NYU

CS-GY 6313 B: Information Visualization

10/24/2024

Logistics

- Assignment 3 due next week
- Final project group + topic due today
  - NYU email to log in
  - https://docs.google.com/spreadsheets/d/1mJ_CGBU1KNzqhw1M9mWNgF0ffI2GqPBT0HaCDUHuPKM/edit?usp=sharing

Interaction & Animation

Managing Complexity in Viz

- Large and complex datasets can lead to cluttered, unhelpful visualizations
- It is often not possible, and usually not desirable, to show *all* the data

- How do we decide what to show and how to show it?
  - *Derive* more meaningful attributes
  - Enable the user to change – *manipulate* – the view
  - *Facet* the data into multiple views and/or layers
  - *Reduce* the number of items and/or attributes to be shown

Interaction benefits and limitations

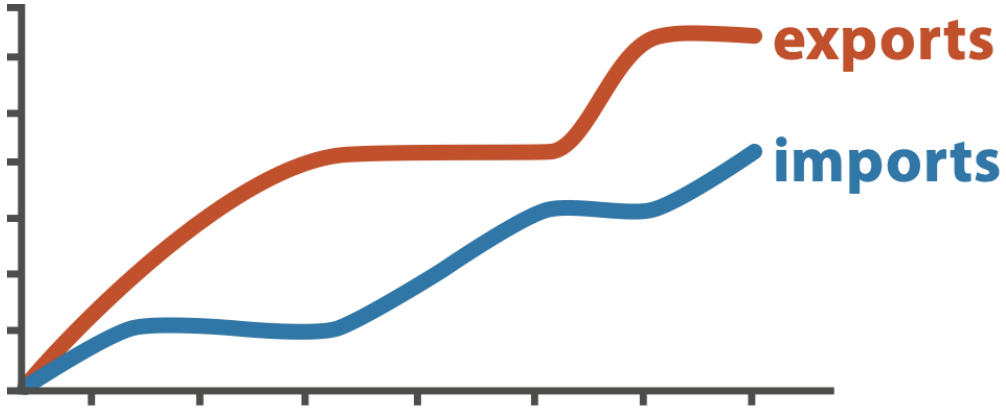
- Pros:
  - Major advantage of computer-based vs paper-based visualization
  - Flexible, powerful, intuitive
    - Exploratory data analysis: change as you go during analysis process
    - Fluid task switching: different visual encodings support different tasks
  - Animated transitions provide excellent support
    - Empirical evidence that animated transitions help people stay oriented

- Cons:
  - Has a time cost
    - Sometimes small, 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

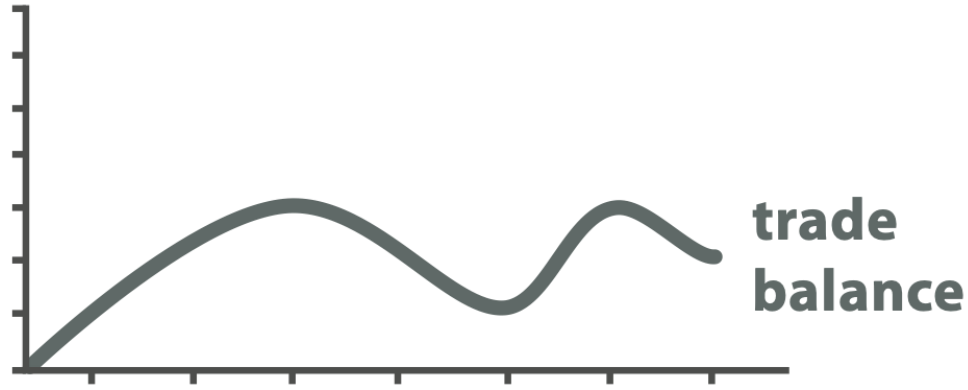
Derive

Derive new data

- Compute (derive) new data from existing data
  - Derived data should be more useful than existing data!
- Combines multiple attributes into one
  - E.g. add, subtract, average, minimum, maximum



Original Data

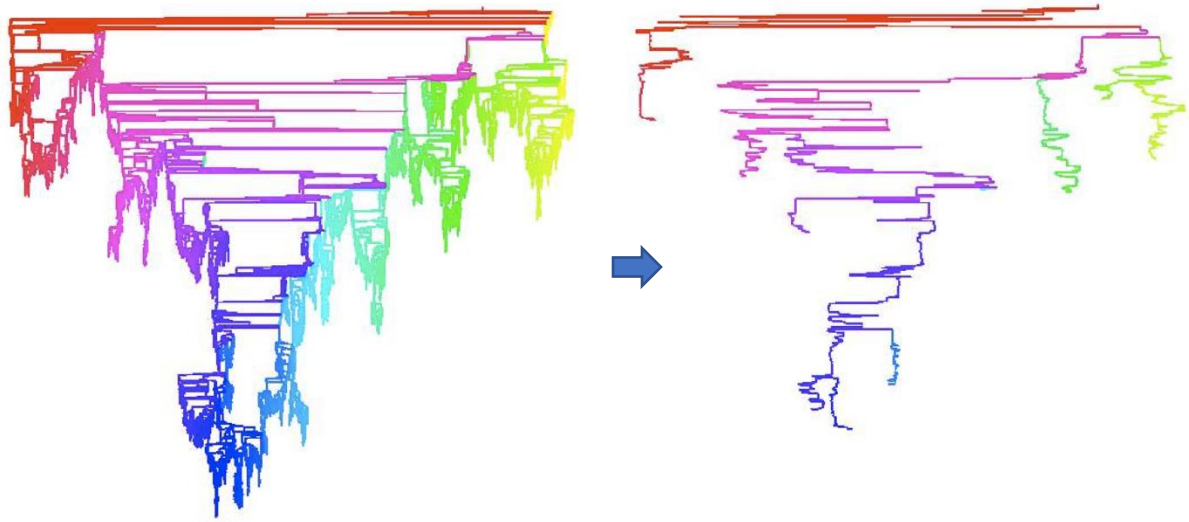


trade balance = *exports* – *imports*

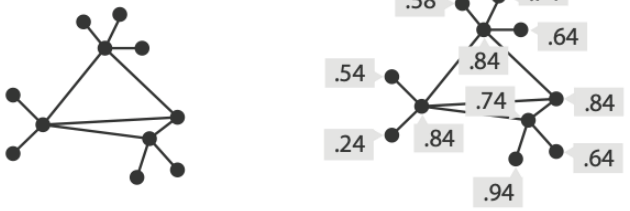
Derived Data

Derive new data

- Strahler measure
  - Centrality metric for networks
  - Derived, quantitative metric



Task 1



In
Tree

Out
Quantitative attribute on nodes

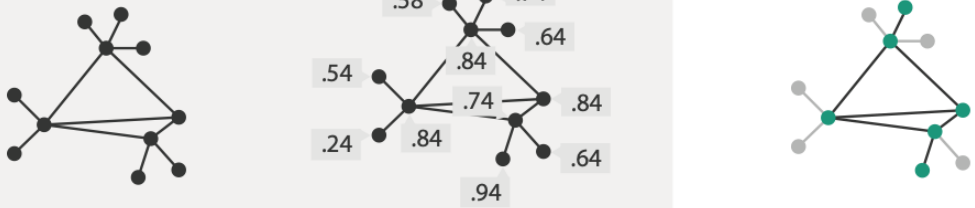
What?

- In Tree
- Out Quantitative attribute on nodes

Why?

- Derive

Task 2



In
Tree

+

In
Quantitative attribute on nodes

Out
Filtered Tree
Removed unimportant parts

What?

- In Tree
- In Quantitative attribute on nodes
- Out Filtered Tree

Why?

- Summarize
- Topology

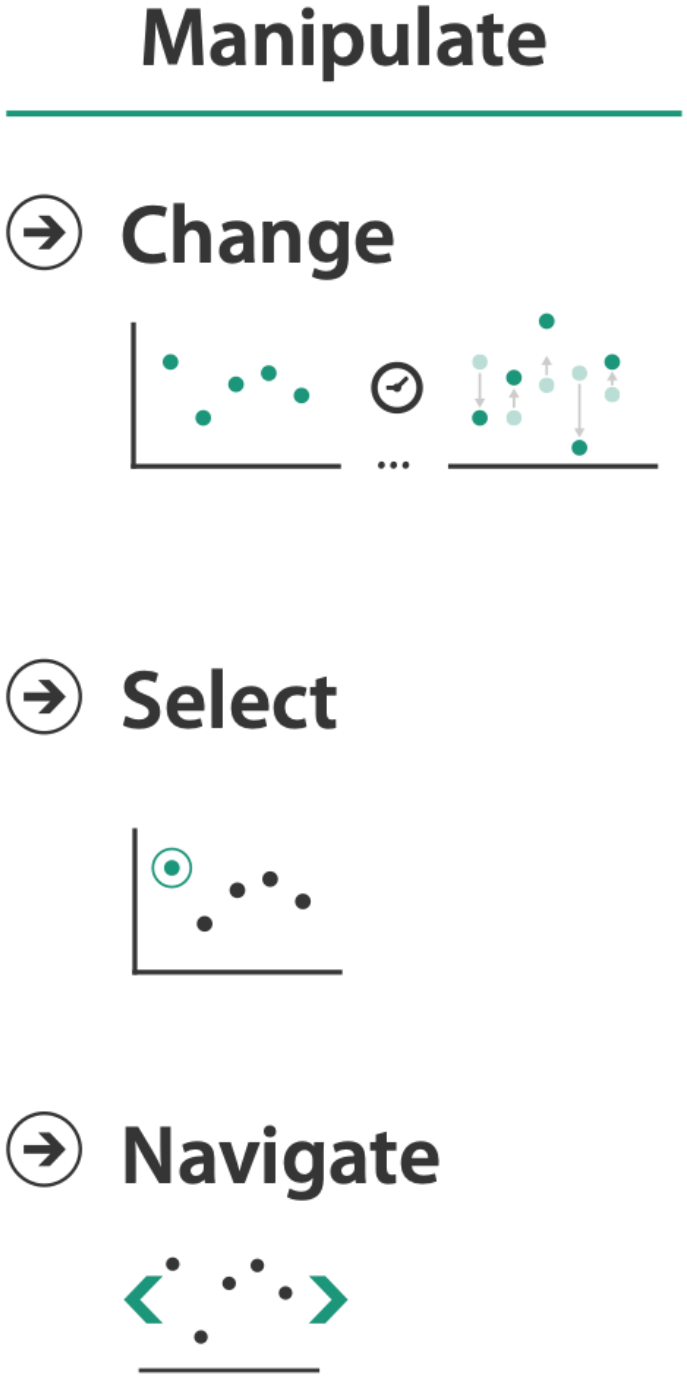
How?

- Reduce
- Filter

Manipulate

Manipulate the view

- Multiple options for how to manipulate:
  - Change the viz itself
  - Select
  - Navigate



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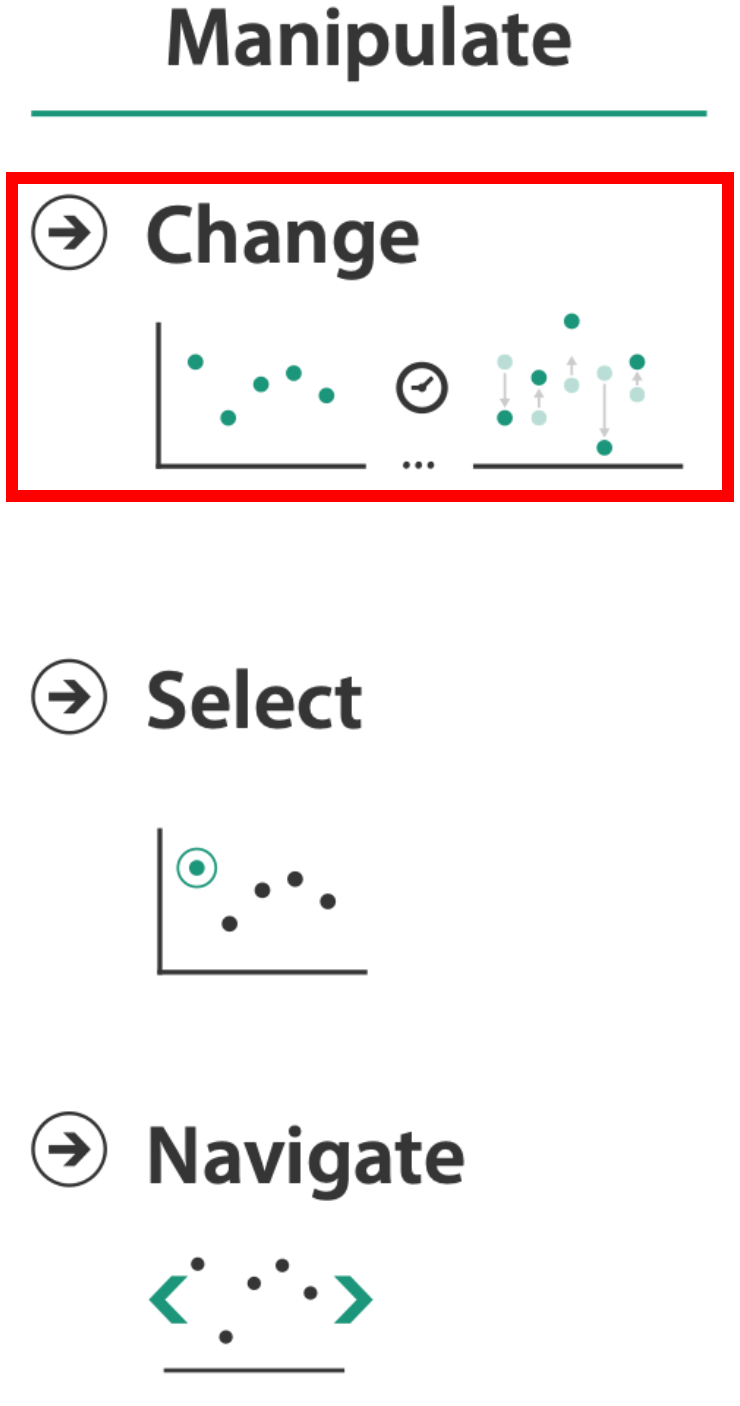
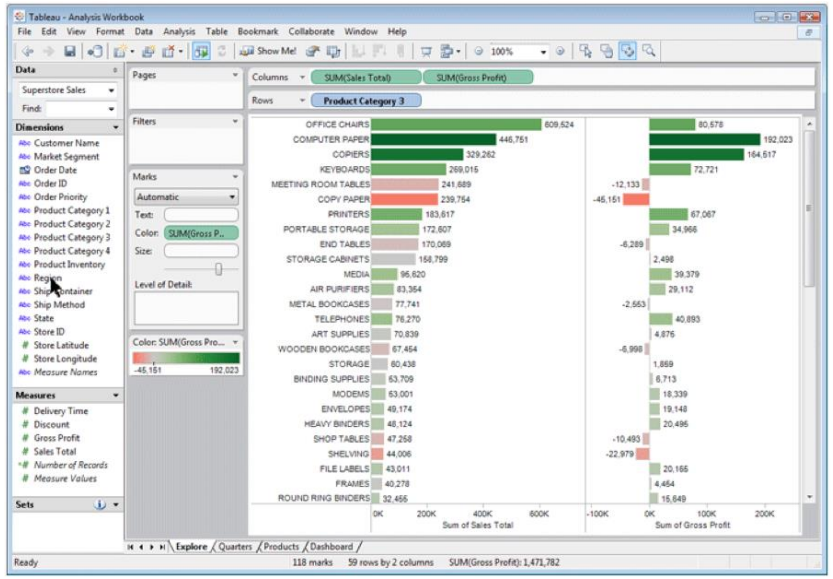


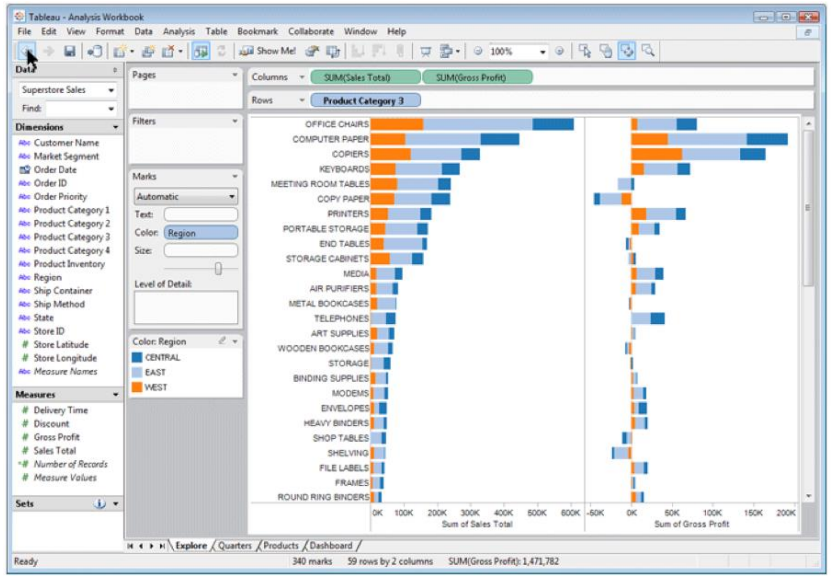
Change the viz itself

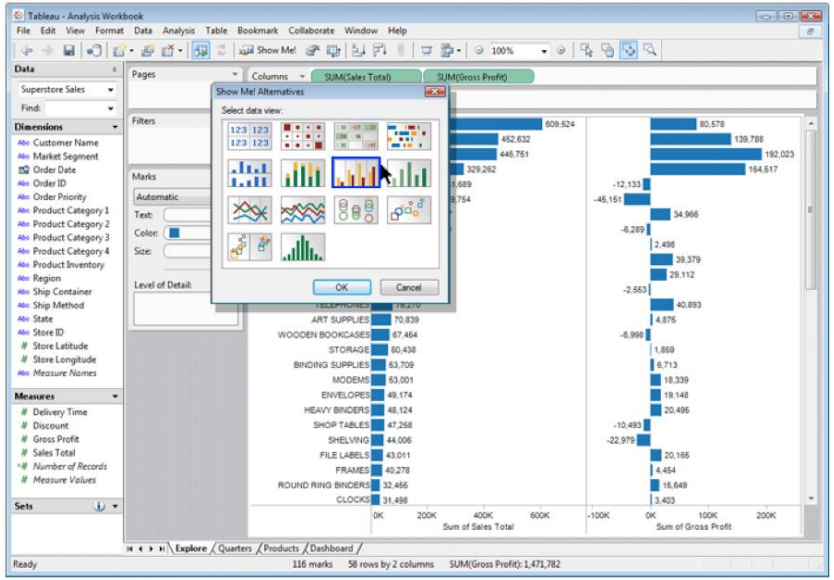
- Change any of the following:
  - Encoding itself
  - Viz parameters
  - Arrangement (rearrange, reorder)
  - Aggregation level, what is filtered...
- Interaction produces change
- Very flexible

