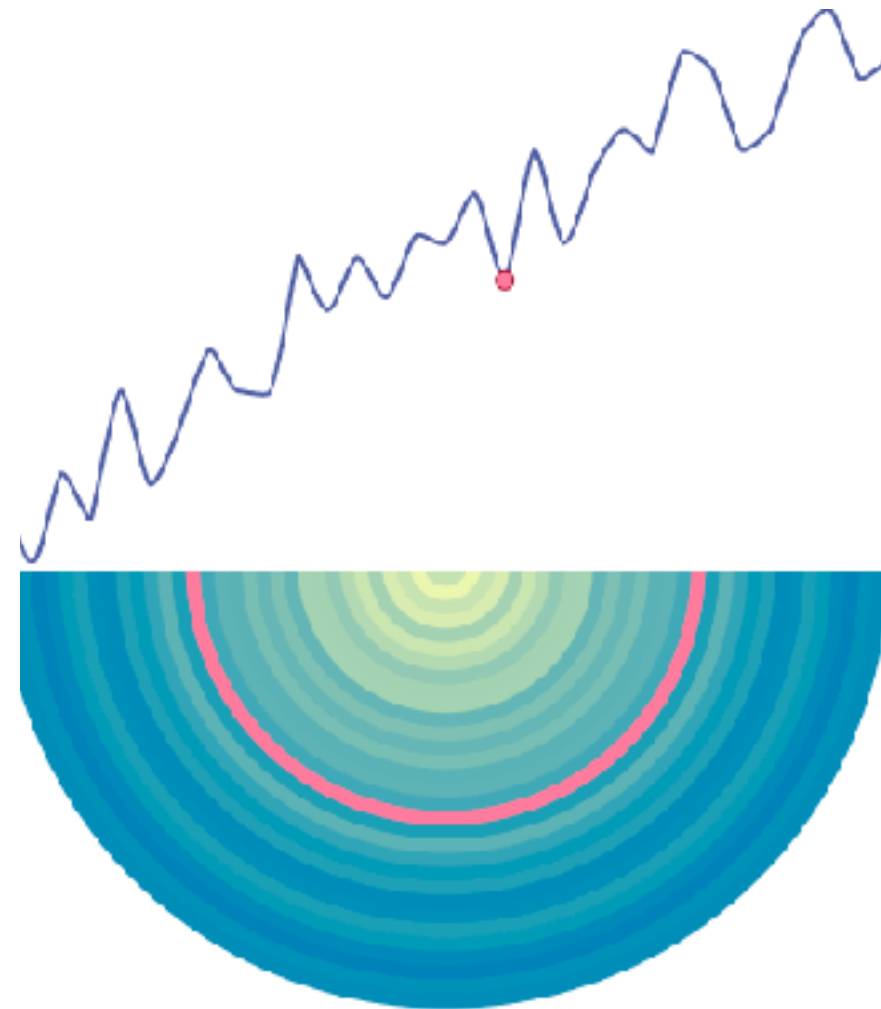
Idiom: **Overview-detail views**   System: **Google Maps**

- encoding: same or different
  - ex: same (birds-eye map)

- data: subset shared
  - viewpoint differences: subset of data items

- navigation: shared
  - bidirectional linking

- other differences
  - (window size)

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

Idiom: **Overview-detail navigation**
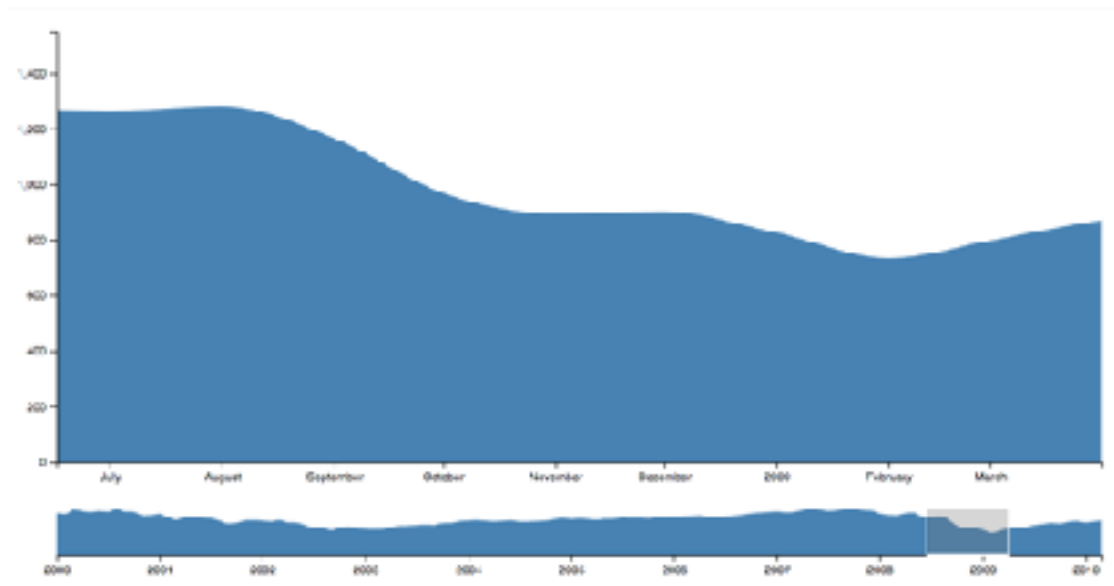
- encoding: same or different

- data: subset shared

- navigation: shared
  - unidirectional linking
  - select in small overview,
    change extent in large detail view

https://observablehq.com/@uwdata/interaction

Idiom: **Tooltips**

- popup information for selection
  - hover or click
  - specific case of detail view:
    provide useful additional detail on demand
  - beware: does not support overview!
    - always consider if there's a way to visually encode directly to provide overview
    - "If you make a rollover or tooltip, assume nobody will see it. If it's important, make it explicit."
      - Gregor Aisch, NYTimes

Historical USD to EUR Exchange Rate
Select an area by dragging across the lower chart

USD to EUR
Monday December 17 2012:
1 USD = 0.76 EUR

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

Idiom: **Small multiples**

- encoding: same
  - ex: line charts
- data: none shared
  - different slices of dataset
    - items or attributes
    - ex: stock prices for different companies

[https://bl.ocks.org/mbostock/1157787]
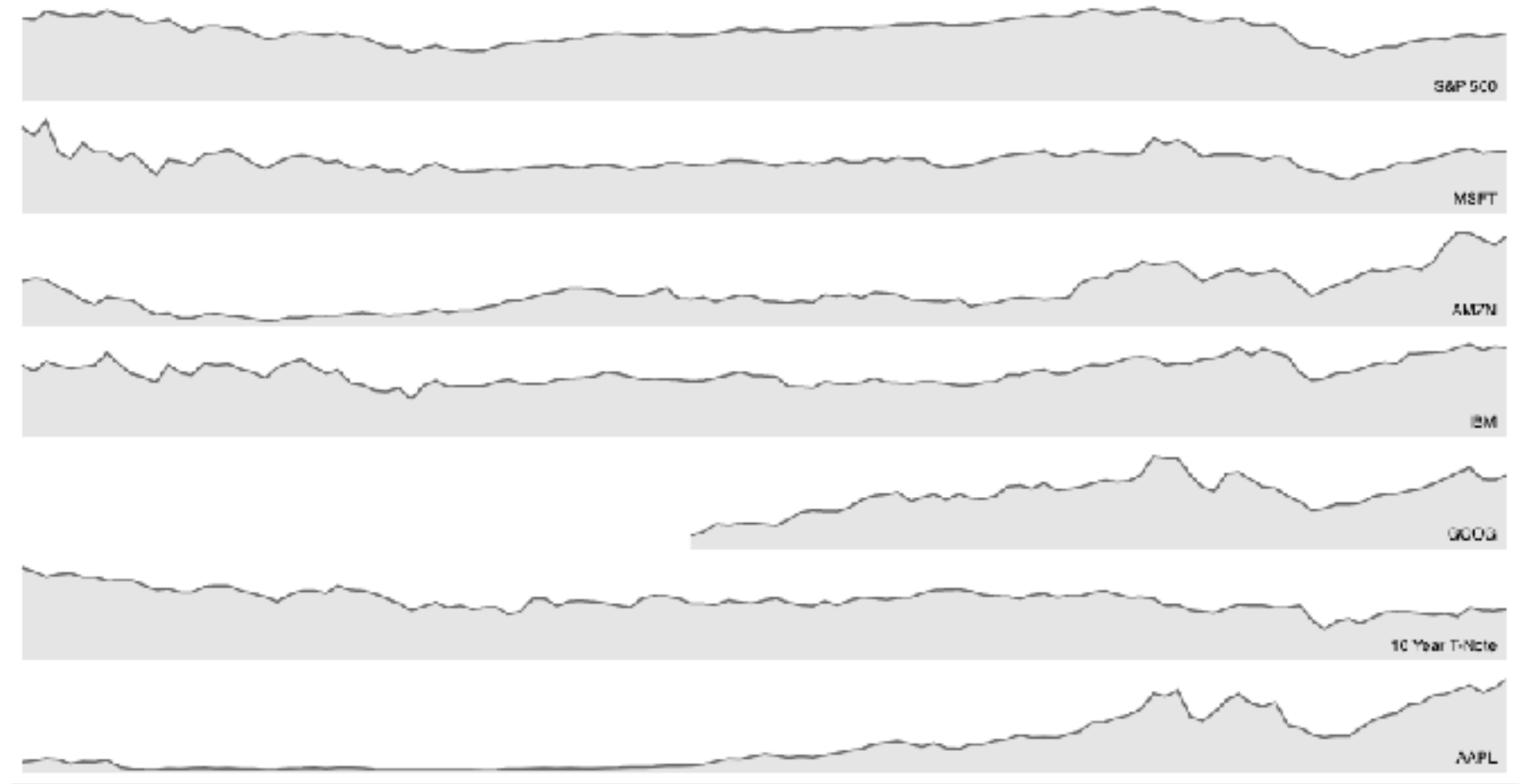
Interactive small multiples

- linked highlighting: analogous item/attribute across views
  - same year highlighted across all charts if hover within any chart

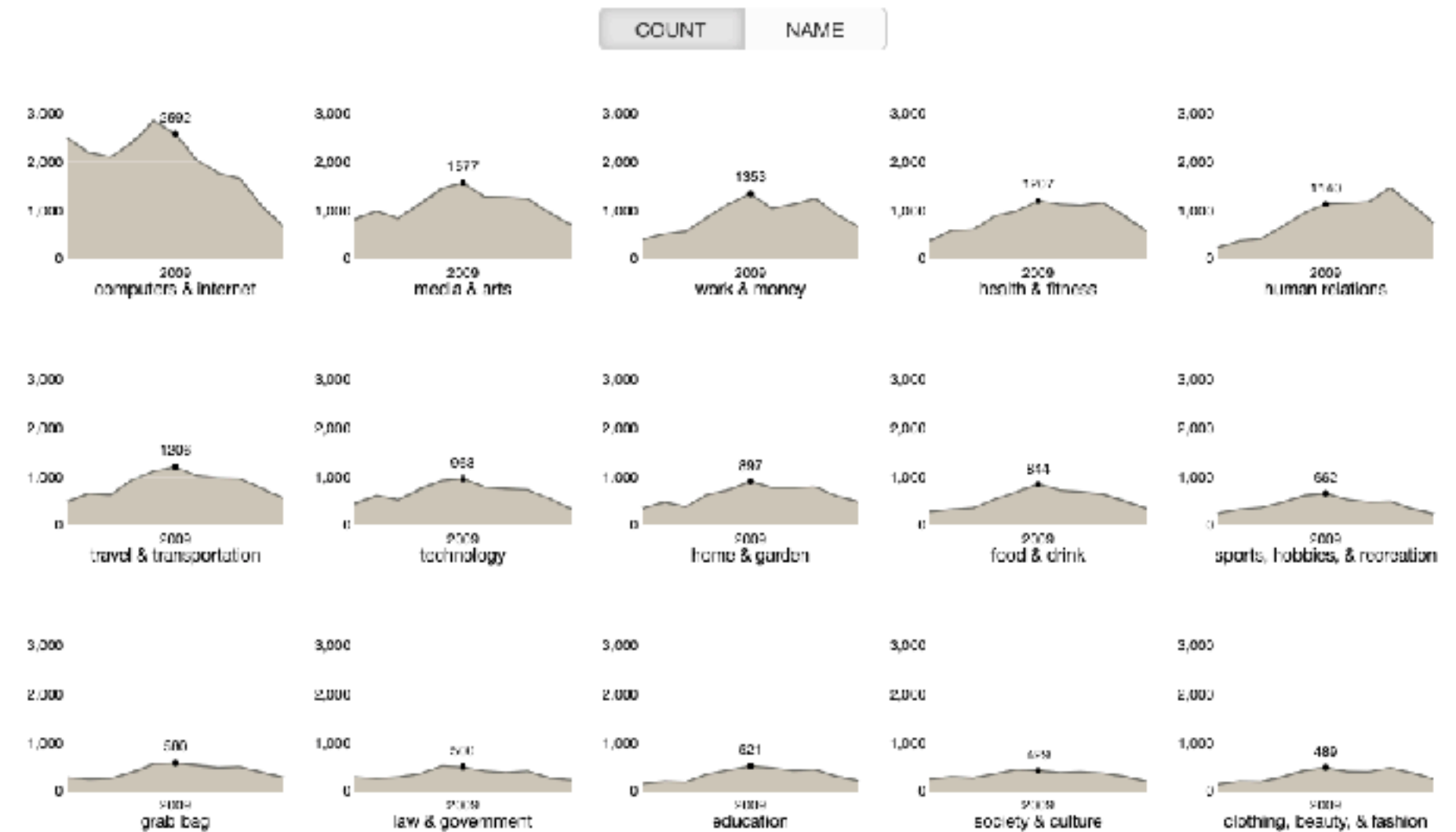The Rise and Decline of Ask MetaFilter

[https://bl.ocks.org/ColinEberhardt/3c780088c363d1515403f50a87a87121]

[https://blog.scottlogic.com/2017/04/05/interactive-responsive-small-multiples.html]

[http://projects.flowingdata.com/tut/linked_small_multiples_demo/]