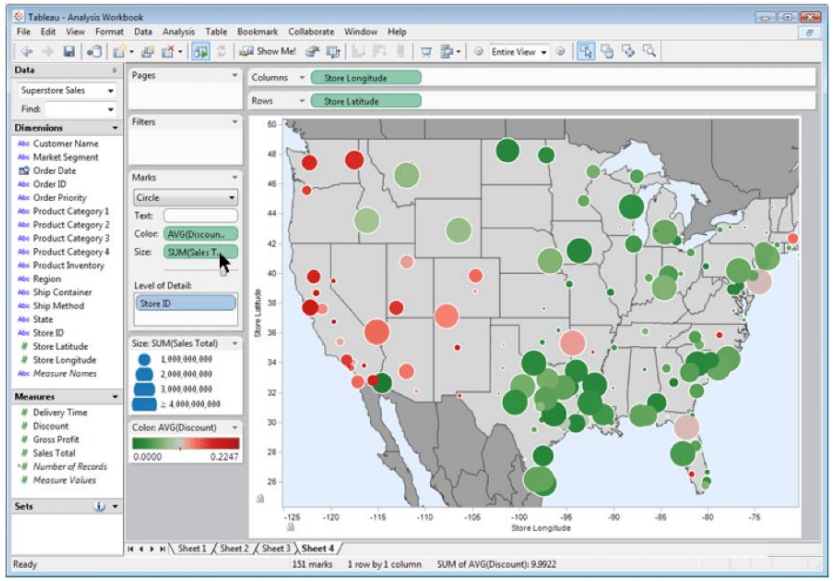
Change the viz itself: Re-encode

- Same data, different encodings



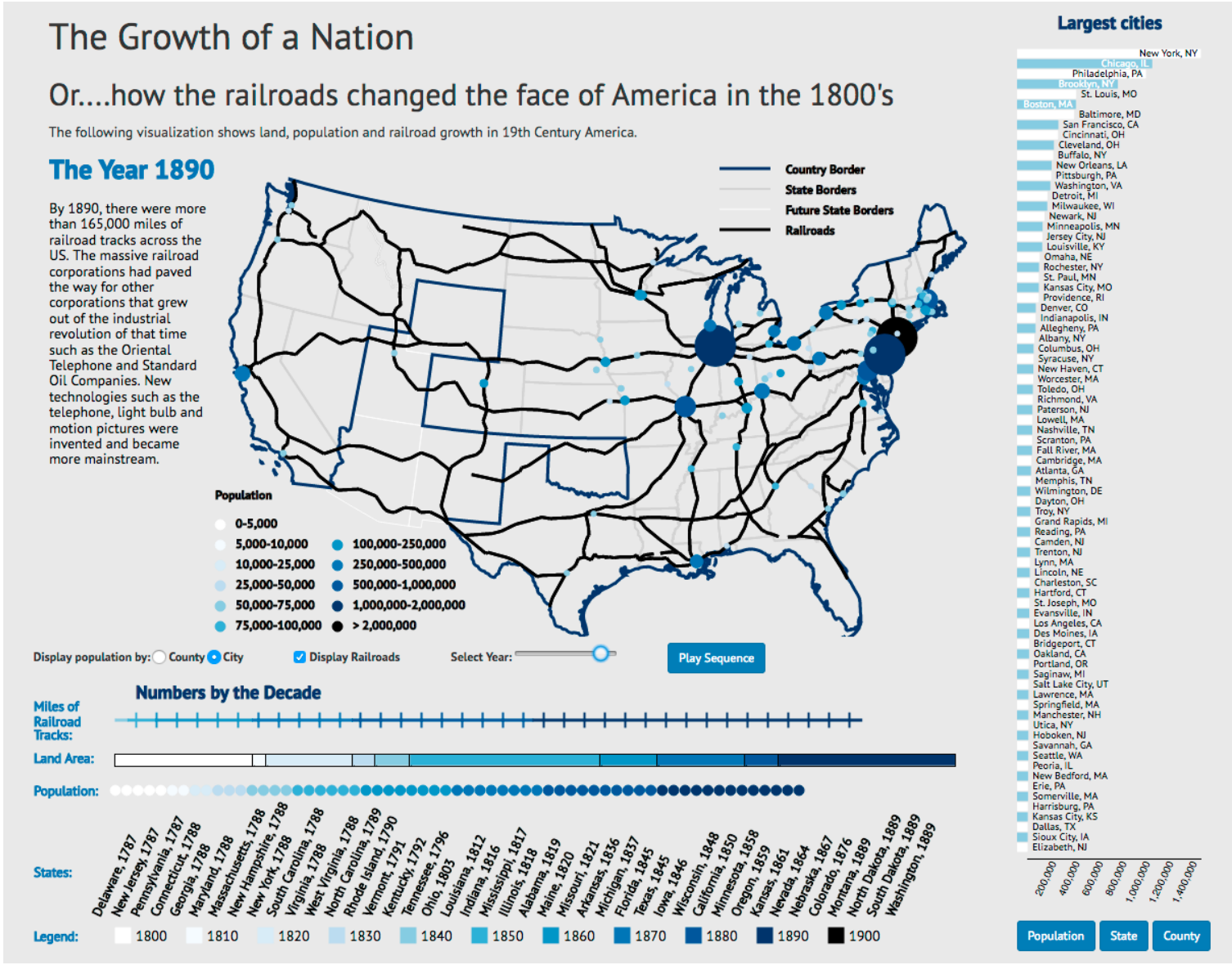






Change the viz itself: Change parameters

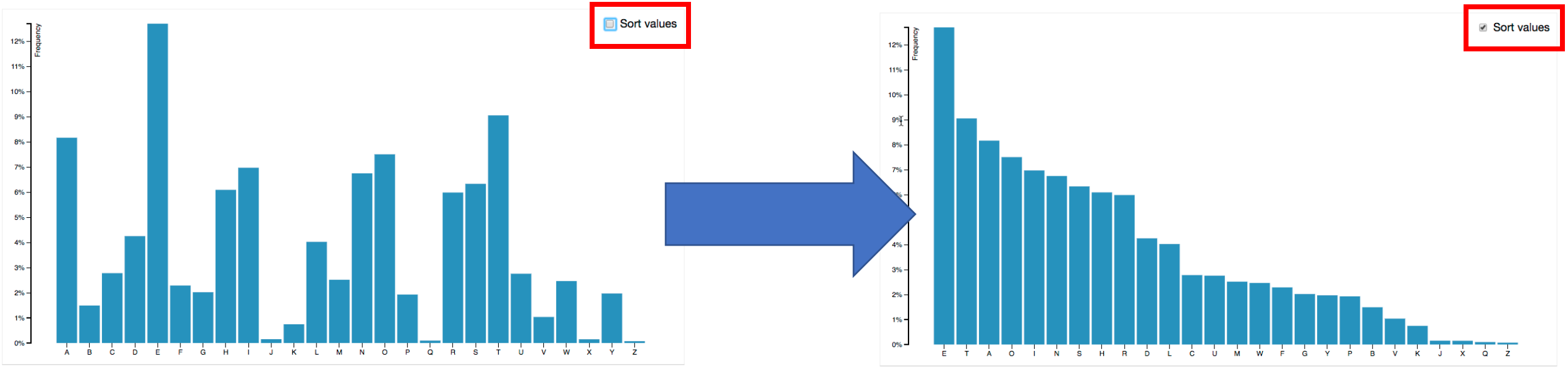
- Widgets and controls
  - Sliders, buttons, radio buttons, checkboxes, dropdowns
- Pros:
  - Clear affordances (Obvious what the user can do)
  - Self-documenting w. labels
- Cons:
  - Uses screen space
- Design choices:
  - Separated vs interleaved



http://laurenwood.github.io/

Change the viz itself: Rearrange/reorder

- AKA “sort”
- Useful for identifying:
  - Extreme values
  - Trends
  - Correlations between attributes



https://observablehq.com/@d3/sortable-bar-chart

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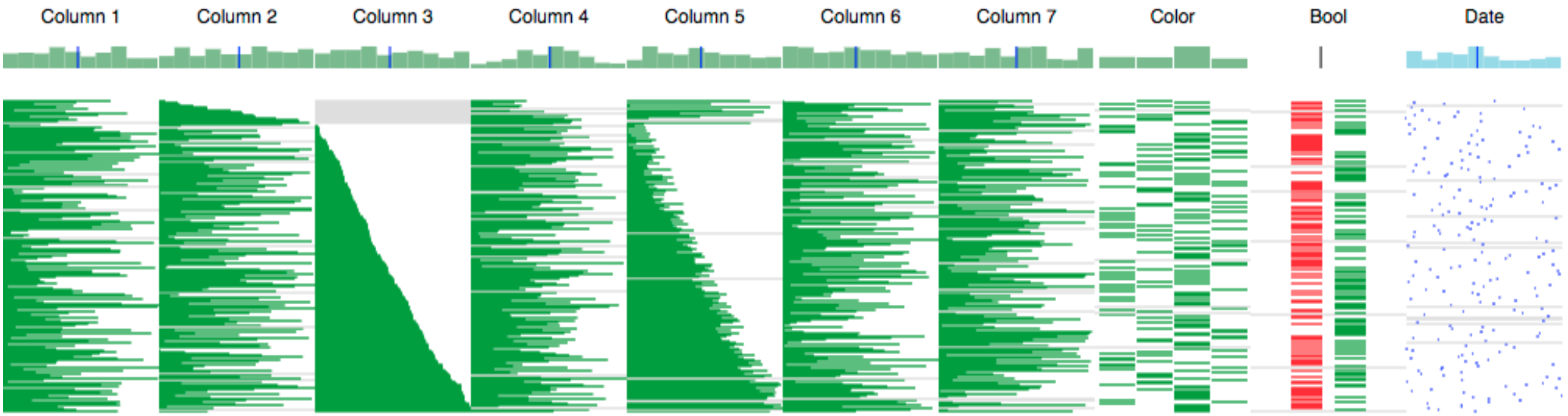
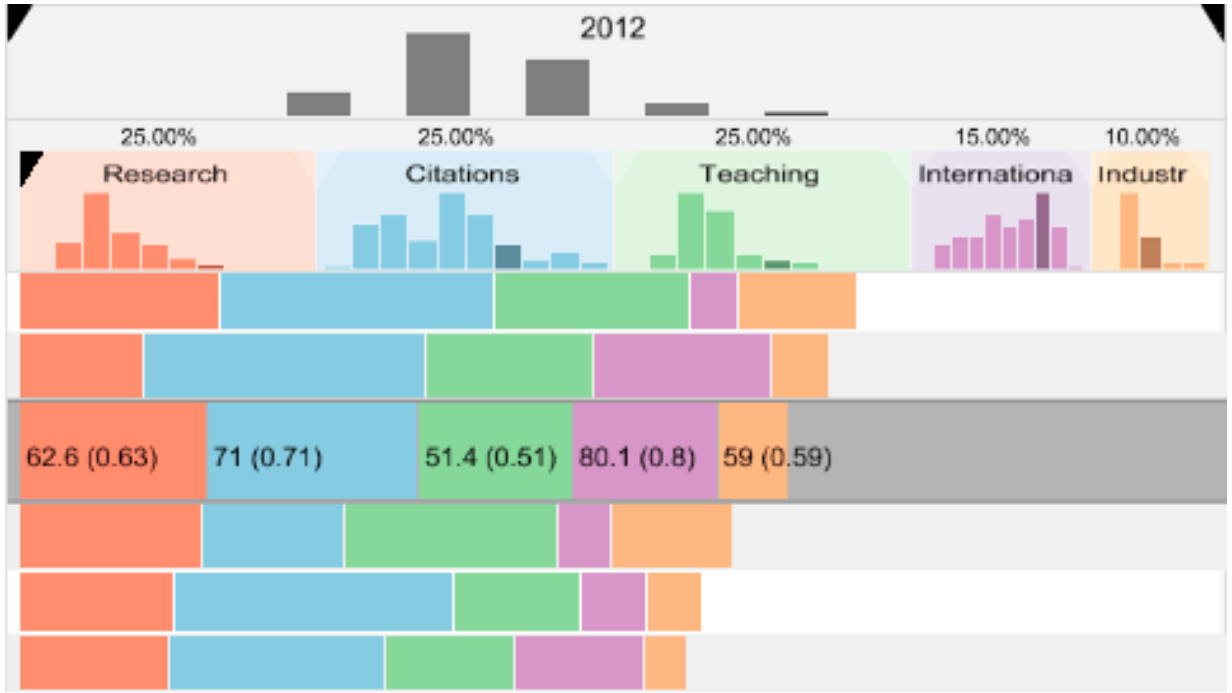
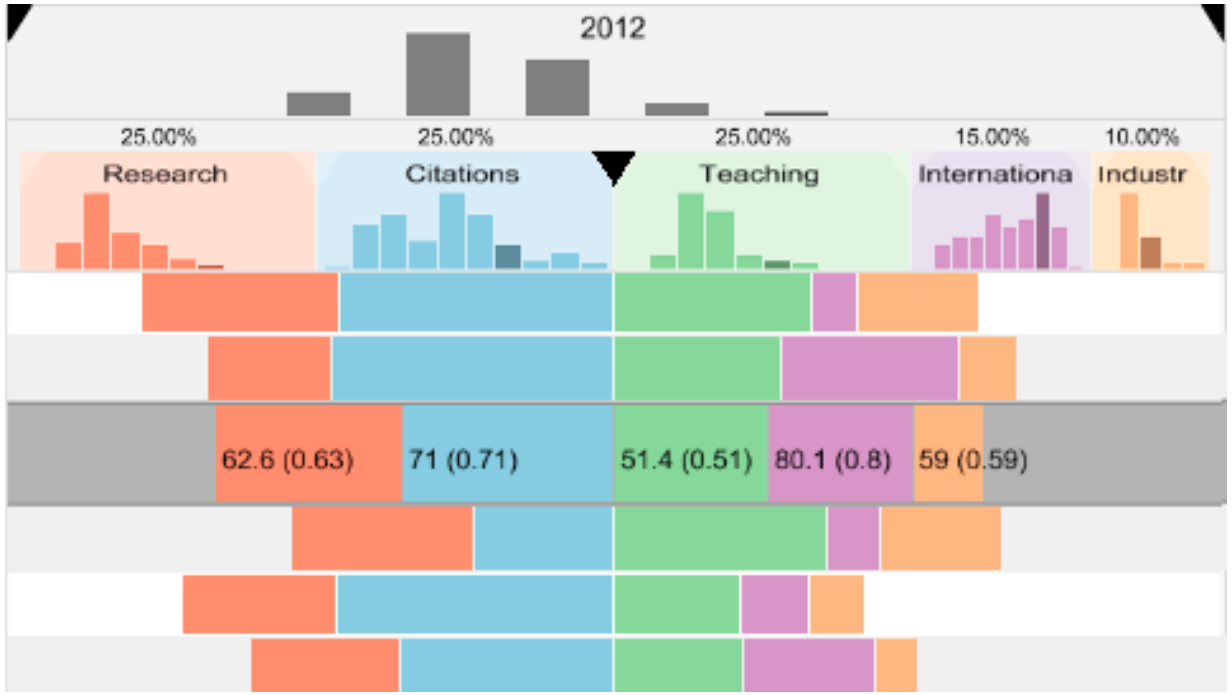


http://carlmanaster.github.io/datastripes/

Change the viz itself: Change alignment

- Comparing aligned lengths is easy
- Allow the user to specify which category is edge-aligned

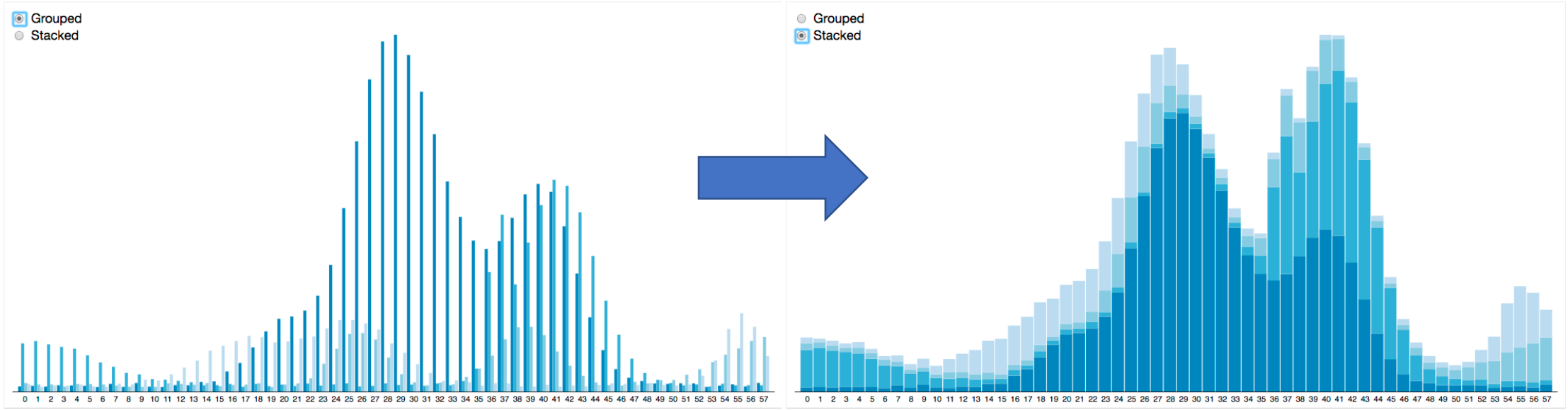




LineUp: Visual Analysis of Multi-Attribute Rankings.Gratzl, Lex, Gehlenborg, Pfister, and Streit. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2013) 19:12 (2013), 2277–2286