Example: Combining many interaction idioms

System: **Buckets**

- multiform
- multidirectional linked highlighting of small multiples
- tooltips

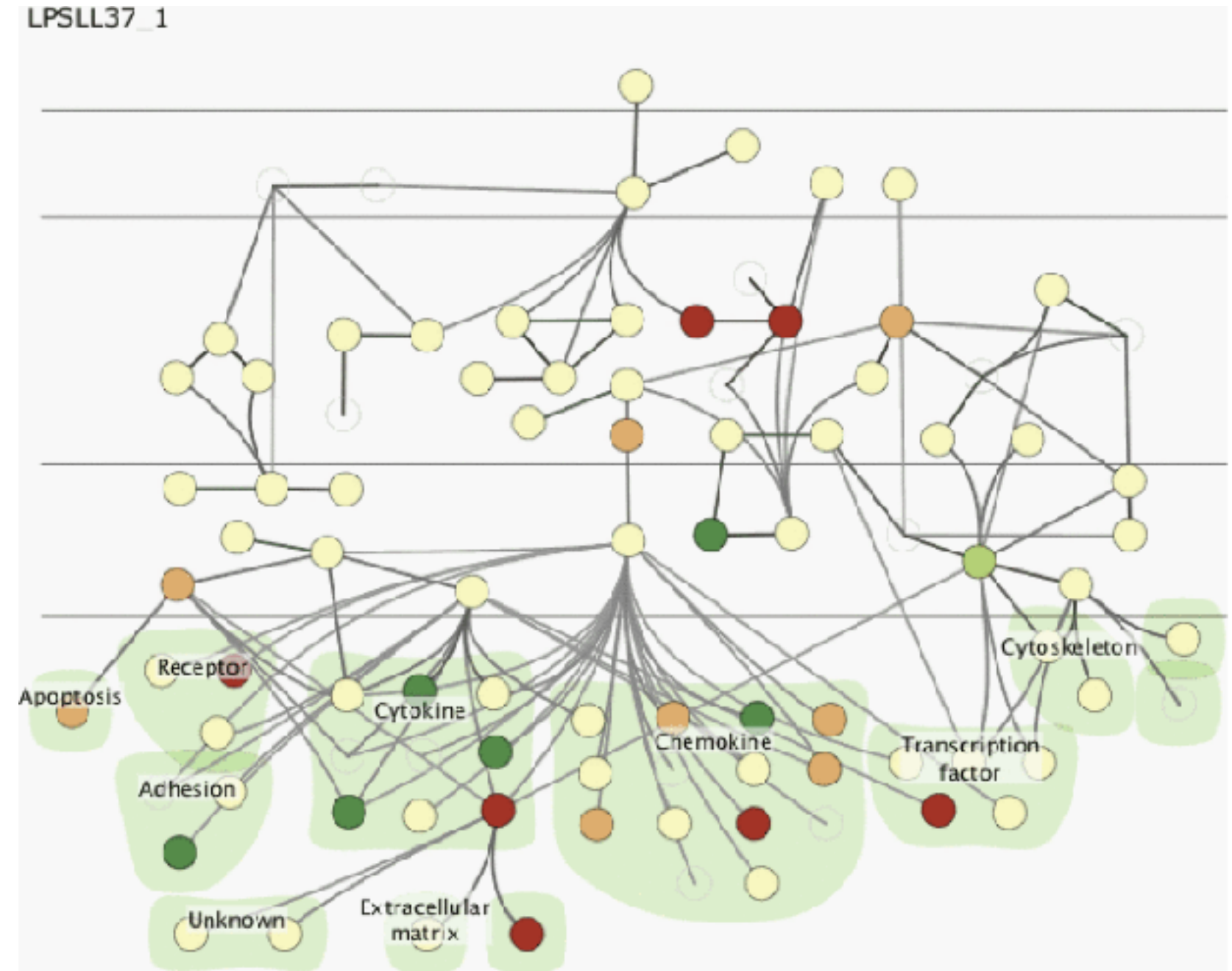*http://buckets.peterbeshai.com/*

Juxtapose views: tradeoffs

- **juxtapose costs**
  - display area
    - 2 views side by side: each has only half the area of one view
- **juxtapose benefits**
  - cognitive load: eyes vs memory
    - lower cognitive load: move eyes between 2 views
    - higher cognitive load: compare single changing view to memory of previous state
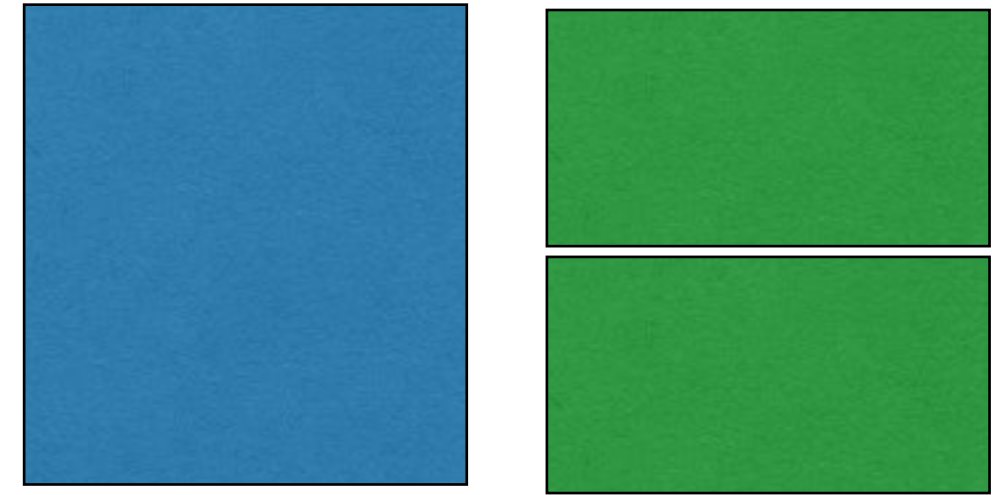
Juxtapose vs animate

- animate: hard to follow if many scattered changes or many frames
  - vs easy special case: animated transitions