Change the viz itself: Animated transitions

- Sudden changes in the viz can be confusing
- Animations can make it easier to track changes



https://observablehq.com/@d3/stacked-to-grouped-bars

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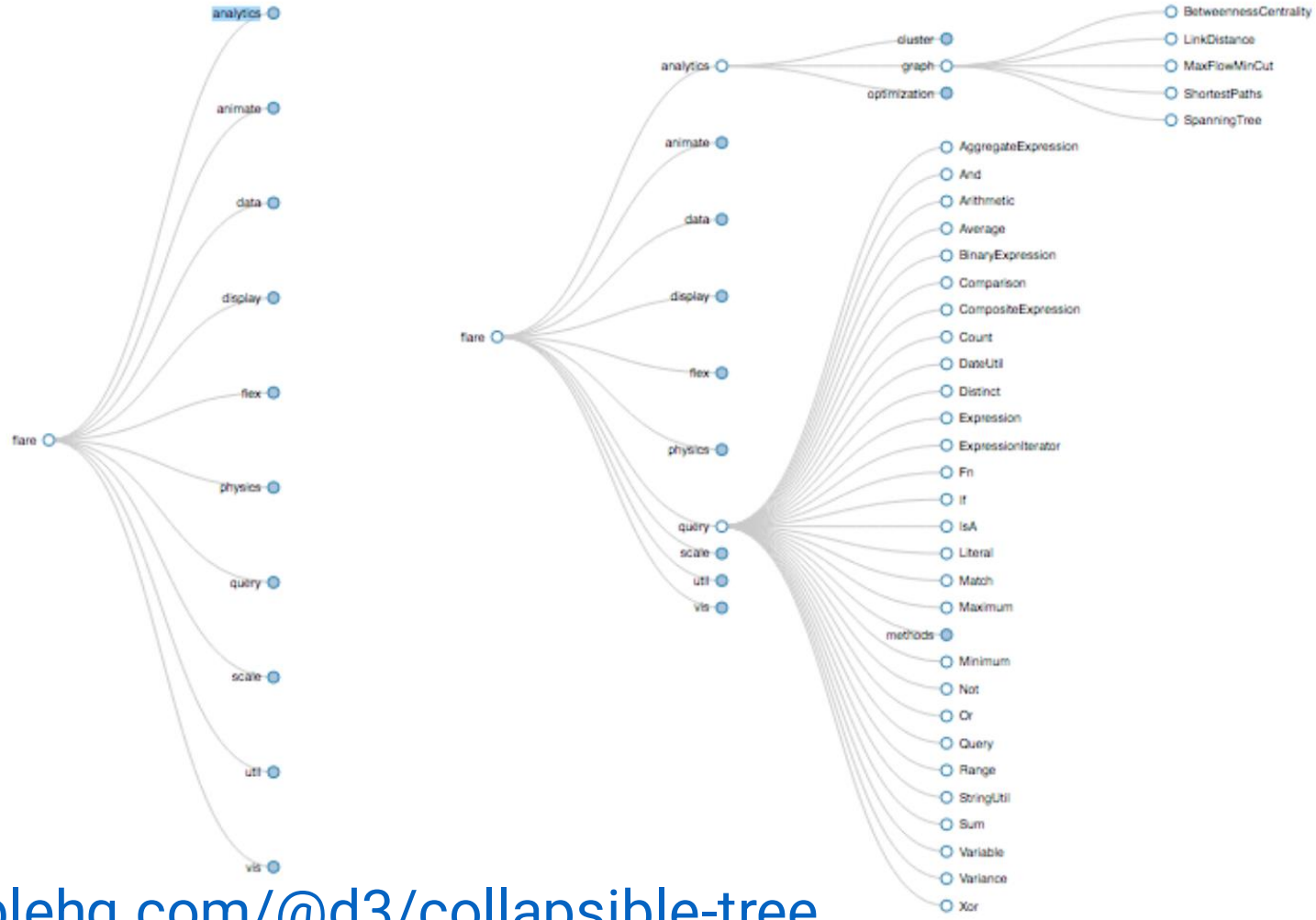

https://observablehq.com/@d3/collapsible-tree

Manipulate the view

- Multiple options for how to manipulate:
  - Change the viz itself
  - Select
  - Navigate

Selection

- Consider the device being used
  - Mouse & keyboard:
    - Large screen, hover, multiple clicks
  - Mobile:
    - Small screen, no hover, just tap
- Gestures from sensors?
  - Mostly just in the movies...
- Eye tracking?
  - Still emerging

I Hate Tom Cruise - Alex Kauffmann
https://www.youtube.com/watch?v=QXLfT9sFcbc

Selection

- Selection is the basic operation for most interactions
- Design choices:
  - How many selection types?
    - Interaction modalities
      - Click/tap (heavyweight) vs hover (lightweight but device-dependent)
      - 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 the selection be null?
      - Primary vs secondary (e.g. source/target nodes in network)

Highlighting

- Visual indication of a selection
- Highlight: change the visual encoding for selected targets
  - The visual feedback is closely tied to but separable from selection
- Design choices: typical visual channels
  - Change item color
    - Hides existing color coding
  - Add outline mark
  - Change size (e.g. increase outline mark linewidth)
  - Change shape (e.g. solid → dashed line for link mark)
- Unusual channels: motion
  - Usually avoid for a single view
  - With multiple views, could justify to draw attention to other views (peripheral vision)

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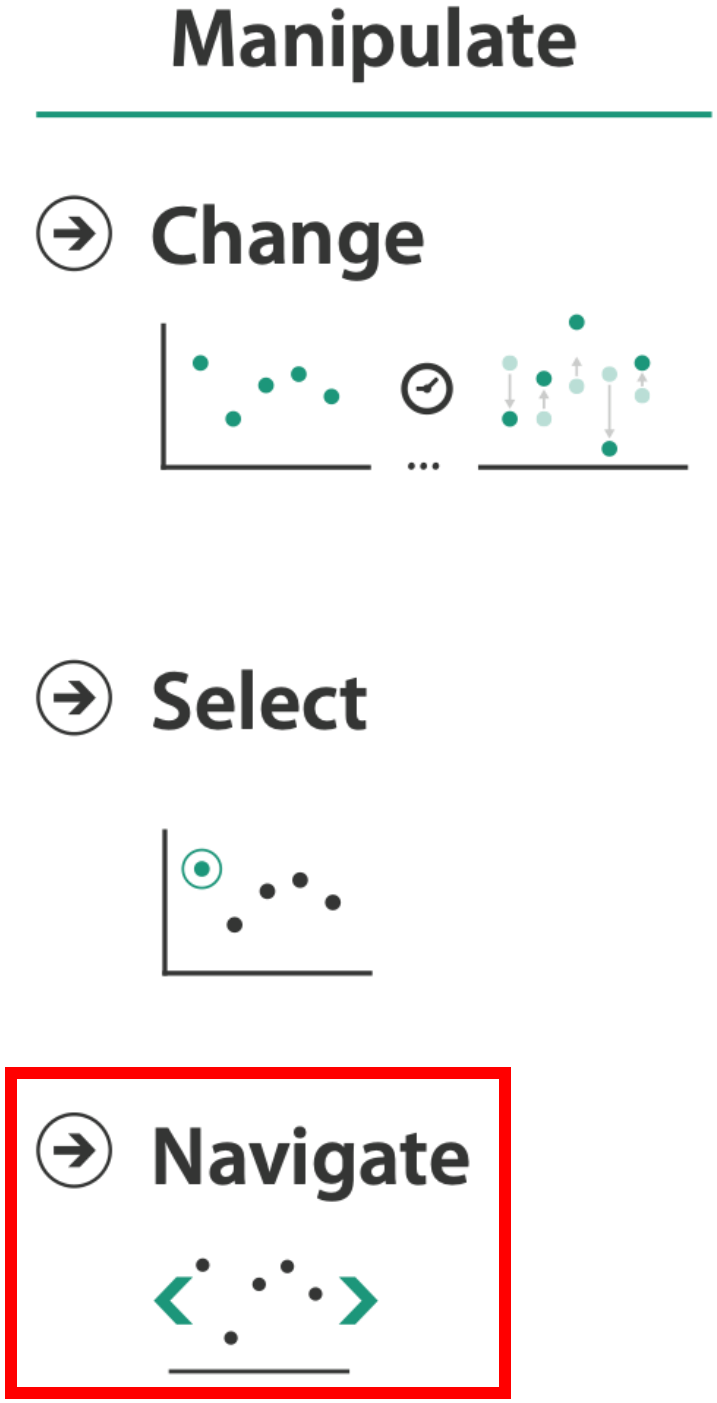


Navigation

- Change viewpoint → changes which items are visible
- Camera metaphor
  - Zoom
  - Pan/translate
  - Constrained view
  - Tilt (usually only 3D)
  - Rotate/spin (usually only 3D)

Navigate

→ Item Reduction

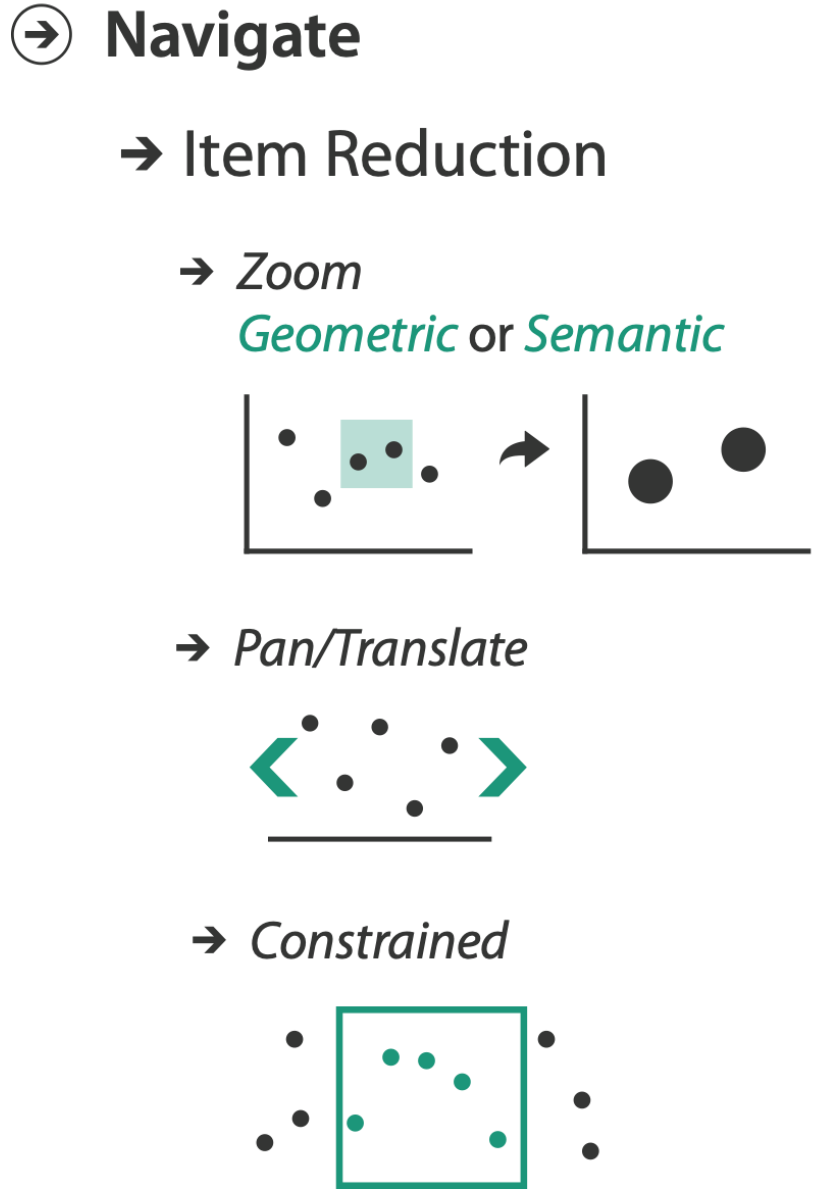
→ *Zoom*
Geometric or *Semantic*

Navigation: constrained vs unconstrained

- Unconstrained navigation – no “guard rails”
  - Easy to implement, hard to use
  - Easy to overshoot/undershoot the desired view

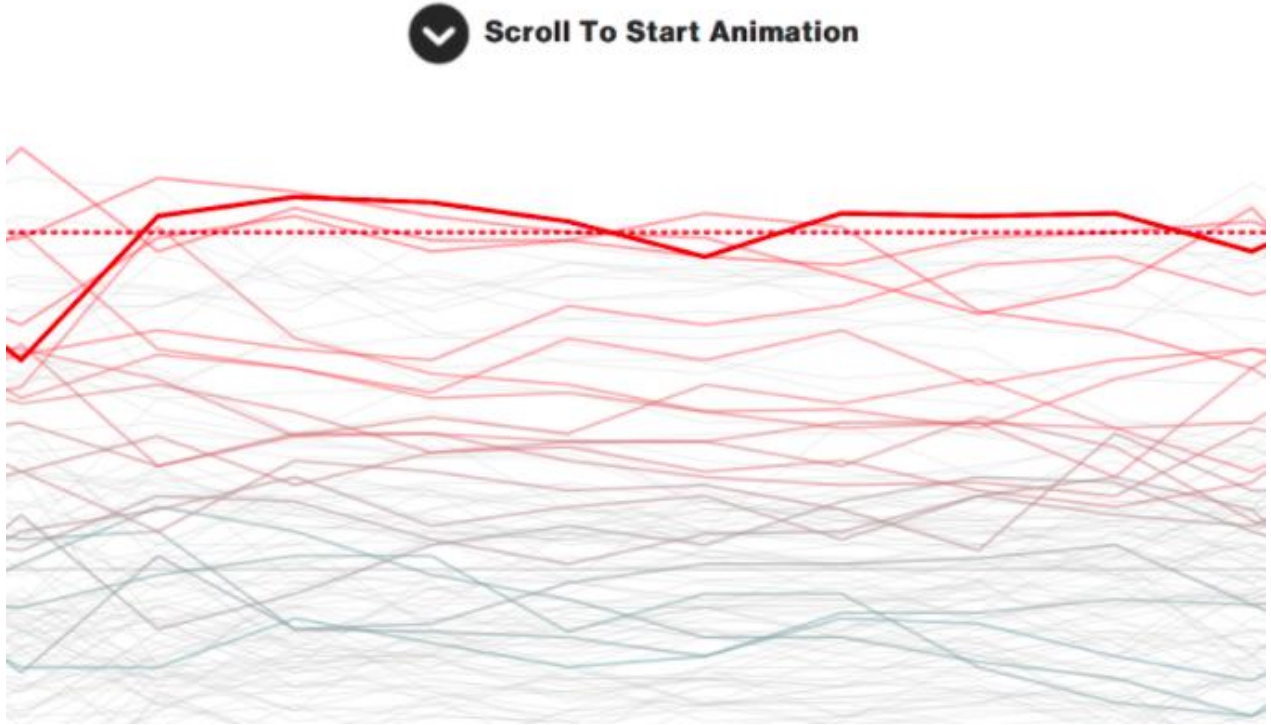
- Constrained navigation
  - Harder to implement, more user friendly
  - Usually uses animated transitions to make it clear
  - E.g. drag to select a subset of data, double click to fill the view with the selection

- E.g. https://observablehq.com/@d3/zoom-to-bounding-box



Navigation idiom: Scrollytelling

- How? Navigate page by scrolling
- Pros:
  - Familiar and intuitive (based on standard web browsing)
  - Linear (only up and down)
  - No overload of too many click-based buttons
- Cons:
  - Full-screen mode may lack affordances (no scrollbar visible)
  - Scrolljacking: user is forced to scroll, which constrains mouse usage
  - Unexpected behavior
  - Continuous control for discrete steps

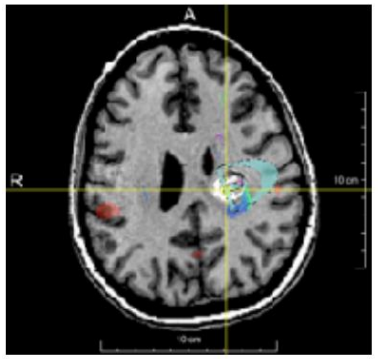


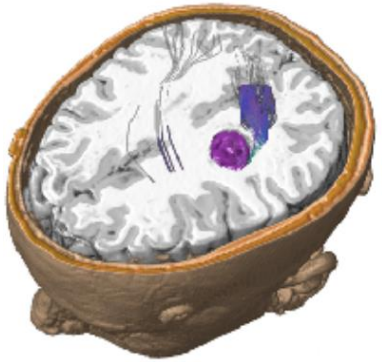
How to Scroll, Bostock: https://bost.ocks.org/mike/scroll/

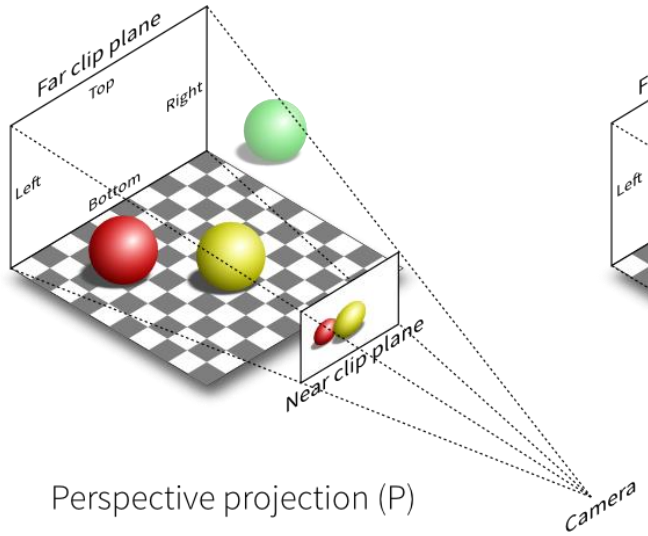
https://eagereyes.org/blog/2016/the-scrollytelling-scourge

Navigation: reducing attributes

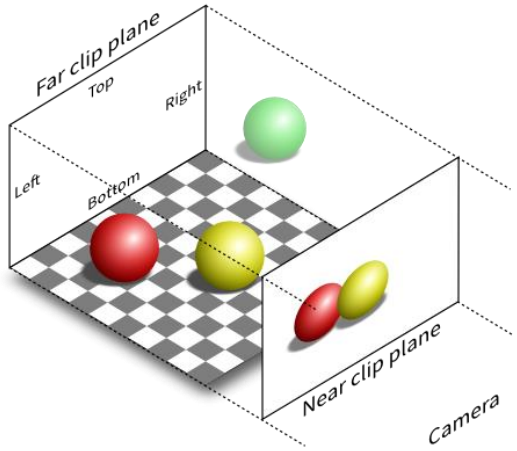
- Extension of the camera metaphor
- Slice
  - Show only items matching specific value for given attribute: slicing plane
  - Axis aligned, or arbitrary alignment
- Project
  - Change mathematics of image creation
    - Orthographic
    - Perspective
    - Many others







Perspective projection (P)



Orthographic projection (O)