[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.]
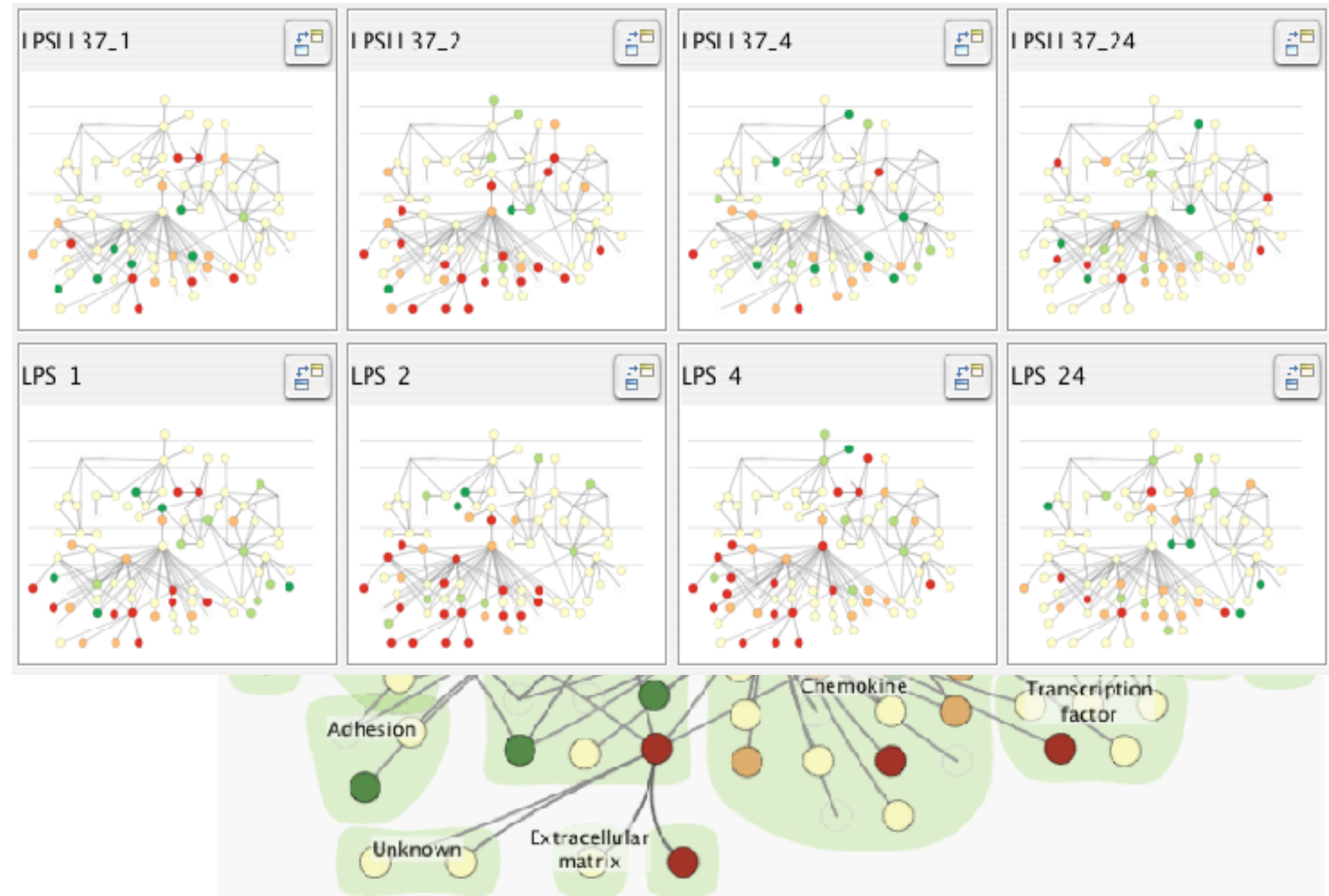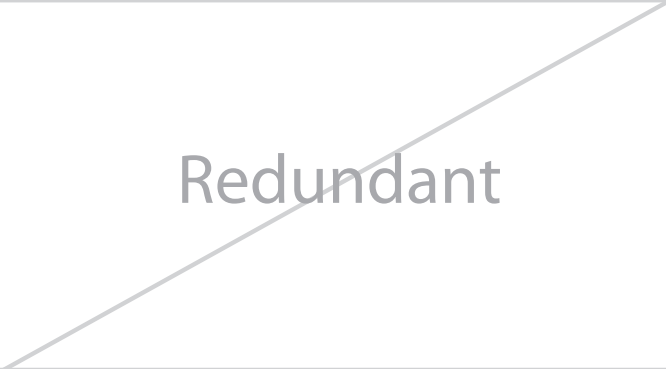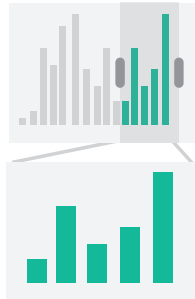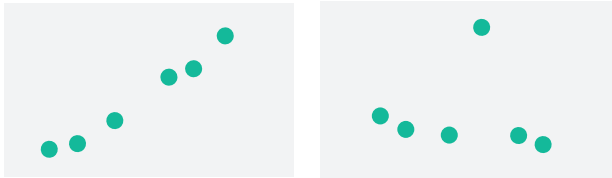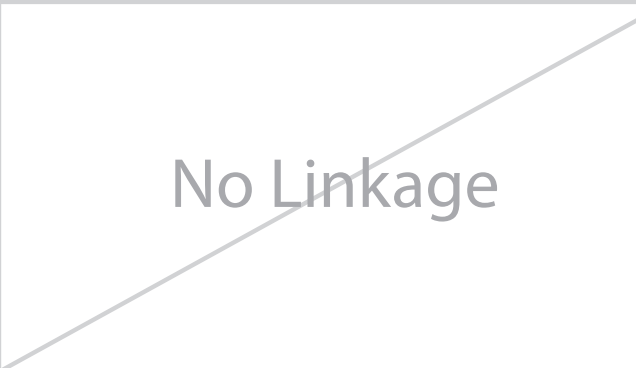
Juxtapose vs animate

- animate: hard to follow if many scattered changes or many frames
  - vs easy special case: animated transitions

- juxtapose: easier to compare across small multiples
  - different conditions (color), same gene (layout)

[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.]

View coordination: Design choices

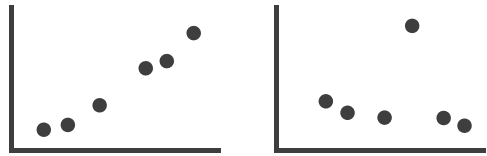|		Data		
		All	Subset	None
Encoding	Same	Redundant	Overview/ Detail	Small Multiples
	Different	Multiform	Multiform, Overview/ Detail	No Linkage

- list views
  - easy lookup
  - useful when linked to other views

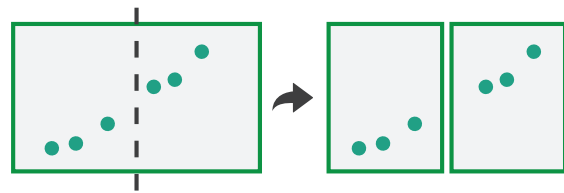- how many views is ok vs too complex?
  - open research question
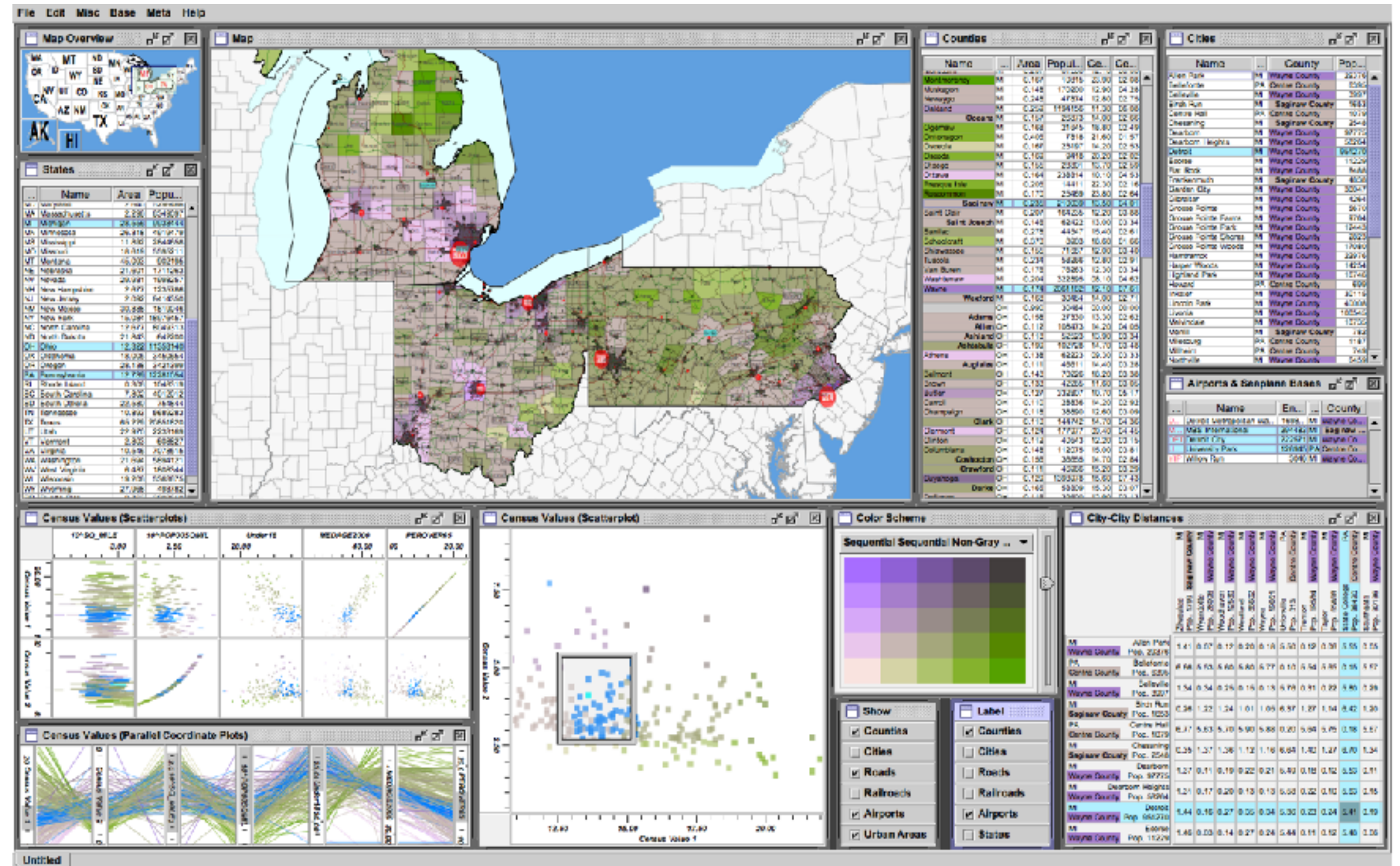
[Building Highly-Coordinated Visualizations In Improvise. Weaver.
Proc. IEEE Symp. Information Visualization (InfoVis), pp. 159–166, 2004.]
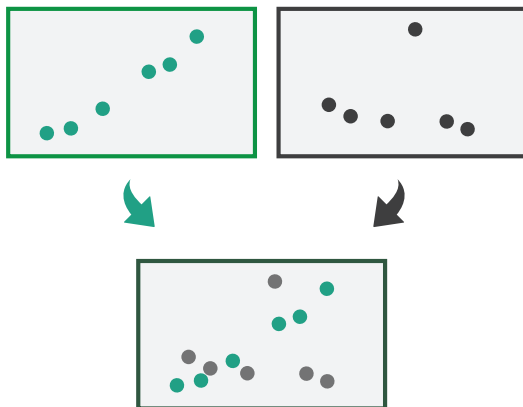
46

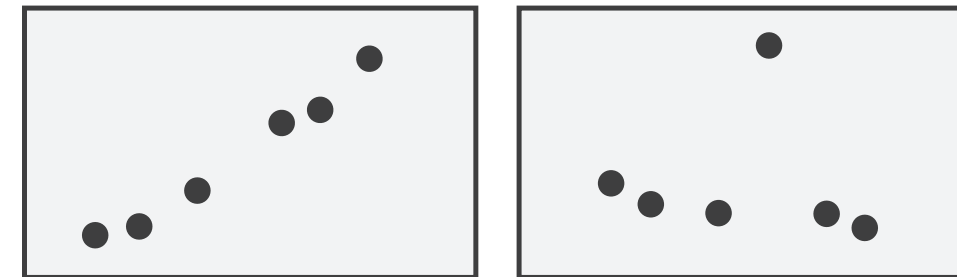# Facet

➔ **Juxtapose**

➔ **Partition**

➔ **Superimpose**

Partition into views

- how to divide data between views

  - split into regions by attributes

  - encodes association between items using spatial proximity

 - order of splits has major implications for what patterns are visible

➔ **Partition into Side-by-Side Views**

Partitioning: Grouped vs small-multiple bars

- 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
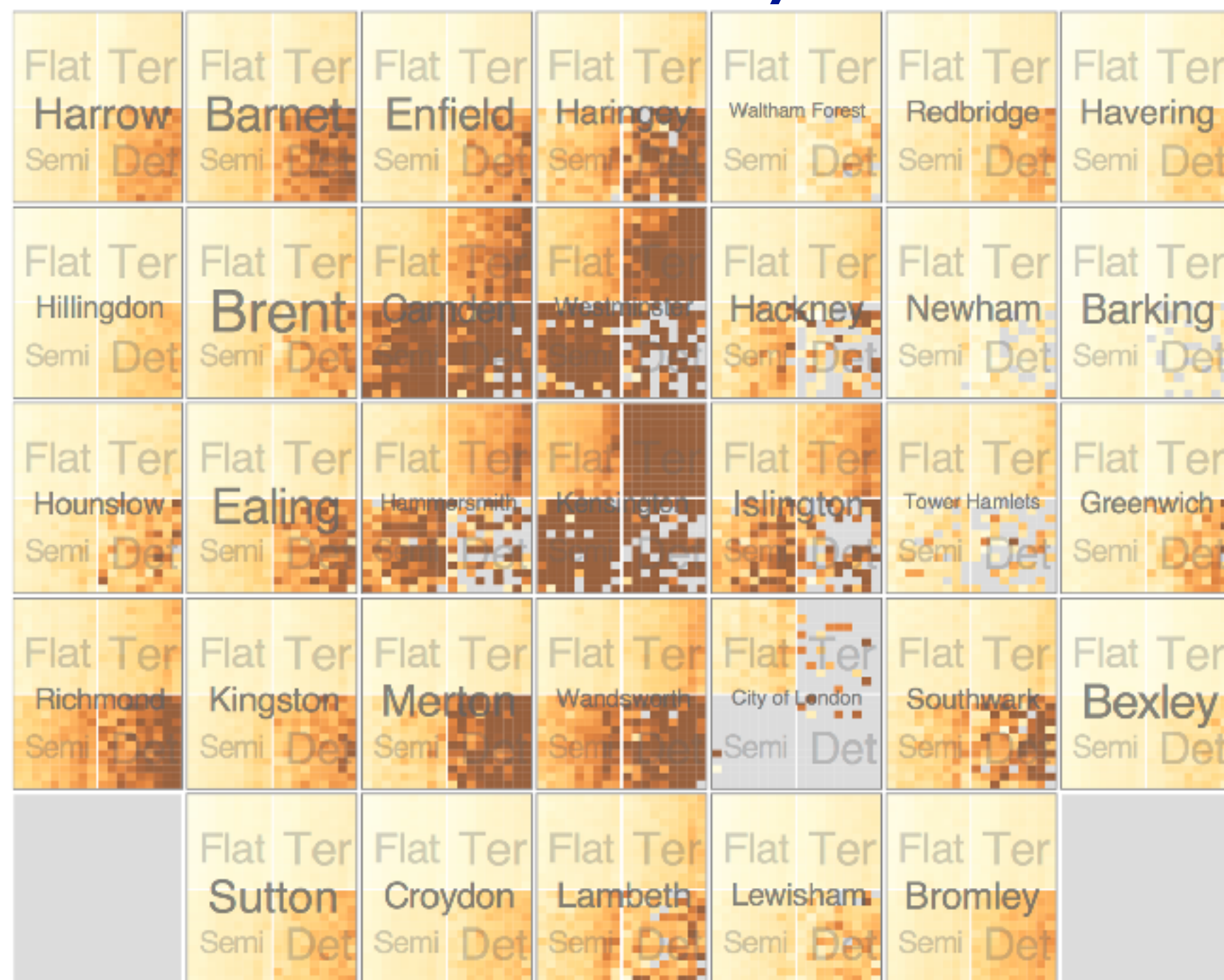 - compare: easy within age, harder across states

[https://observablehq.com/@d3/grouped-bar-chart]