→ Attribute Reduction

→ *Slice*

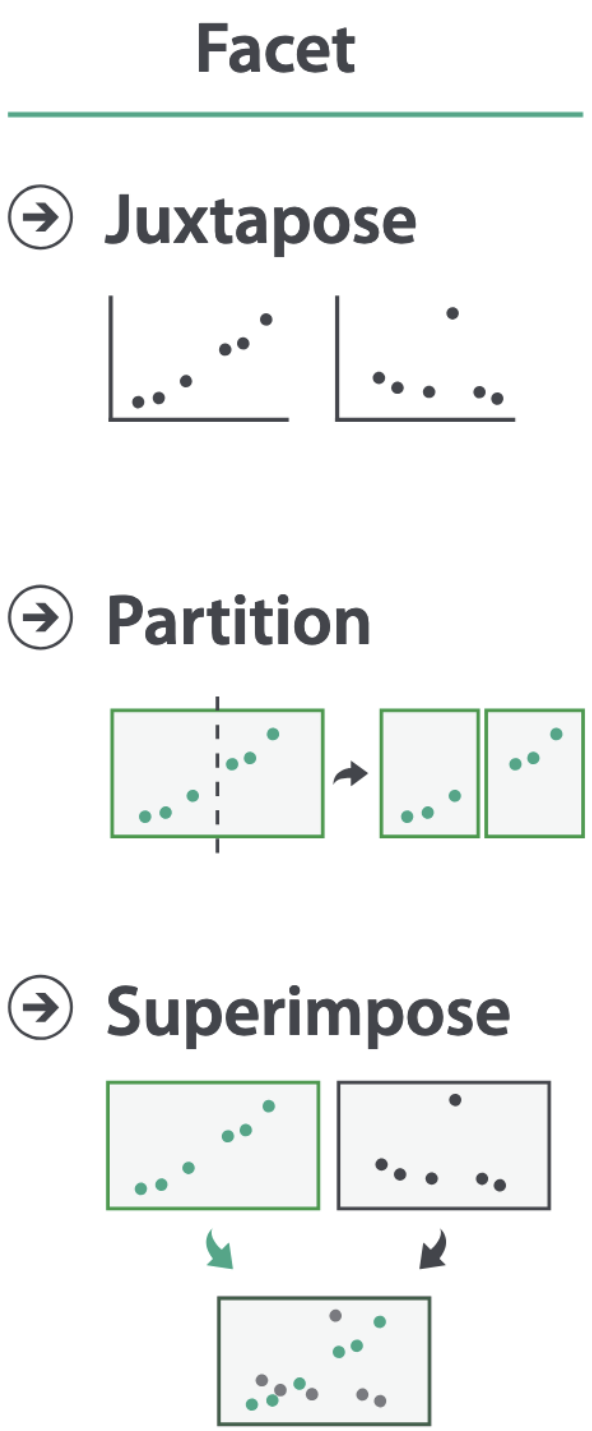
→ *Cut*

→ *Project*

Multiple Views

Facet

- Another way to handle complexity
- Juxtapose
  - Put multiple views of the same data next to each other
- Partition
  - Split one view into two (or more) views
- Superimpose
  - Store multiple views as different layers that can be displayed on top of one another



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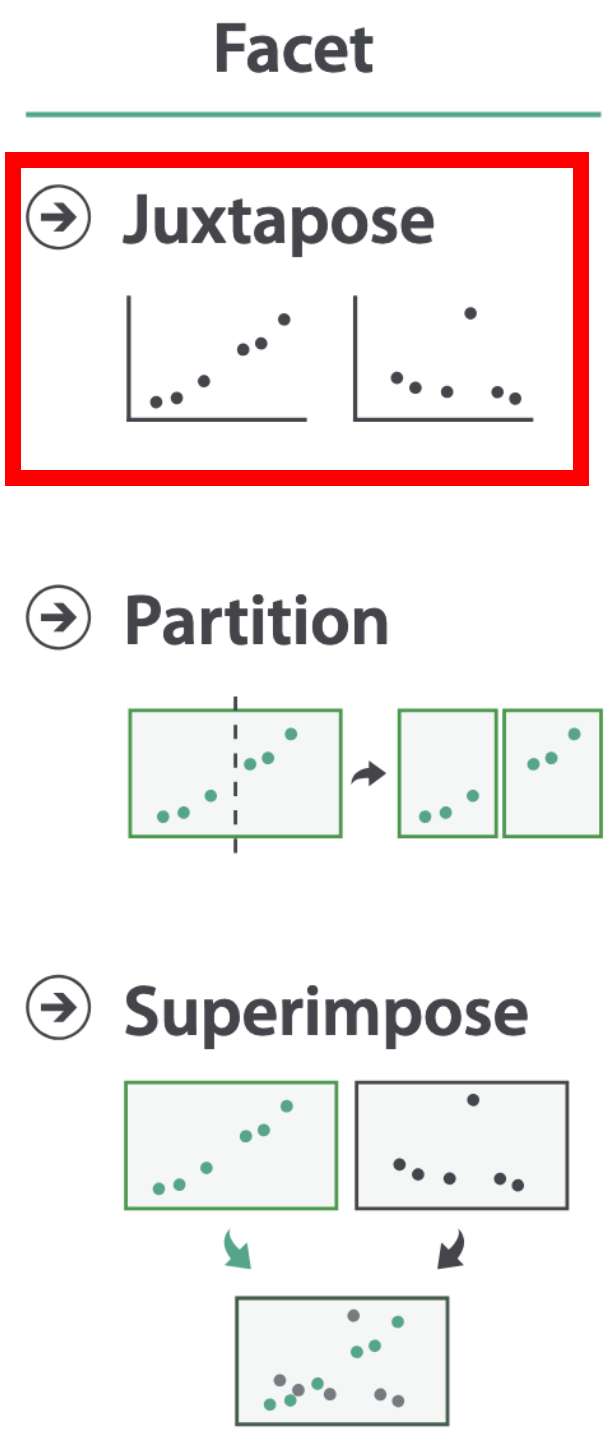


Juxtapose and coordinate views

- Main problem: How to link the views?
  - How to design the views so that manipulating one view does (or does not) change the other view
- 4 main design questions:
  - Do the views have the same or different visual encoding idioms?
  - Is selection/highlighting linked across multiple views?
  - Do the views show the same data, or different data?
  - Is navigation synchronized between the views?

➔ Share Encoding: Same/Different

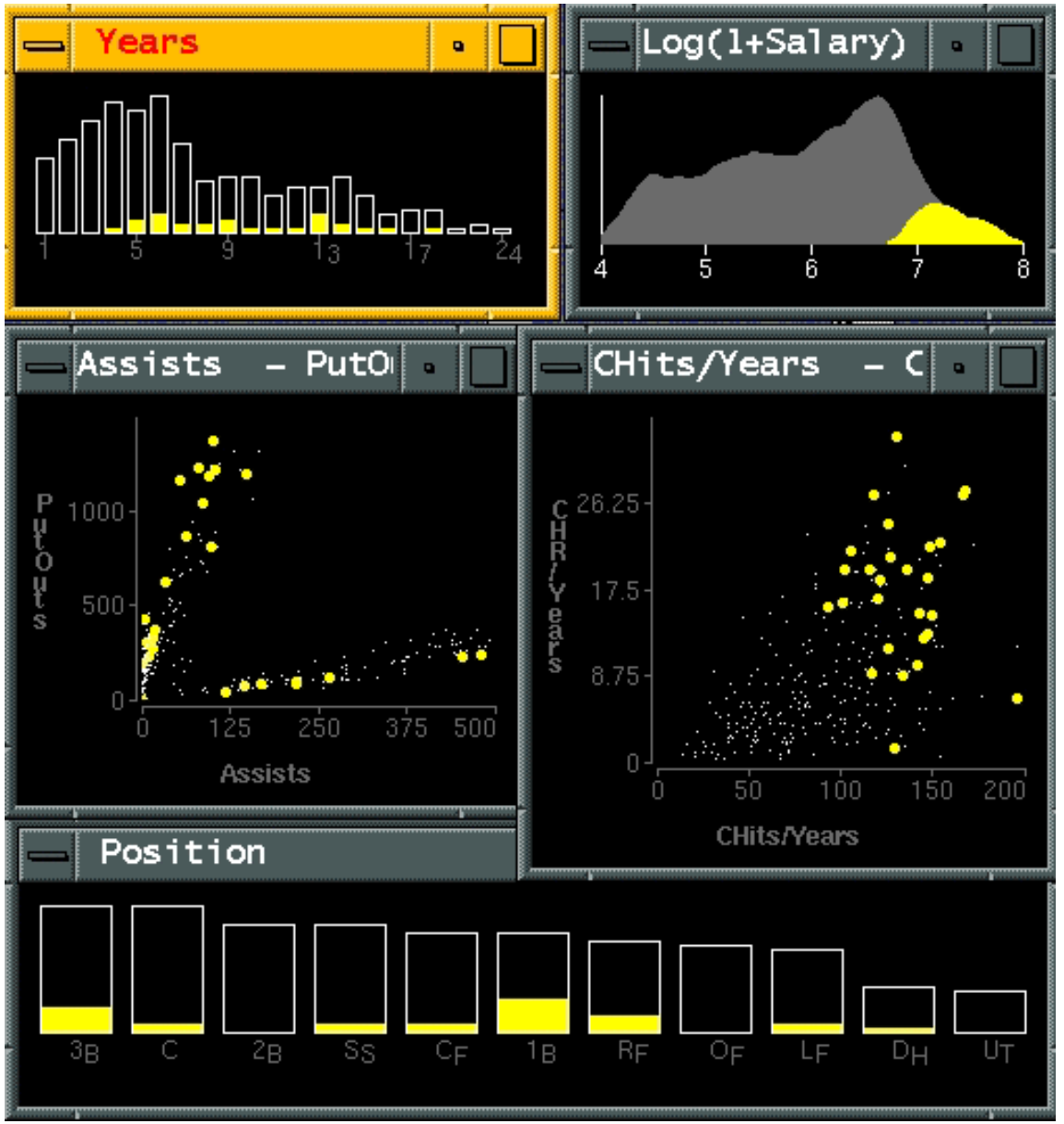
➔ *Linked Highlighting*

➔ Share Data: All/Subset/None

➔ Share Navigation

Juxtapose idiom: Linked highlighting

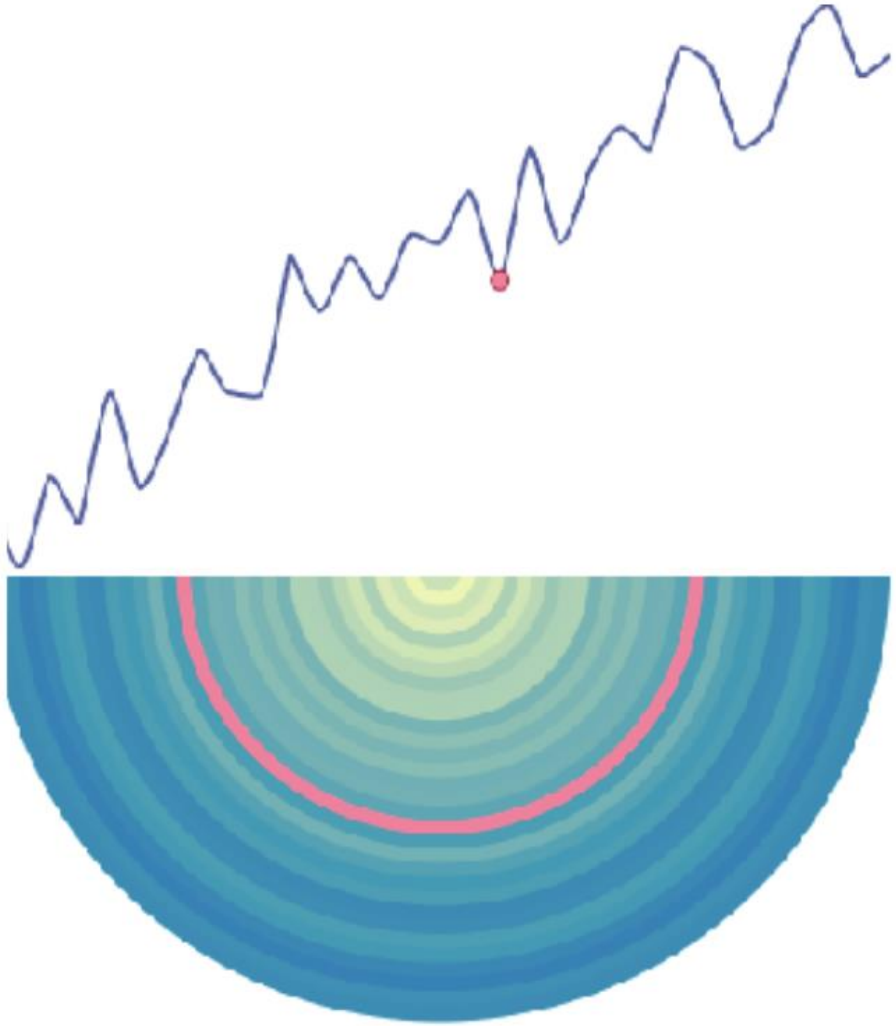
- See how regions contiguous in one view are distributed in another
  - Powerful and pervasive interaction idiom
- Encoding: different
  - Multiform
- Data: all shared
  - All **items** shared
  - Different **attributes** across the views
- AKA: brushing and linking



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

Linked views: directionality

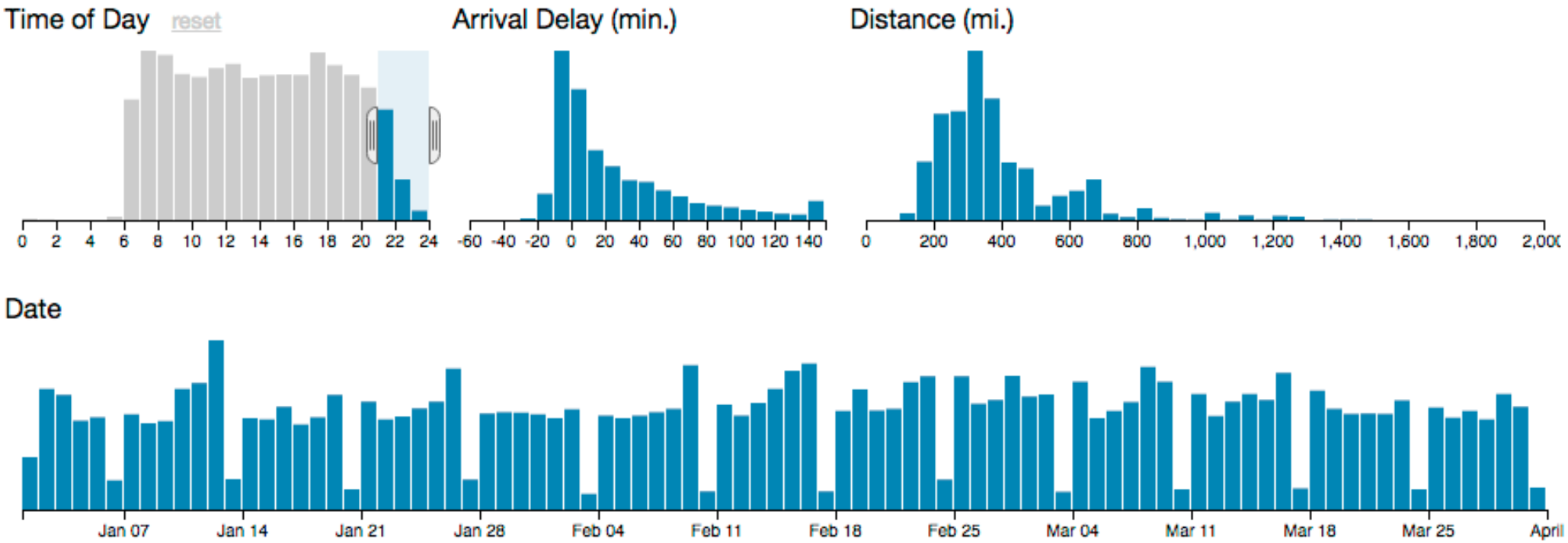
- Unidirectional vs bidirectional linking
  - Bidirectional is almost always better!



http://pbeshai.github.io/linked-highlighting-react-vega-redux/
https://medium.com/@pbesh/linked-highlighting-with-react-d3-js-and-reflux-16e9c0b2210b

Example: Cross filter

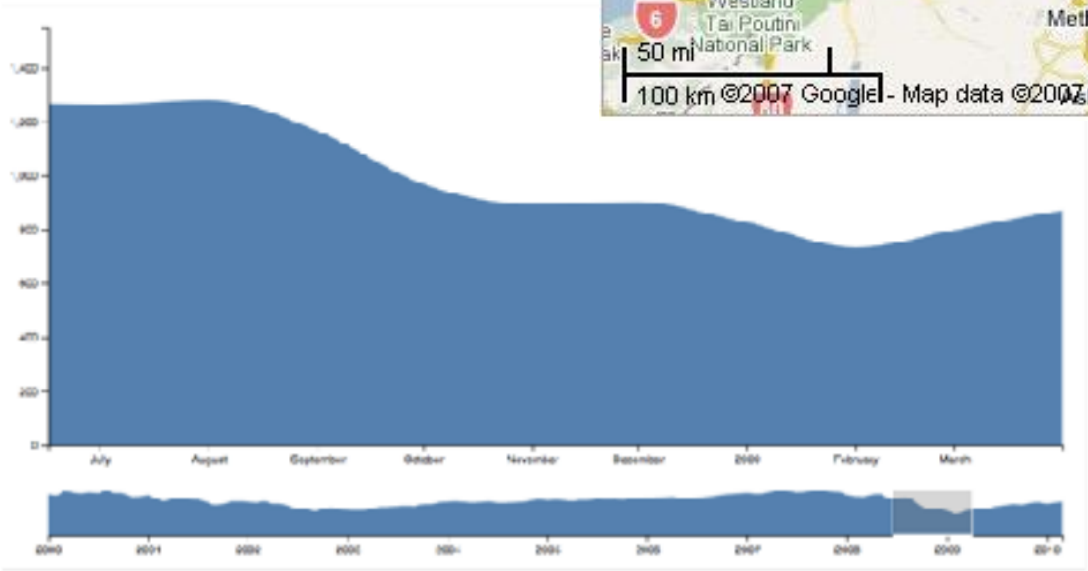
- Very fast javascript library: http://square.github.io/crossfilter/



Juxtapose idiom: overview-detail views

- Encoding: same or different
  - e.g. same (birds-eye map)
- Data: shared subset
  - Viewpoint differences
- Navigation: shared
  - Bidirectional linking