[https://bl.ocks.org/mbostock/4679202]
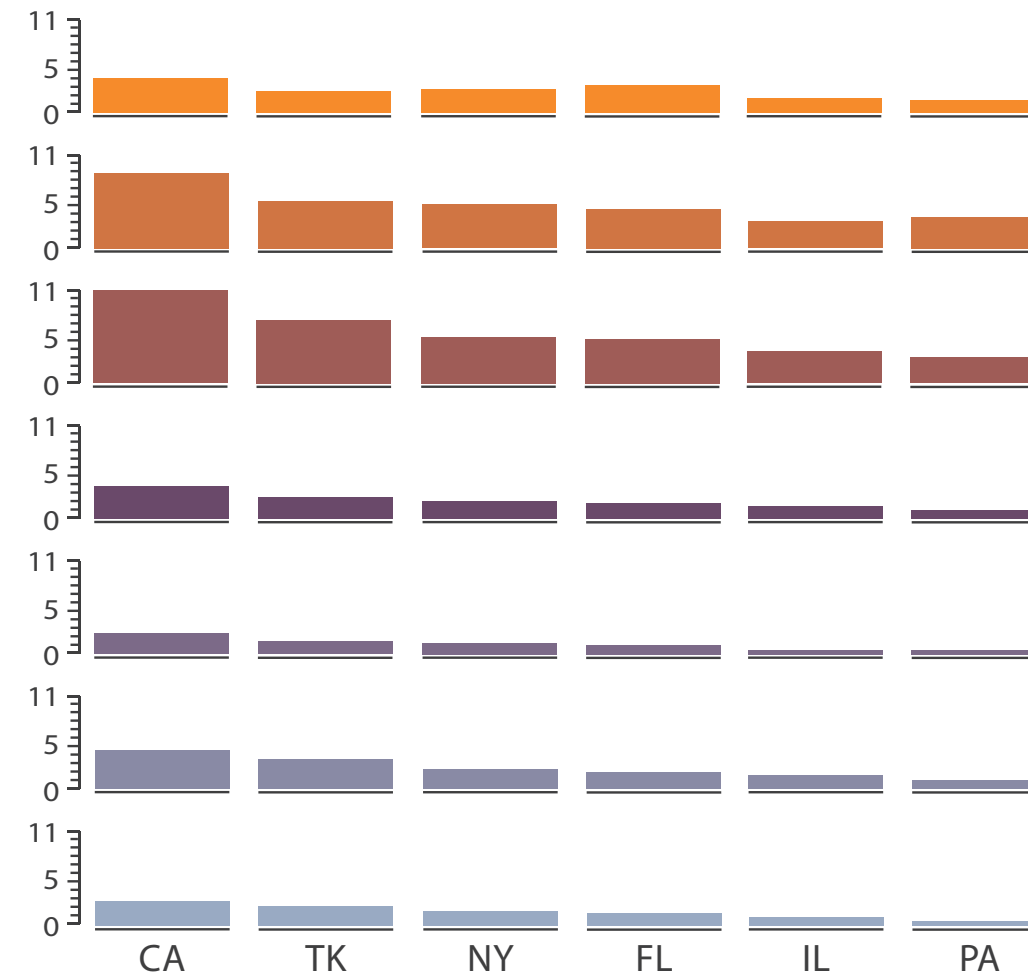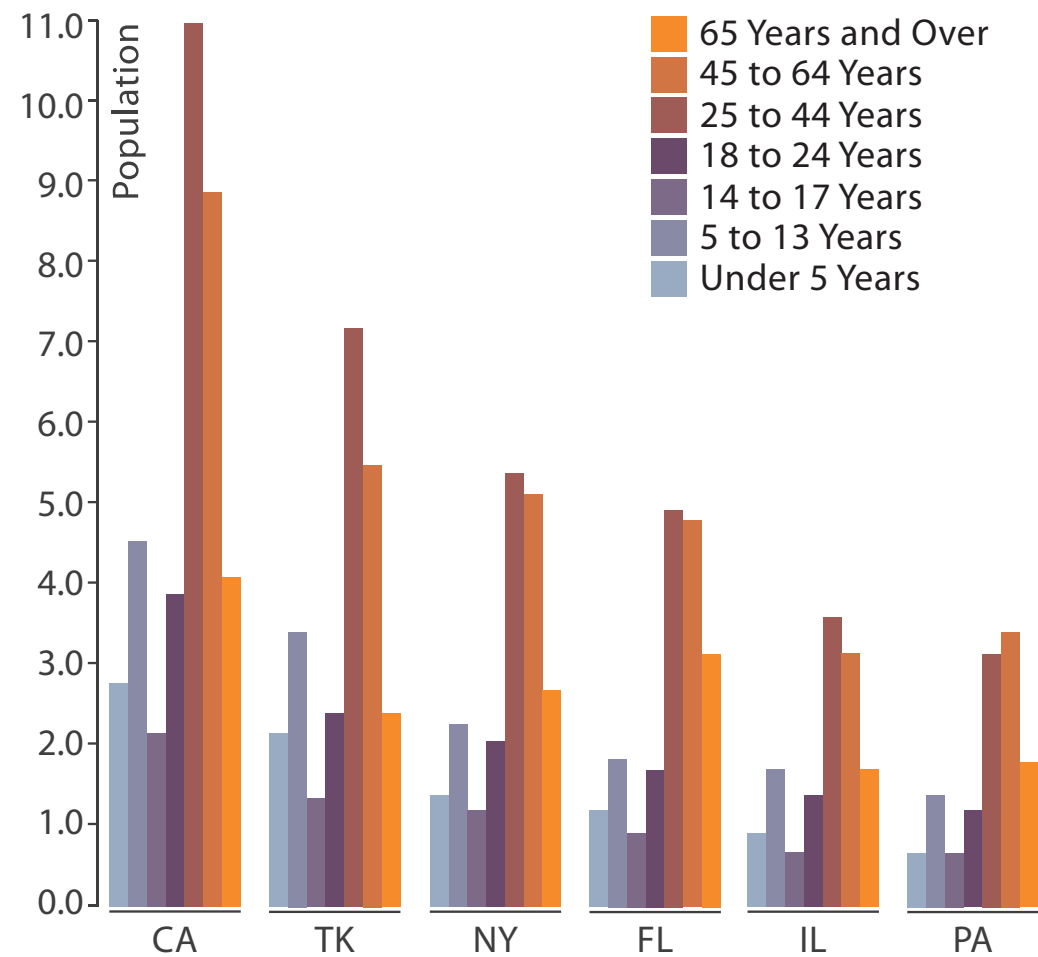
Partitioning: Recursive subdivision

- split by neighborhood
- then by type
  - flat, terrace, semi-detached, detached
- then time
  - years as rows
  - months as columns
- color by price