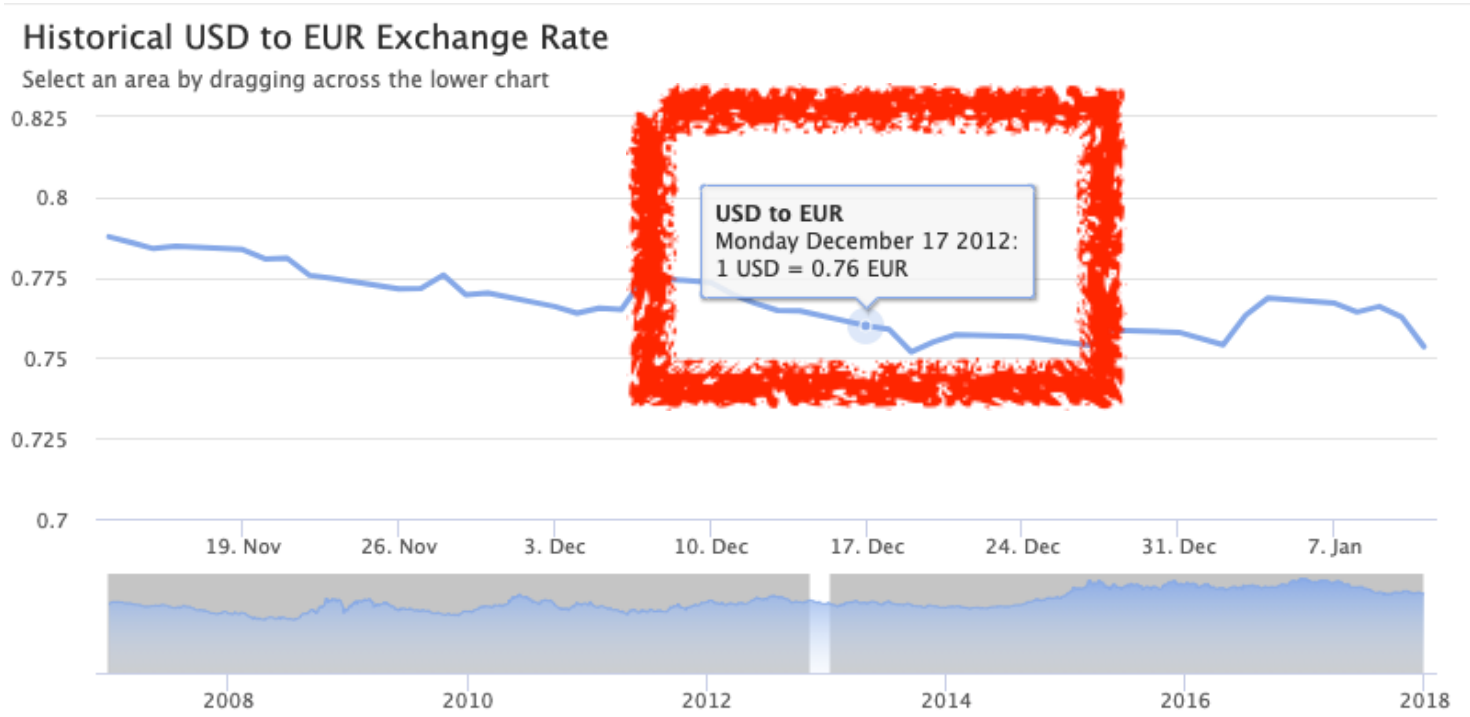
- Other differences
  - Window size
  - Level of detail



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

Juxtapose idiom: tooltips

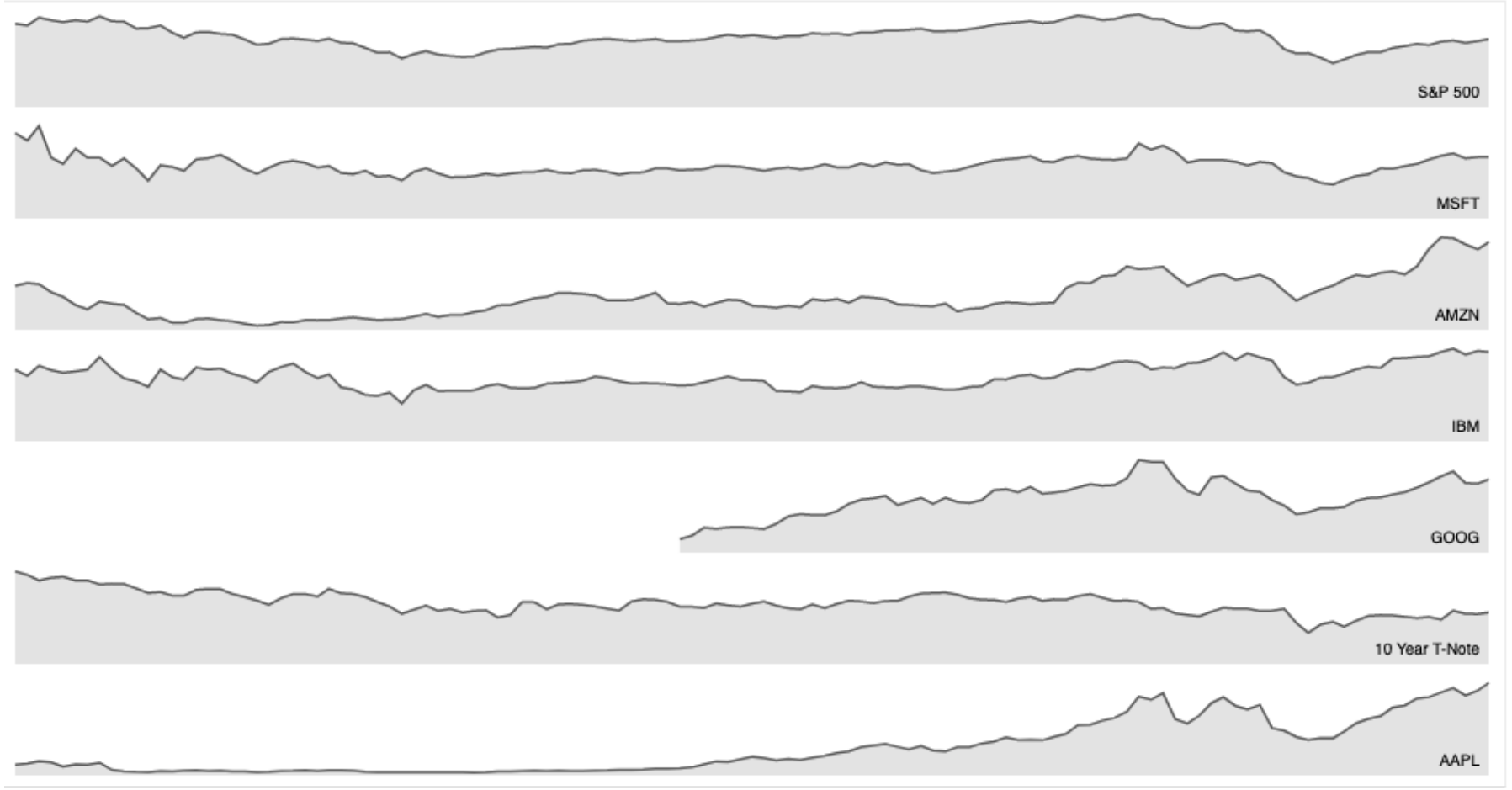
- Pop-up information for selection
  - Hover or click
  - Specific case of “details on demand”
- Beware: tooltips do **not** support overview
  - Possibly add an additional visual encoding to support overview
  - “If you make a rollover or tooltip, assume nobody will see it. If it’s important, make it explicit.”
    - Gregor Aisch, New York Times
- Prefer tooltips that provide more details instead of completely new information



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

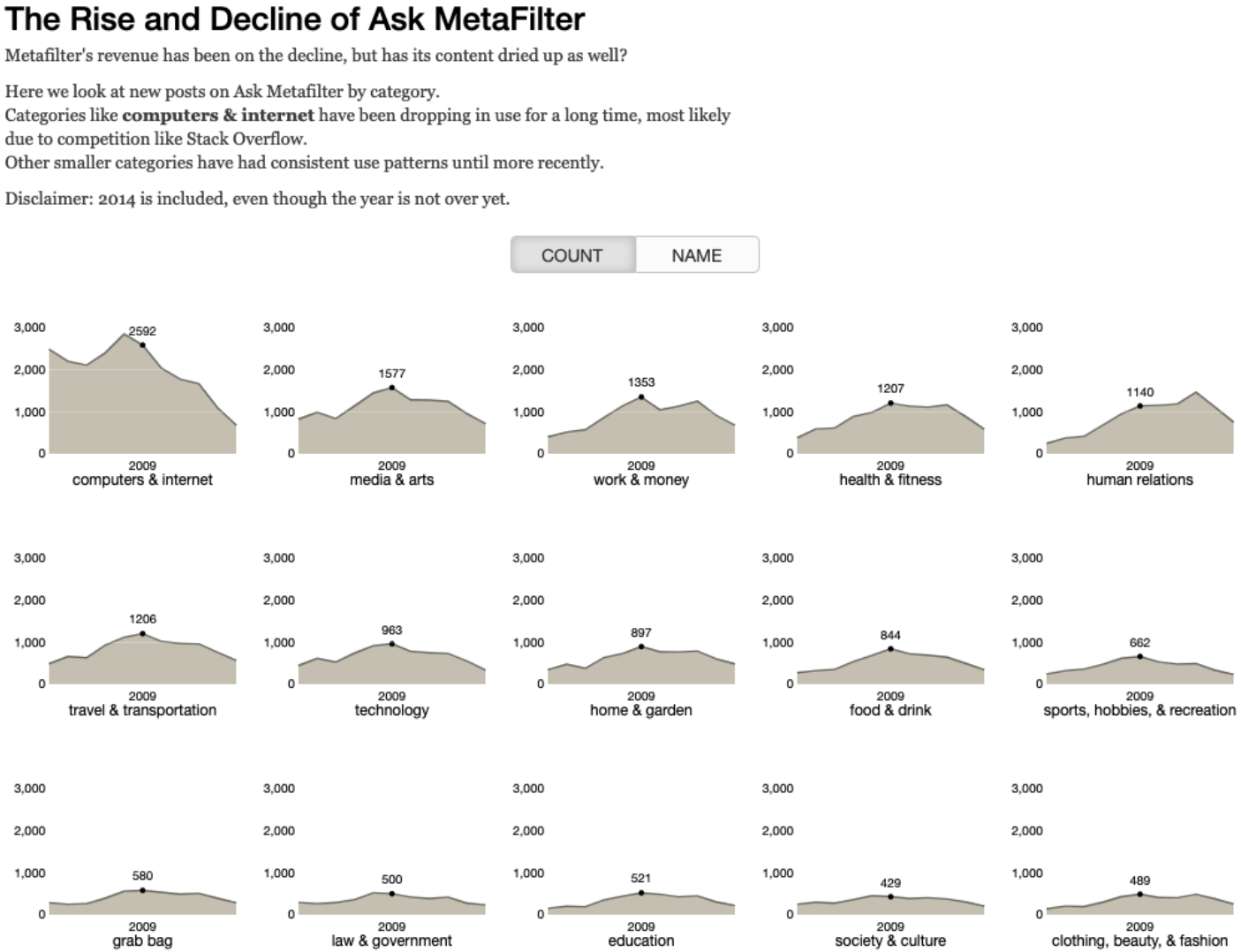
Juxtapose idiom: small multiples

- We've seen this before
- Encoding: same
  - E.g. line charts
- Data: none shared
  - Different slices of dataset
  - E.g. stock prices for different companies



Interactive small multiples

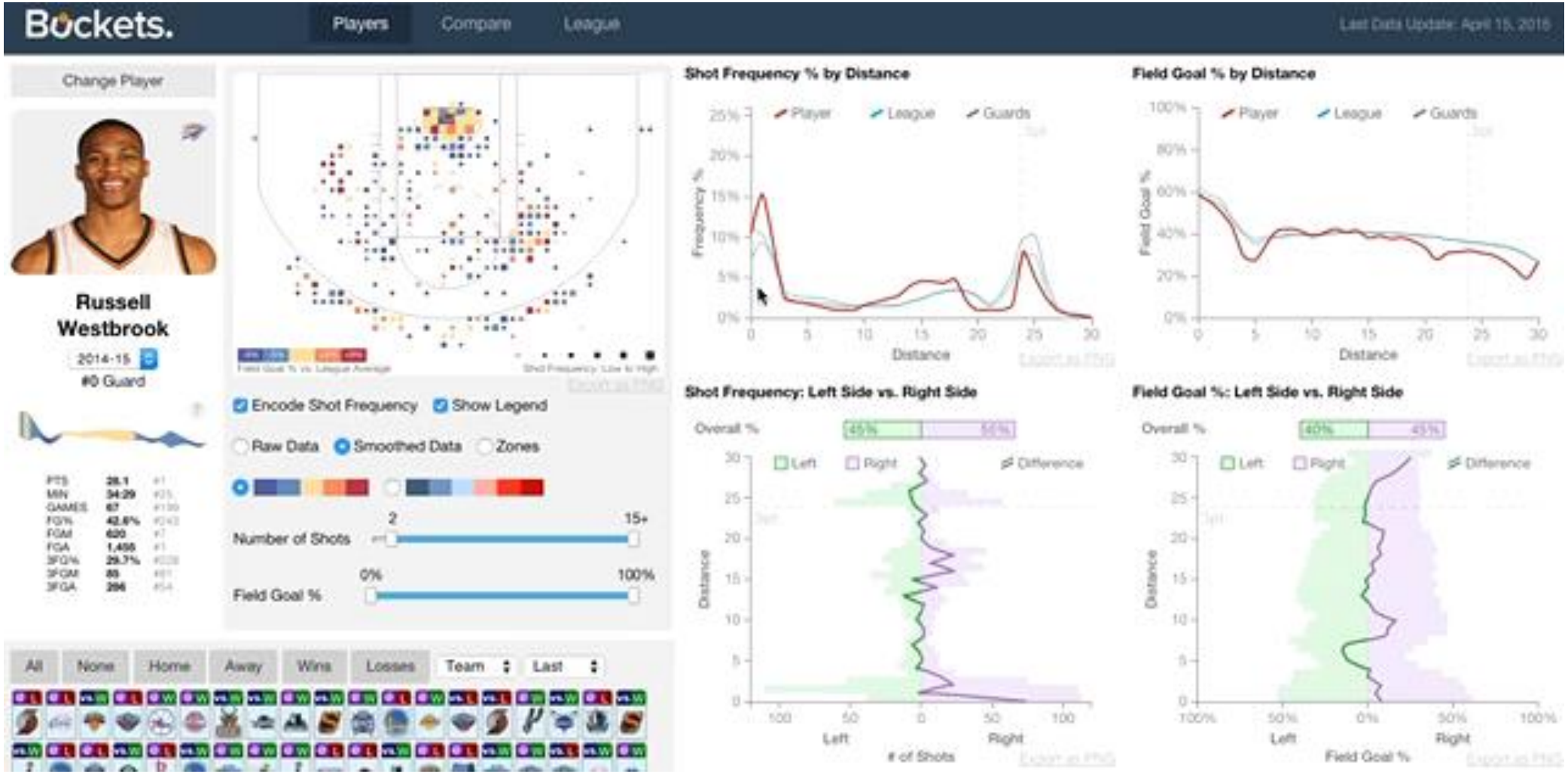
- Linked highlighting: analogous item/attribute shown across views
  - E.g. same year highlighted across all charts when hovering in any single chart



https://projects.flowingdata.com/tut/linked_small_multiples_demo/

Example: combining many interaction idioms

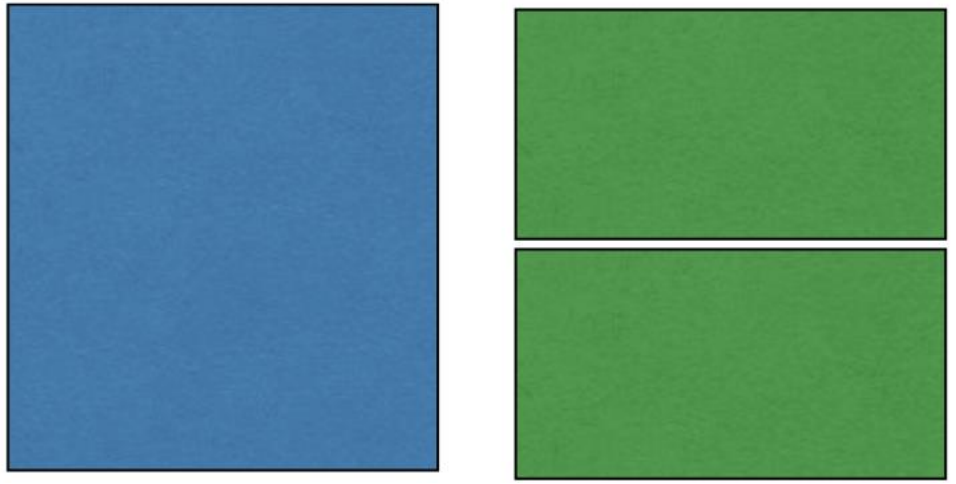
- https://buckets.peterbeshai.com/app/#/playerView/201935_2015



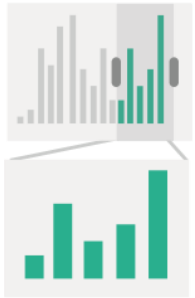
- Multiform
- Multidirectional linked highlighting of small multiples
- Tooltips

Juxtapose views: tradeoffs

- Juxtapose pros:
  - Cognitive load: eyes > memory
    - Lower cognitive load: move eyes between 2 views
    - Higher cognitive load: compare single changing view to memory of previous state
- Juxtapose cons:
  - Display area
    - 2 views side by side → each view has half the area