- neighborhood patterns
  - where it's expensive
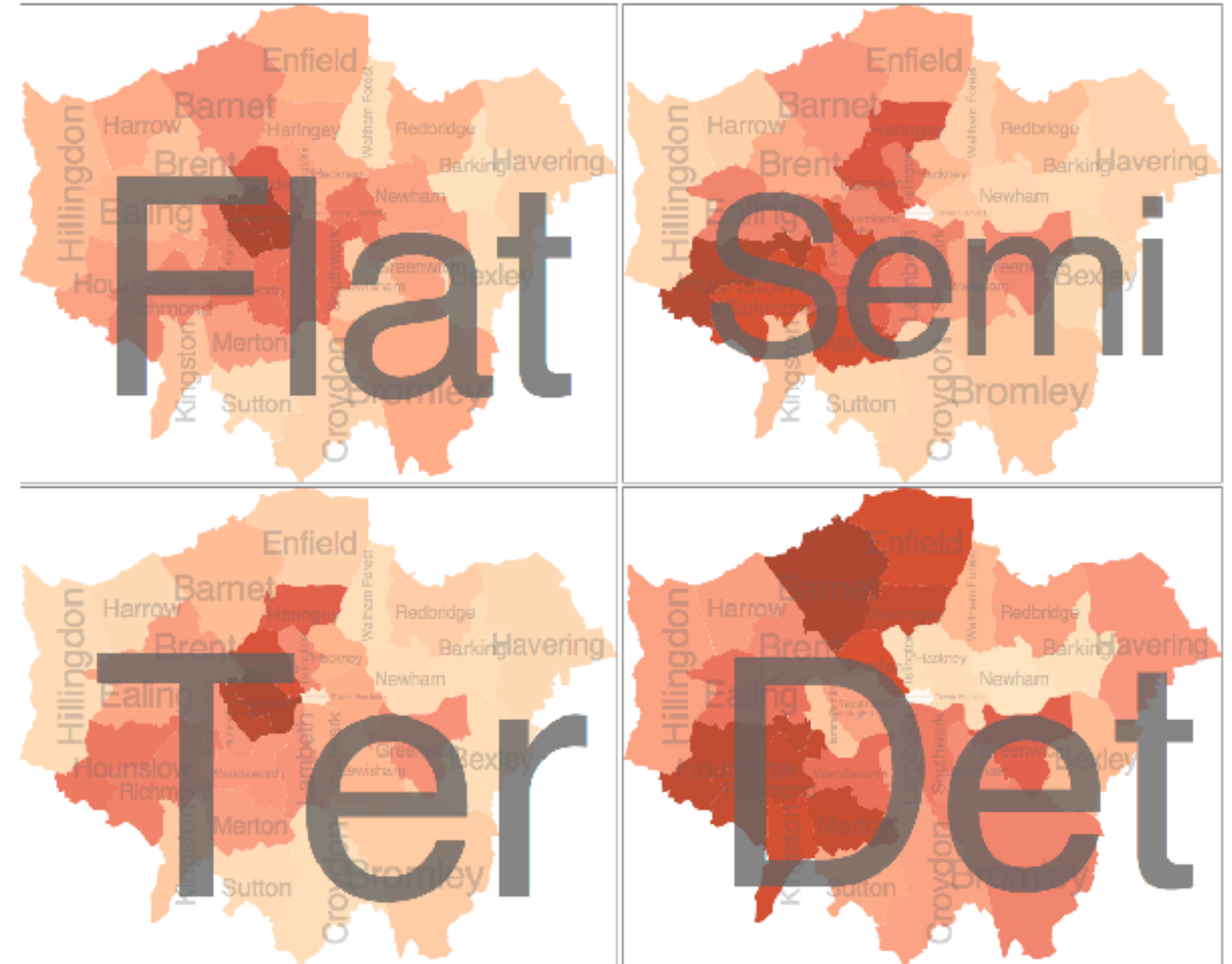 - where you pay much more for detached type

- switch order of splits
  - type then neighborhood

- switch color
  - by price variation

- type patterns
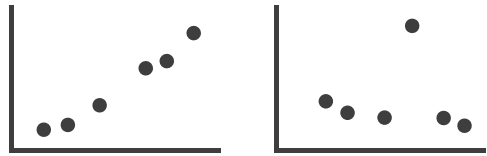 - within specific type, which
    neighborhoods inconsistent

- different encoding for second-level regions
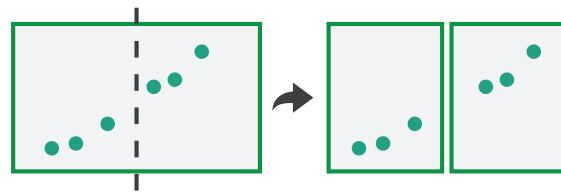 - choropleth maps

Facet

→ **Juxtapose**

→ **Partition**

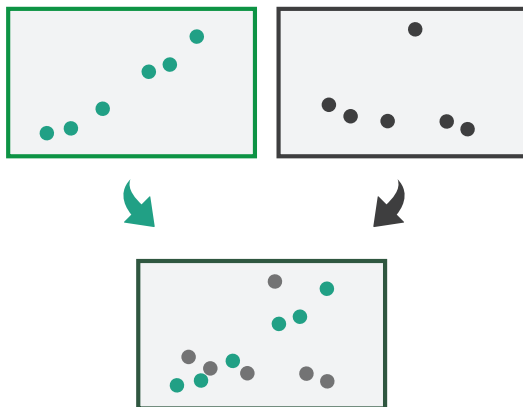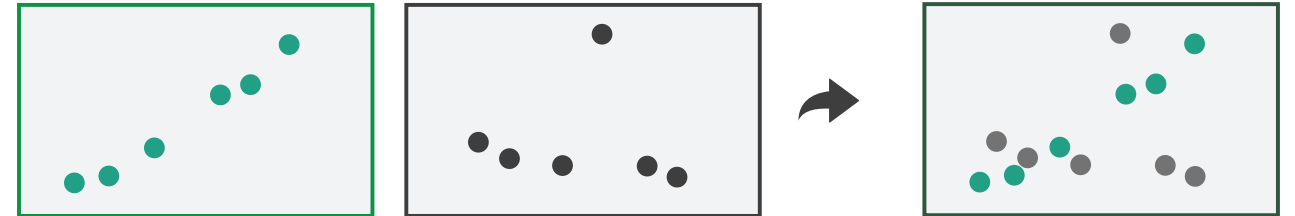→ **Superimpose**

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 to distinguish?
    - encode with different, nonoverlapping channels
    - two layers achievable, three with careful design
  - small static set, or dynamic from many possible?

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

Idiom: **Trellis plots**

- superimpose within same frame
  - color code by year

- partitioning
  - split by site, rows are barley varieties

- main-effects ordering
  - derive value of median for group
  - order rows within view by variety median
 - order views themselves by site median

*[The Visual Design and Control of Trellis Display. Becker, Cleveland, & Shyu.
Journal of Computational and Graphical Statistics 5(2):123-155 1996.]*

Superimposing limits (static)

- few layers, more lines
  - up to a few dozen lines
  - but not hundreds
- superimpose vs juxtapose: empirical study
  - same size: all multiples, vs single superimposed
    - superimposed: local tasks
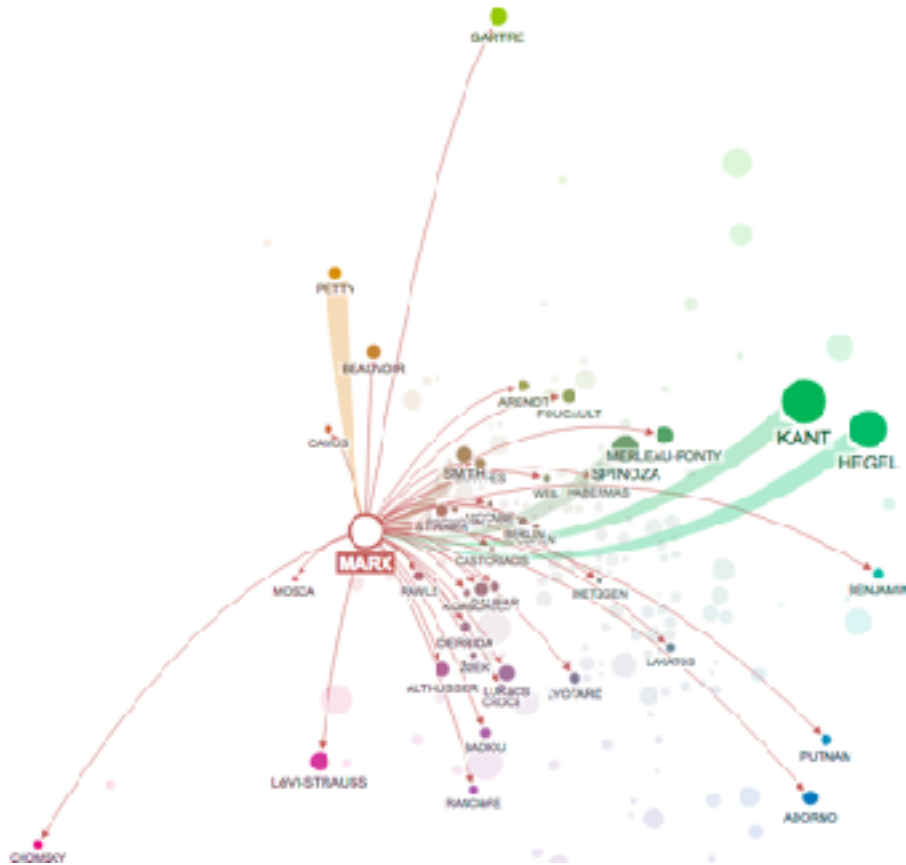   - juxtaposed: global tasks, esp. for many charts

[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.]
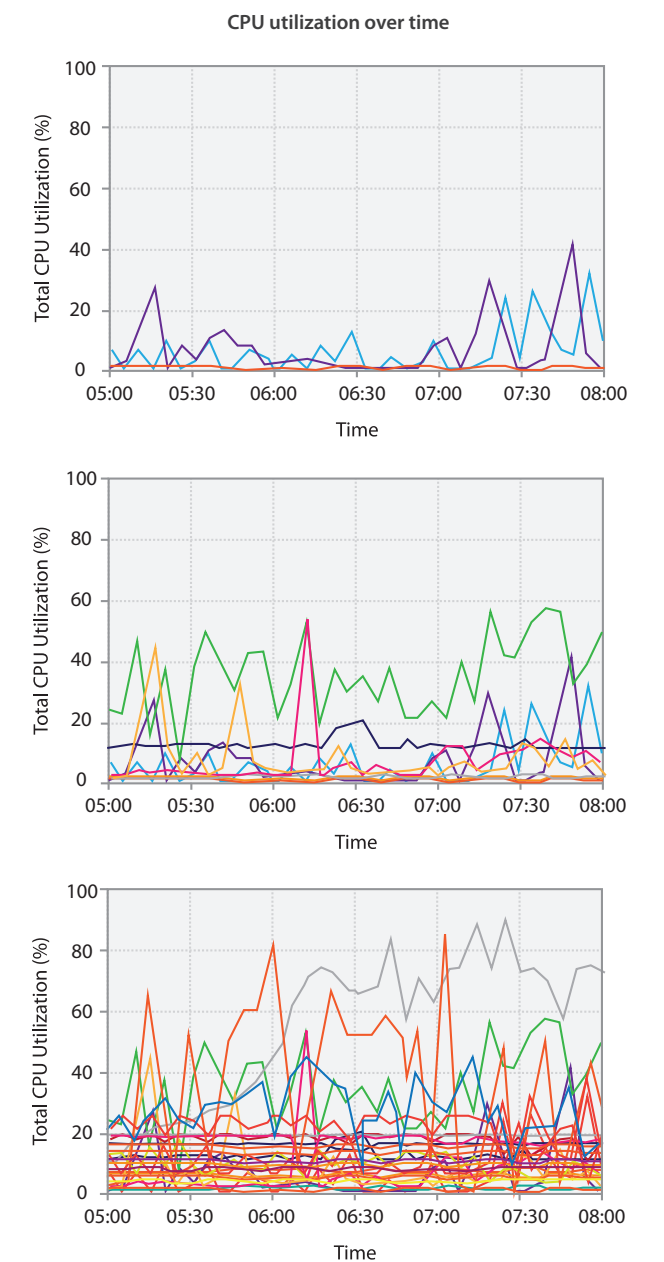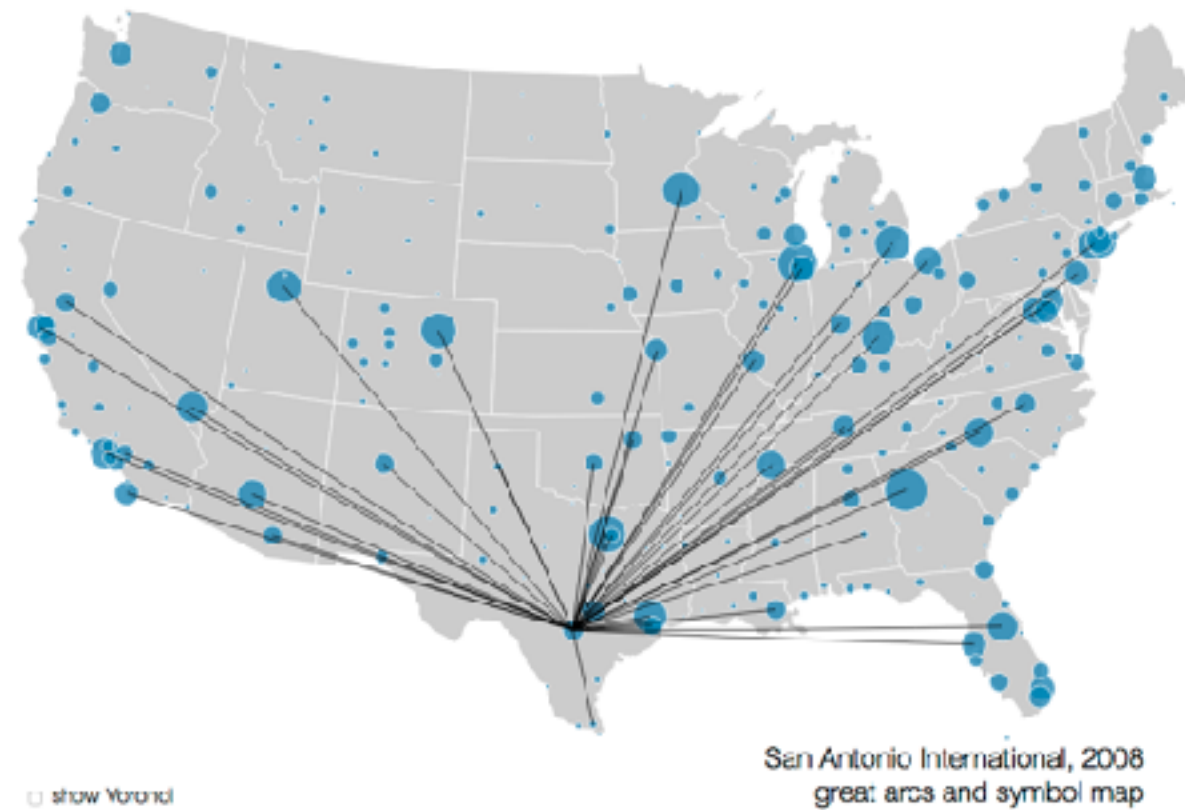
Dynamic visual layering

- interactive, based on selection
- one-hop neighbour highlighting

click (heavyweight)

hover (fast)

San Antonio International, 2008
great arcs and symbol map

https://mariandoerk.de/edgemaps/demo/

http://mbostock.github.io/d3/talk/20111116/airports.html

Encode

Arrange

→ Express

→ Separate

→ Order

→ Align

→ Use

Map

from categorical and ordered attributes

→ Color

→ Hue → Saturation → Luminance

→ Size, Angle, Curvature, …

→ Shape
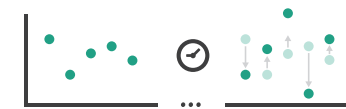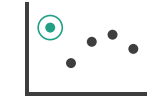
→ Motion
Direction, Rate, Frequency, …
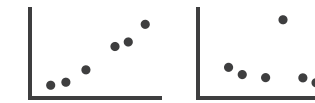
Manipulate

Change

Select

Navigate

Facet

Juxtapose

Partition

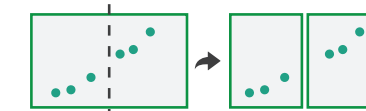### Superimpose

Reduce

Filter

Aggregate

Embed

What?

Why?

How?