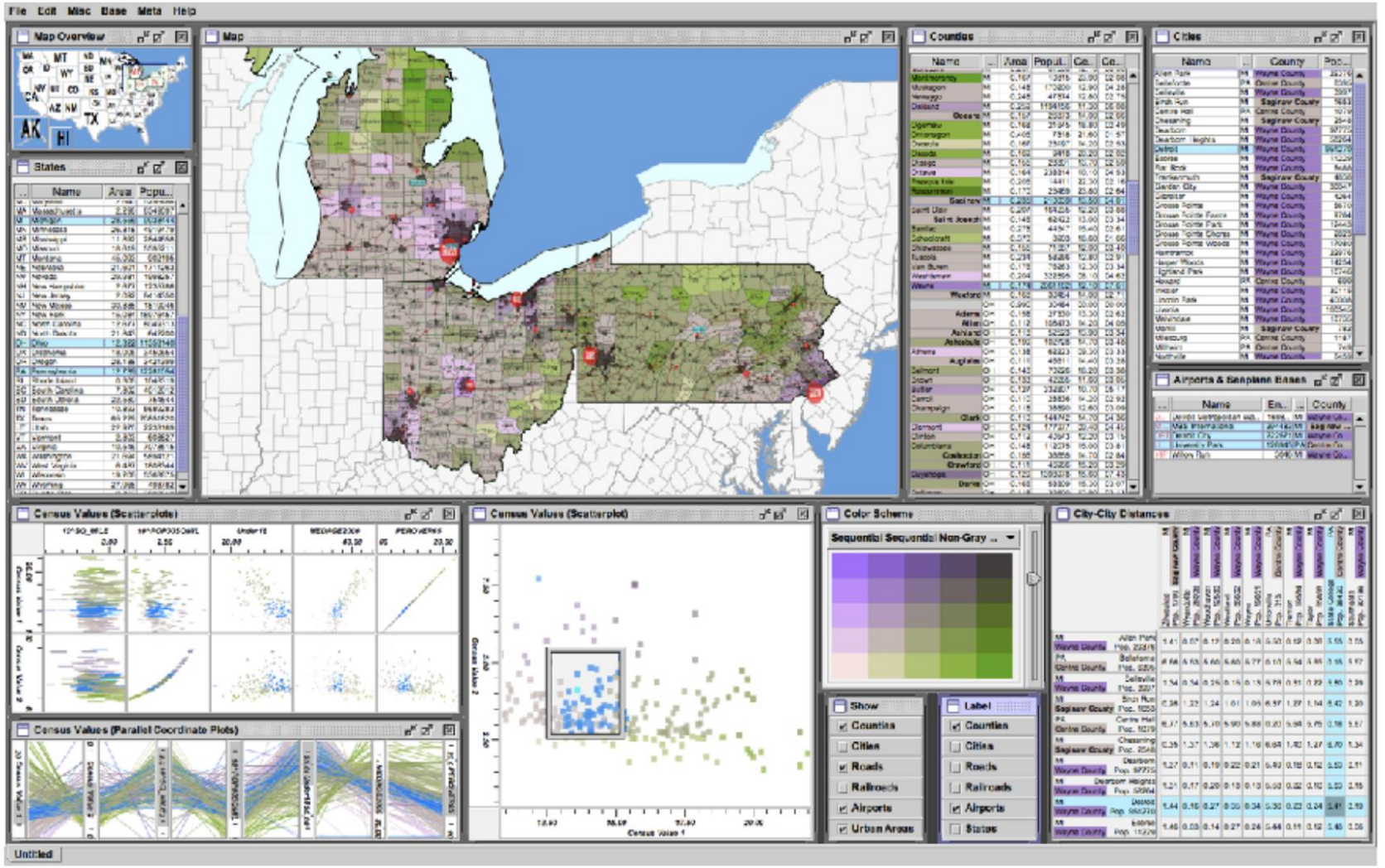


View coordination: design choices

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

Juxtapose idiom: reorderable lists

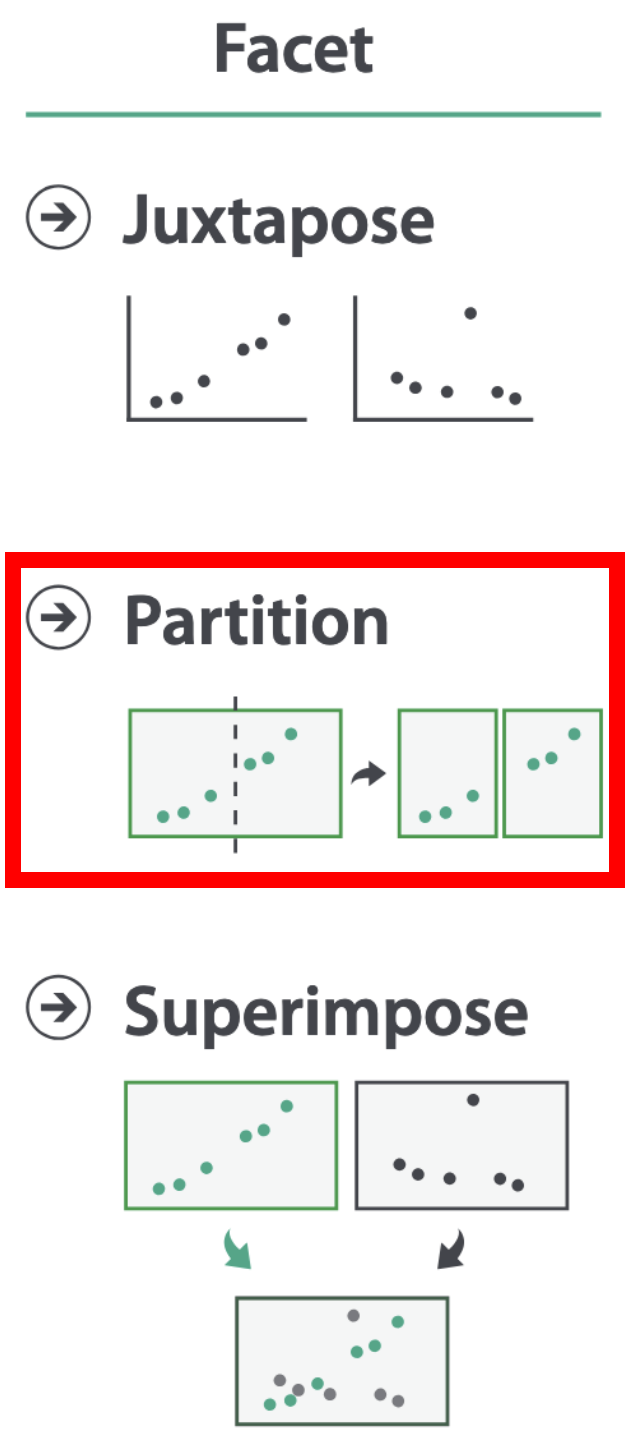
- List views
  - Easy lookup
  - Useful when linked to other views, not so useful on their own
- How many views is okay vs too complex?
  - Open research question



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

Facet

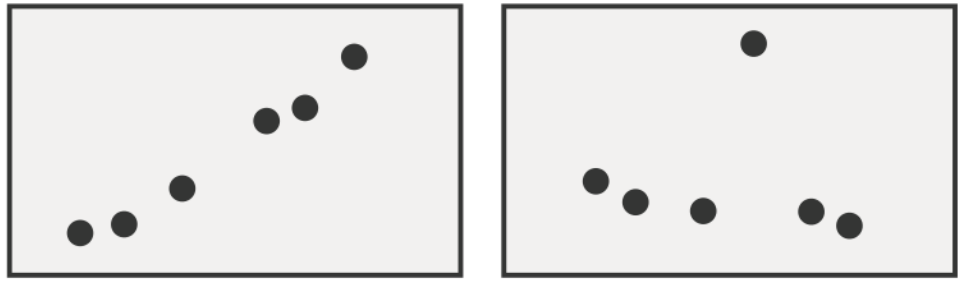
- Another way to handle complexity
- Juxtapose
  - Put multiple views of the same data next to each other
- Partition
  - Put multiple views of the same data next to each other
- Superimpose
  - Store multiple views as different layers that can be displayed on top of one another



Partition into views

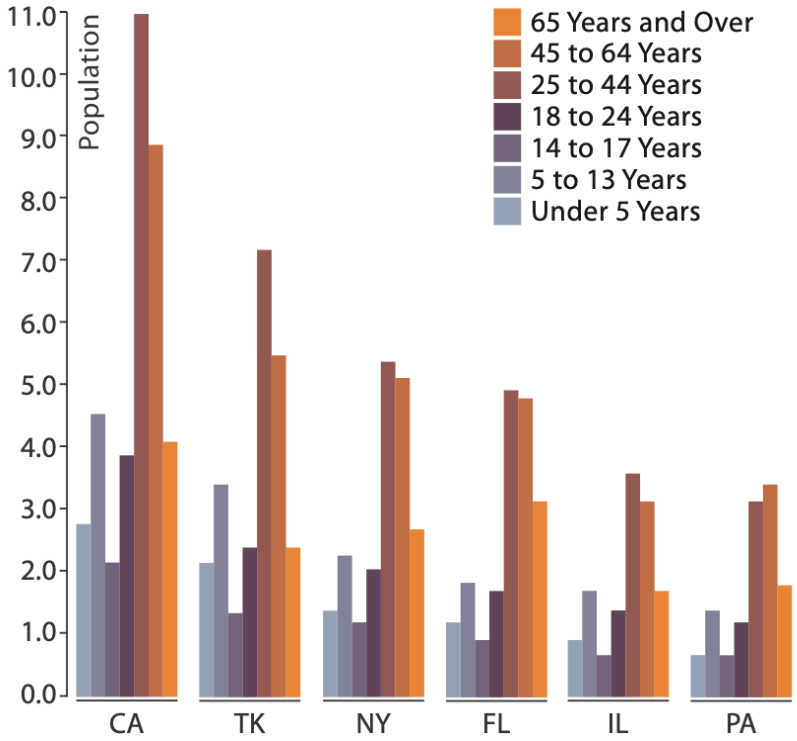
- How to divide data between views
  - Usually split into regions by attributes
  - Encodes association between items using spatial proximity
  - Order of splits has major implications for visible patterns
- Major choices:
  - How many views to split into?
  - How to order the views?

Partition into Side-by-Side Views

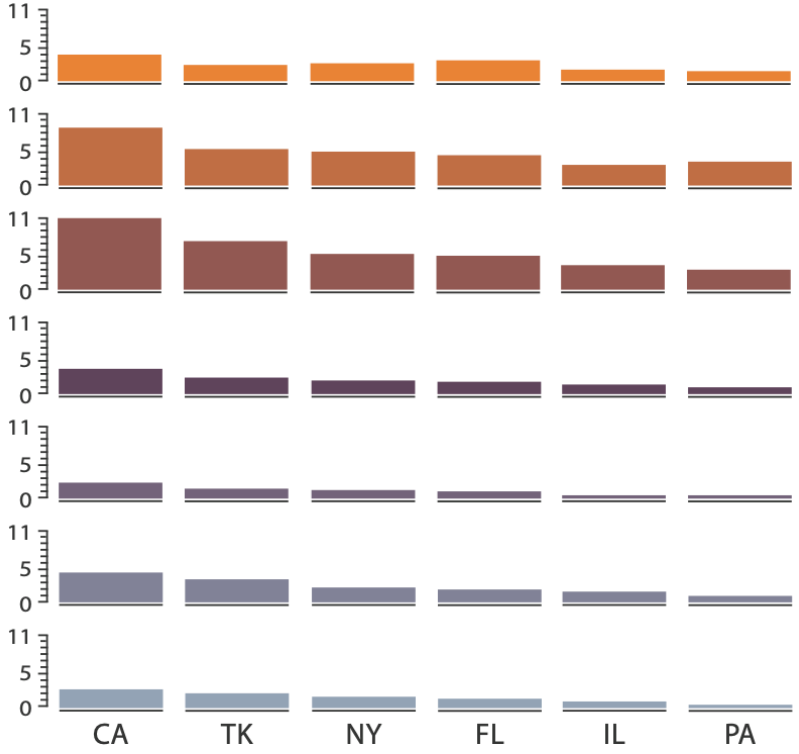


Partitioning: grouped vs small-multiple bars

- Single bar chart with grouped bars
  - Split by state into regions
  - Compare: easy within sate, hard across ages
- Small-multiple bar charts
  - Split by age into regions
  - Compare: easy within age, hard across states



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



https://bl.ocks.org/mbostock/4679202

Partitioning: recursive subdivision

- Real estate in London
- Split by neighborhood
- Then by type
  - Flat, terrace, semi-detached, detached
- Then by time
  - Years as rows
  - Months as columns
- Color by price

- What patterns?
  - Where it's expensive
  - Where you pay 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.

Partitioning: recursive subdivision

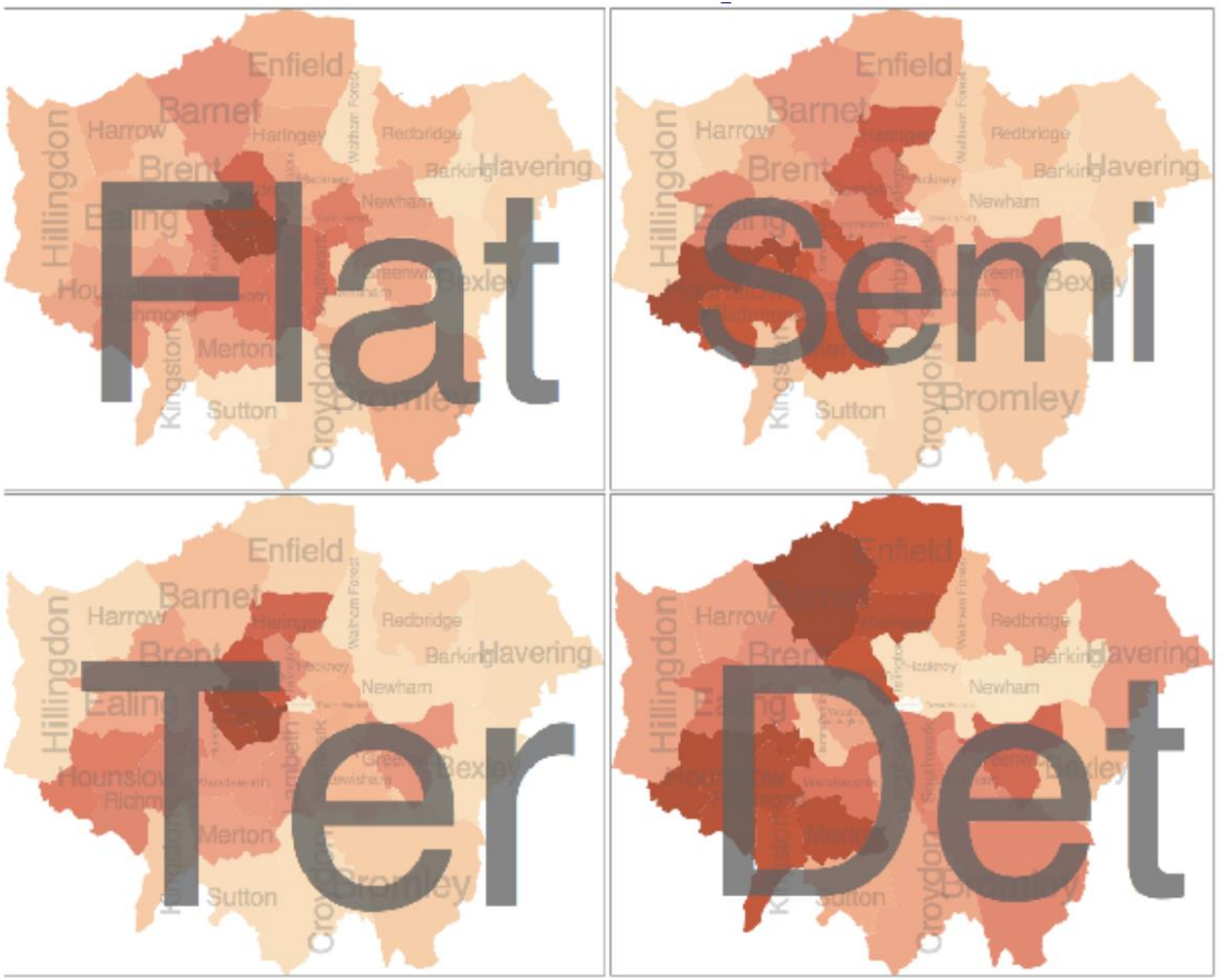
- Switch order of splits
  - Type then neighborhood
- Switch color
  - By price variation

- What pattern?
  - Within specific type, which neighborhood is inconsistent

- Order of division matters!

Partitioning: recursive subdivision

- Different encoding: choropleth map
  - Highlights geographic patterns



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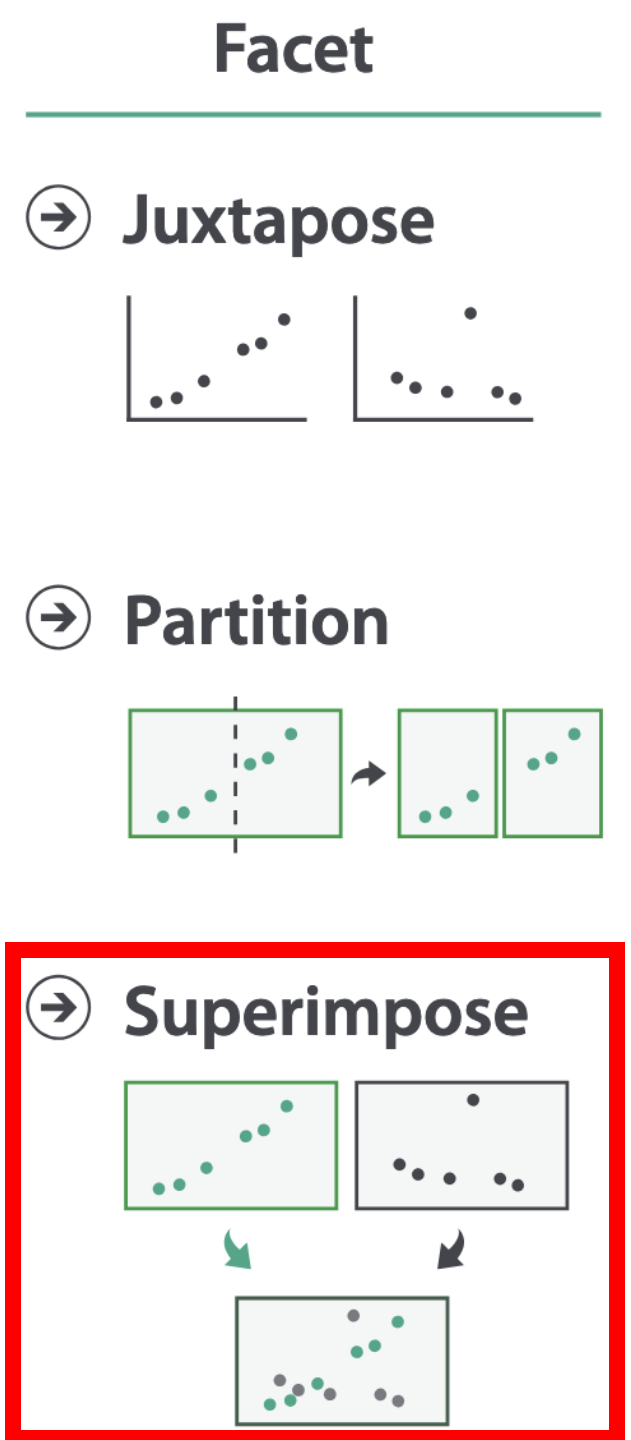
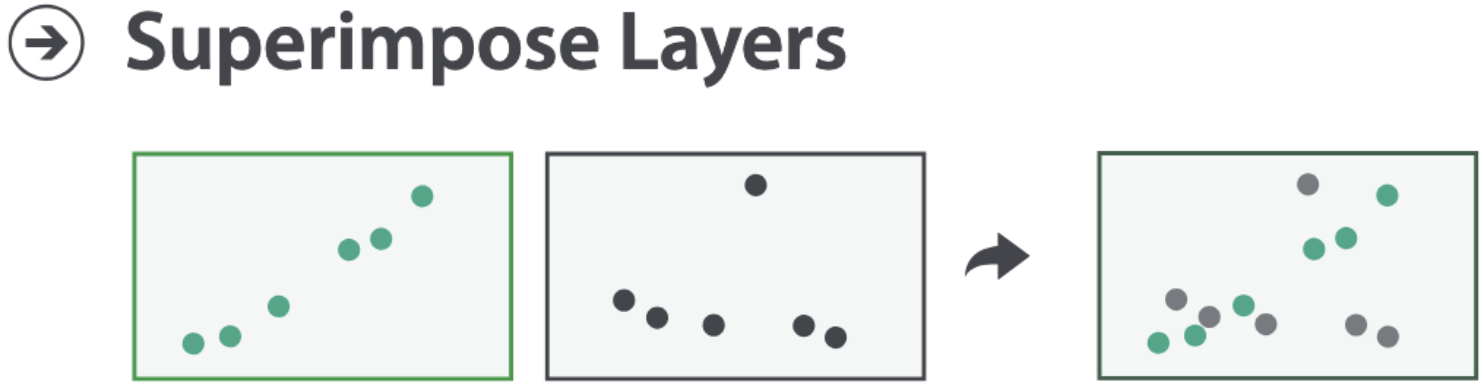


Superimpose layers

- Layer: set of objects spread out over a region
  - Each set is a visually distinguishable group
  - Covers the whole view
- Design choices:
  - How to distinguish layers?
    - Encode layers with different, nonoverlapping channels
  - How many layers?
    - 2 is achievable, 3 with careful design
  - Small static set, or dynamic with interaction?

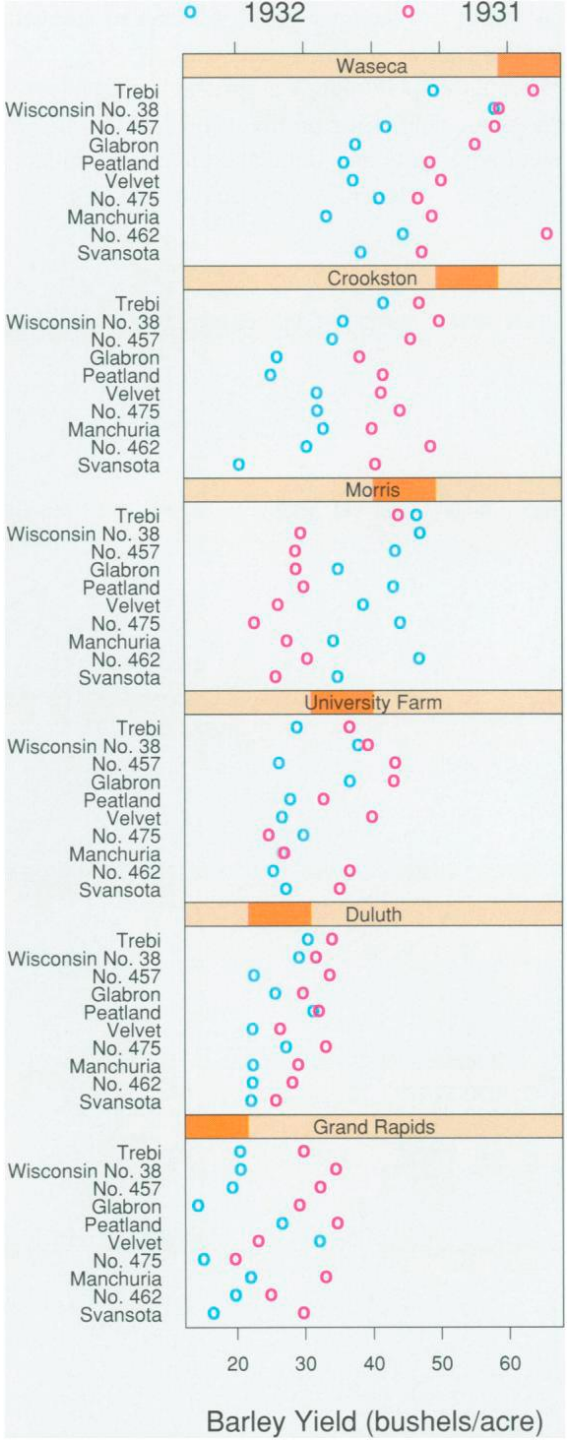


Static visual layering

- Foreground layer: roads
  - Hue, size to distinguish major from minor
  - High luminance contrast from background
- Background layer: regions
  - Desaturated colors for regions
- User can selectively focus attention

Static layering 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
- What patterns emerge?
  - Blue and pink swapped for Morris!

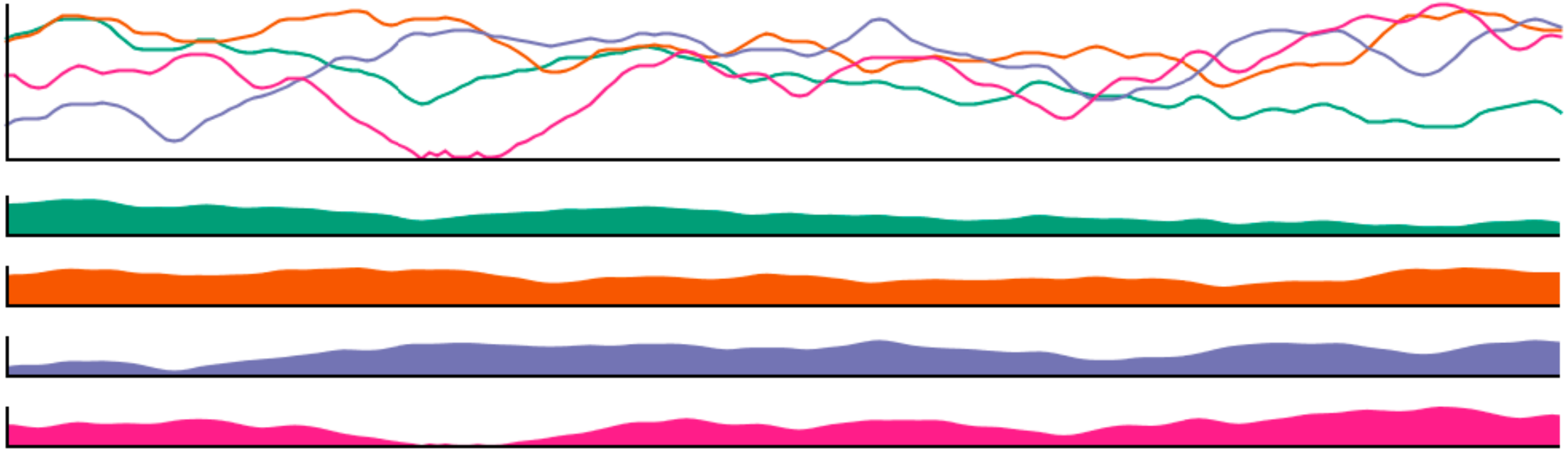


The Visual Design and Control of Trellis Display. Becker, Cleveland, & Shyu. Journal of Computational and Graphical Statistics 5(2):123-155 1996.

Limits of superimposing (static)

- Limit on number of layers
  - A few dozen for lines, but not hundreds
- Superimpose vs juxtapose: empirical study
  - Same size: small multiples vs single superimposed
    - Need to have the same number of pixels!
  - Superimposed: good for local tasks
  - Juxtaposed: good for global tasks, esp. for many charts

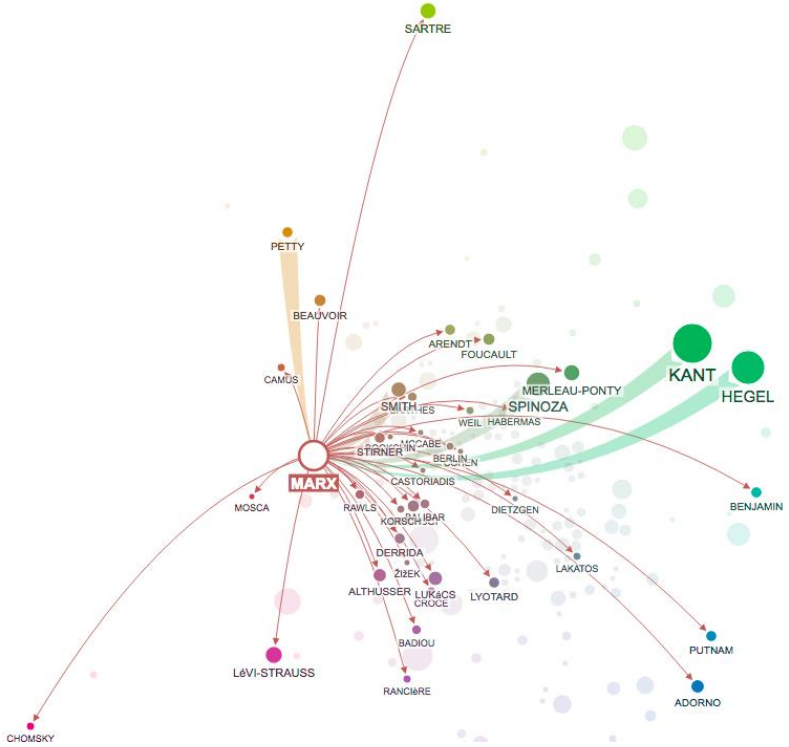
Graphical Perception of Multiple Time Series.Javed, McDonnel, and Elmqvist. IEEE Transactionson Visualization and Computer Graphics (Proc.IEEE InfoVis 2010) 16:6 (2010), 927–934



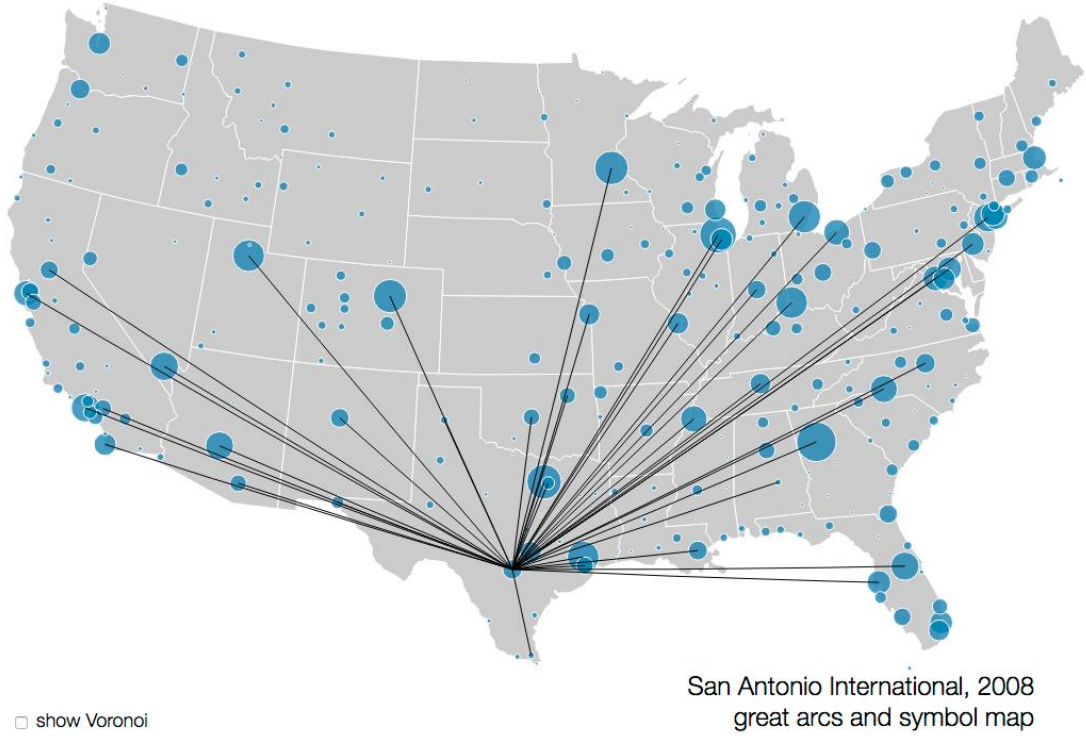
Dynamic visual layering

- Interactive, based on selection!
- One-hop neighbor highlighting

Clicking (heavyweight)



Hovering (lightweight)



https://mariandoerk.de/edgemaps/demo/ http://mbostock.github.io/d3/talk/20111116/airports.html

Other Options

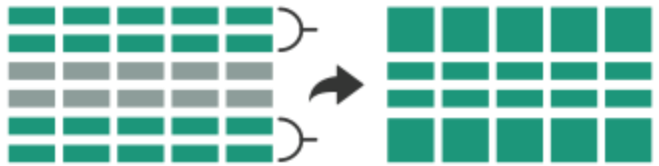
Reduce items or attributes

- Within a single view, *show less stuff*
  - With *filtering*, you simply show fewer items and/or attributes
    - Maybe they aren't needed for the particular viz question
  - With *aggregating*, many items and/or attributes are combined

Reduce

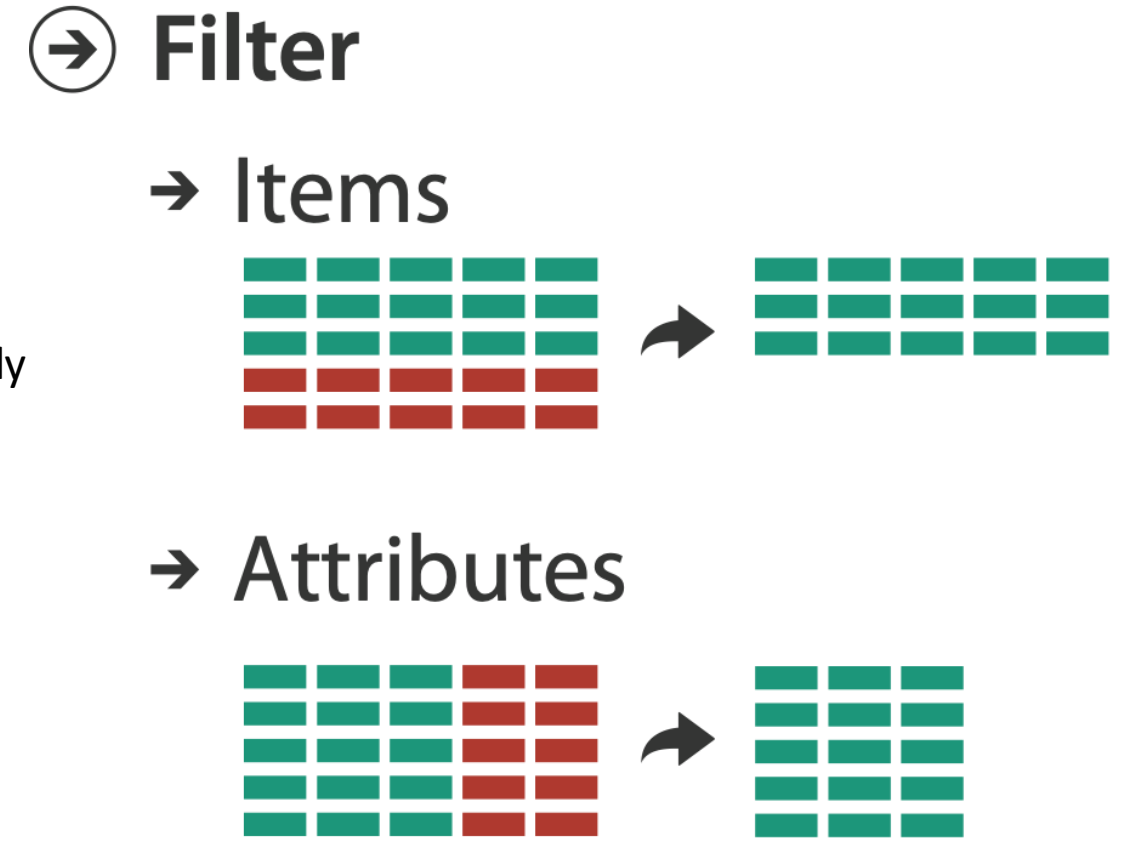
Filter

Aggregate



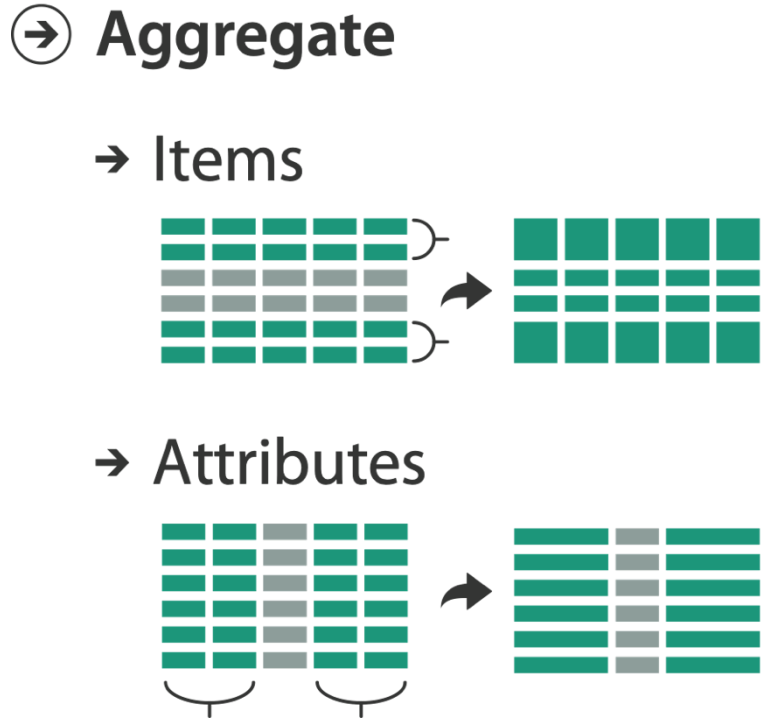
Filter items or attributes

- Pros:
  - Straightforward and intuitive
    - Easy to understand
    - Easy to implement
- Cons:
  - Once data is out of sight, it is often out of mind
    - Data may be filtered unintentionally/erroneously and never looked at again



Aggregate items or attributes

- Pros:
  - Preserves (and even enhances) data about the whole set
- Cons:
  - Difficult to avoid losing ”signal” (detail)



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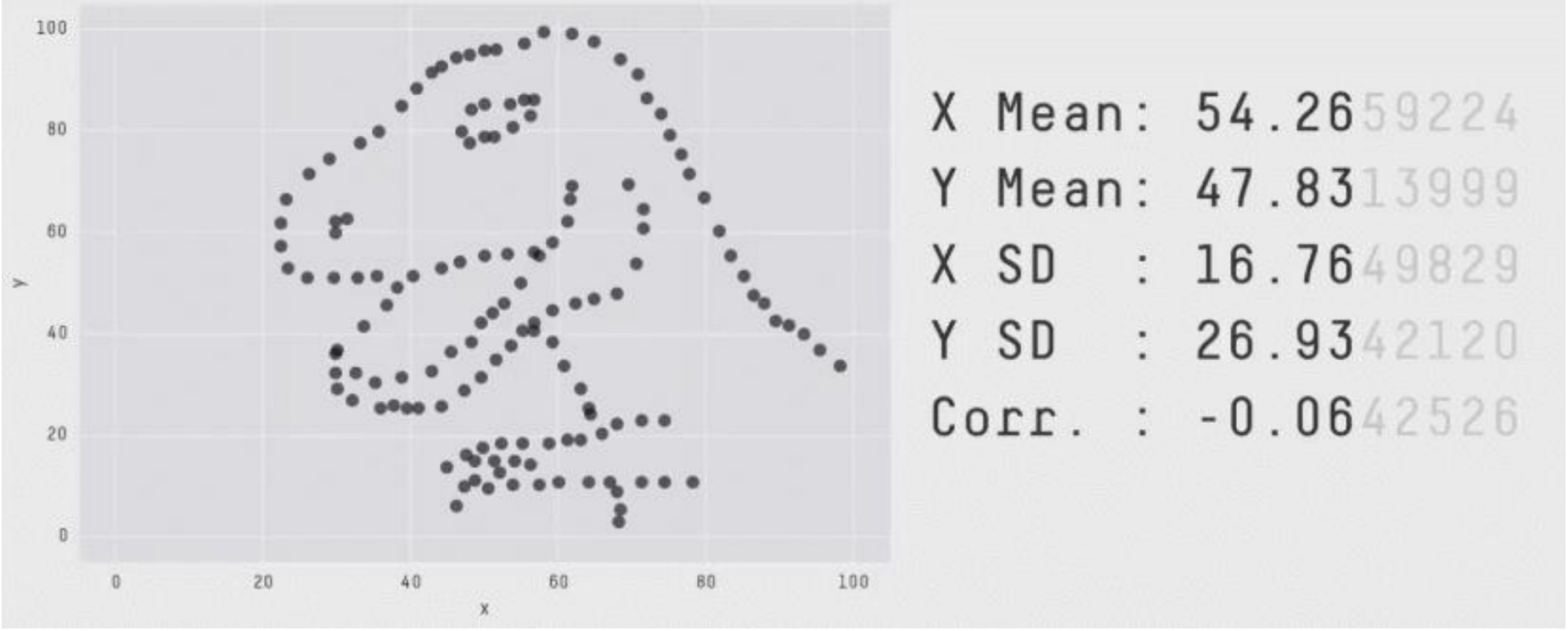
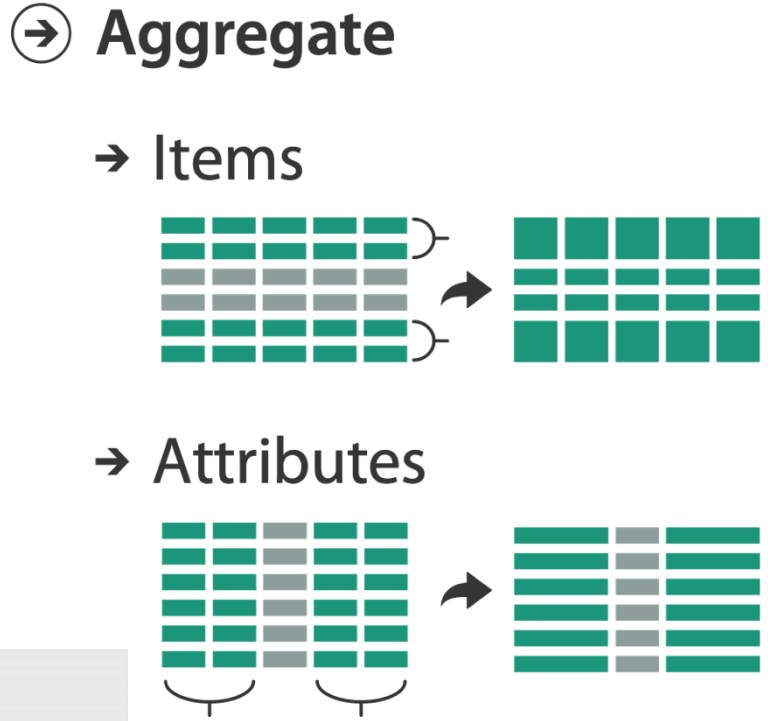
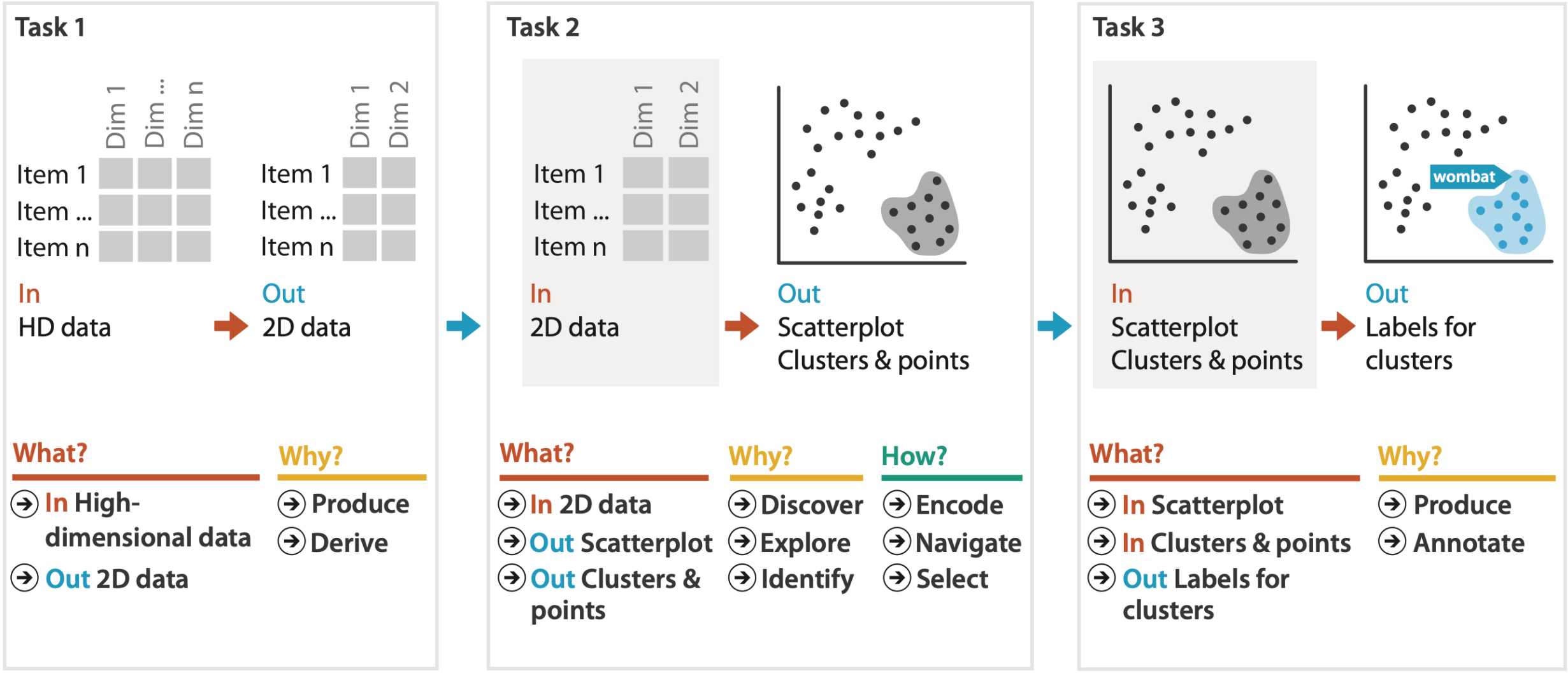


Matejka, Justin, and George Fitzmaurice. "Same stats, different graphs: generating datasets with varied appearance and identical statistics through simulated annealing." *Proceedings of the 2017 CHI conference on human factors in computing systems*. 2017.



Aggregation = dimensionality reduction

- Derive a low-dimensional target space from a high-dimensional measurement space
- Goal: Capture maximum variance with minimum error



Not mutually exclusive

- A visualization can combine filtering and aggregation
- It can also combine reduction, manipulation, and faceting
- Your responsibility to use them as you see fit

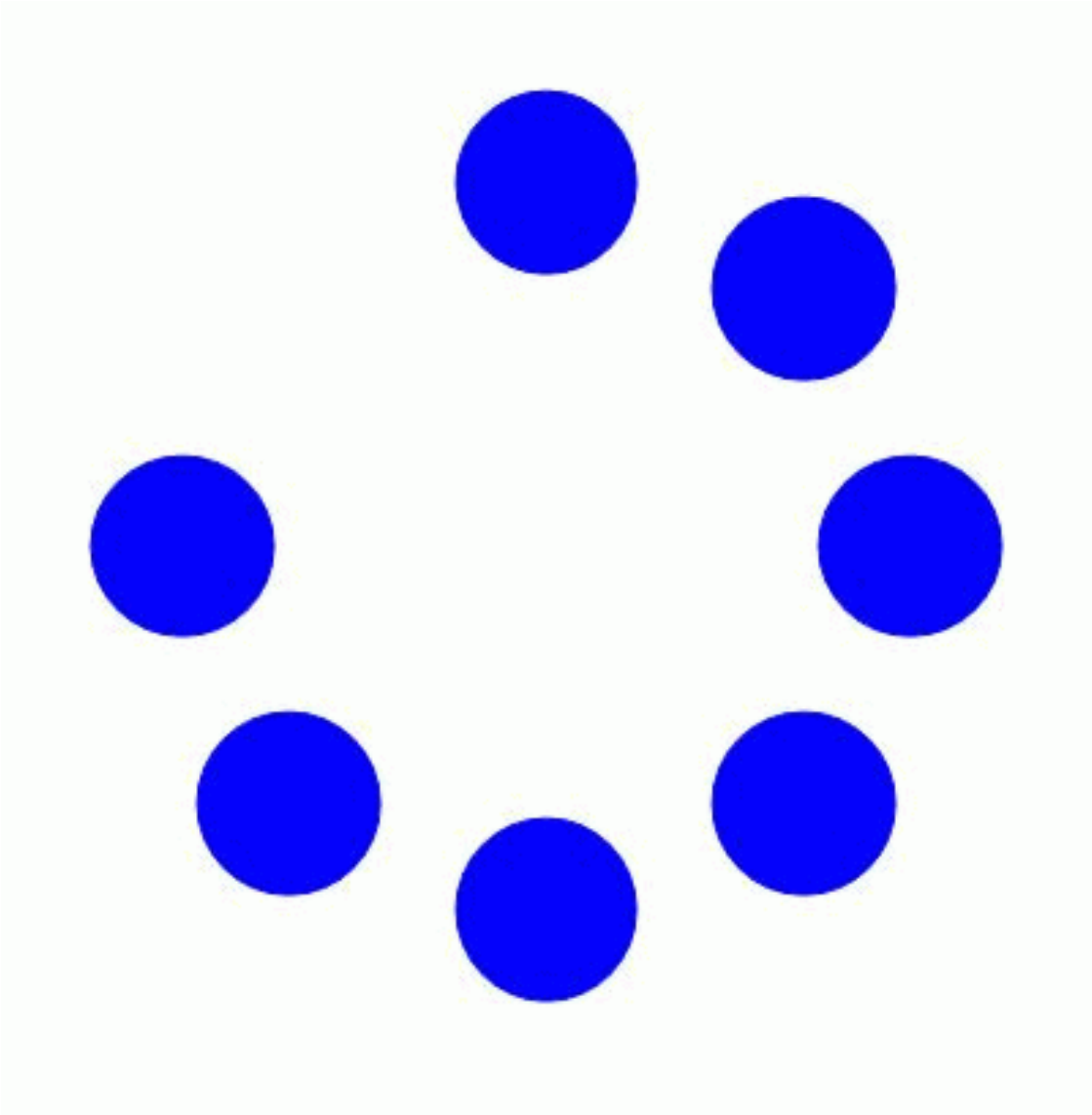
Animation

Why use motion?

- Visual variable to encode data
- Direct attention
- Understand system dynamics
- Understand state transition
- Increase engagement

Perceiving animation

- Motion is perceived at about ~10 frames/sec (100 ms).
  - But this does not have to be smooth motion! We can tell that frames are discrete yet still perceive movement.
- More generally, phi phenomenon

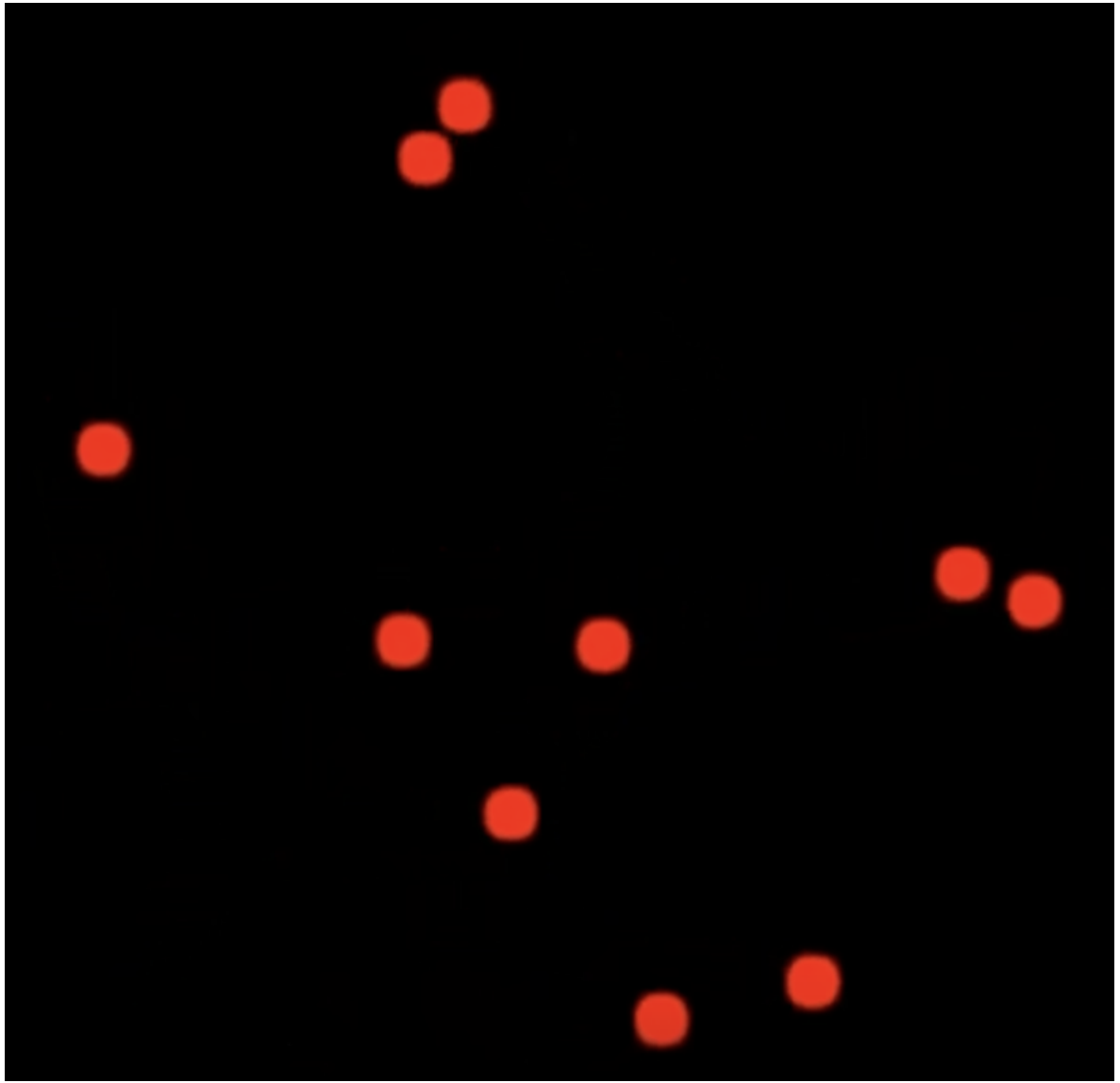


Motion as Visual Cue

- Pre-attentive, stronger than color, shape, …
- More sensitive to motion at periphery. Why?
- Similar motions perceived as a group

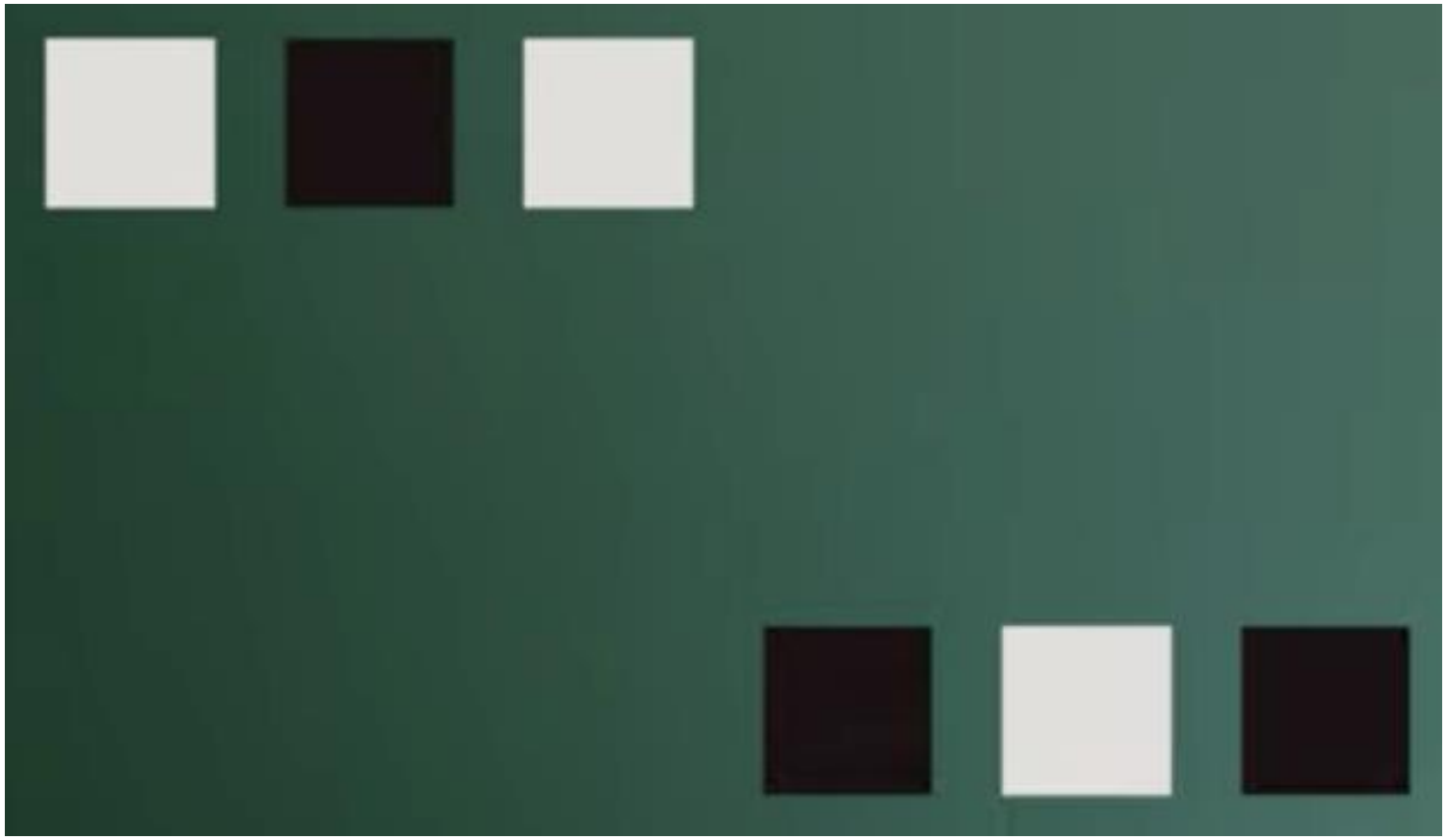
Multiple object tracking

- https://www.youtube.com/watch?v=V3-HL7MgzzA



Similar motion gets grouped together

- https://youtu.be/WUfpM8pvhrk?t=66



Animation pros and cons

Animation...	Helps...	Hurts...
Attention	Direct attention	Distraction
Constancy	Track changes	False relations
Causality	Cause and effect	False agency
Engagement	Increase interest	Too slow: boring Too fast: errors

Break