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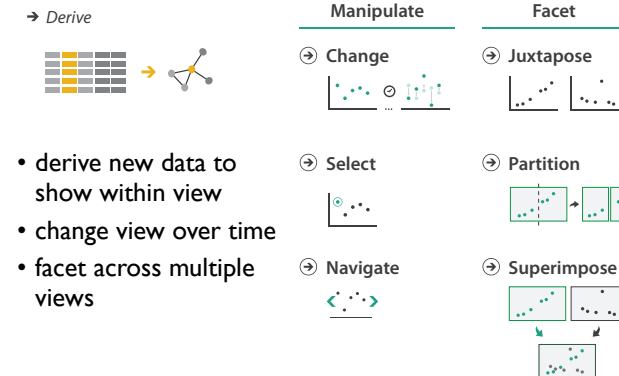
How to handle complexity: 1 previous strategy



- derive new data to show within view

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How to handle complexity: 1 previous strategy + 2 more



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

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Manipulate View

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Manipulate

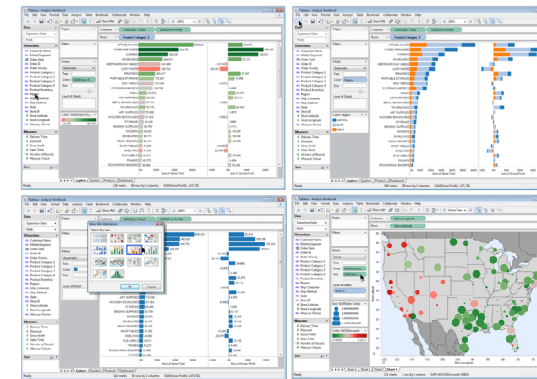


Change over time

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

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Idiom: Re-encode

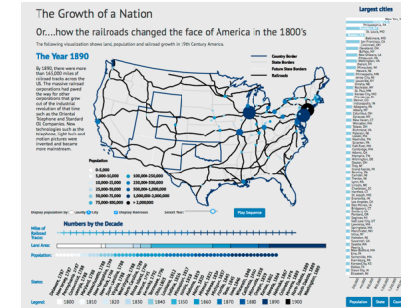


made with Tableau, <http://tableausoftware.com>

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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

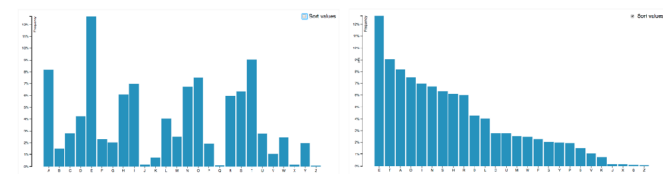


[Growth of a Nation](<http://laurenwood.github.io/>) made with D3

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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

System: DataStripes

- what: table with many attributes
- how: data-driven reordering by selecting column
- why: find correlations between attributes



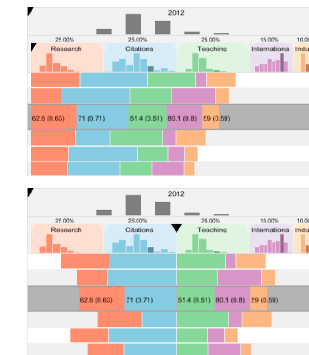
[<http://carlmanaster.github.io/datastripes/>] made with D3

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Idiom: Change alignment

System: LineUp

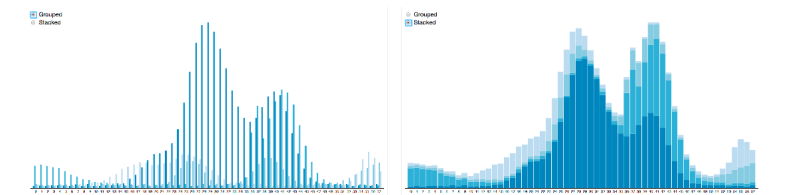
- stacked bars
 - easy to compare
 - first segment
 - total bar
- align to different segment
 - supports flexible comparison



[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

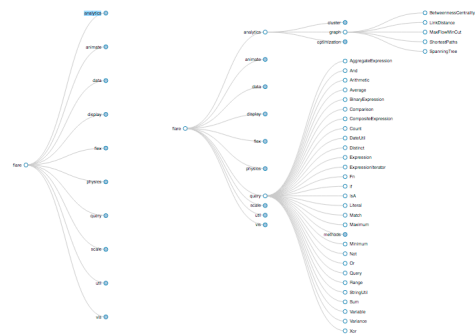


[Stacked to Grouped Bars] <https://observablehq.com/@d3/stacked-to-grouped-bars>

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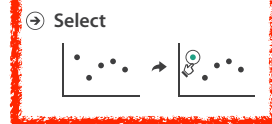
Idiom: Animated transition - tree detail

- animated transition
 - network drilldown/rollup



[Collapsible Tree] <https://observablehq.com/@d3/collapsible-tree>

Manipulate



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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=QXLIT9sFcbE

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, ...)



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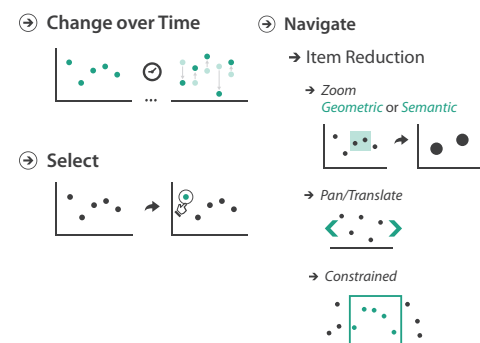
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Highlighting

- **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

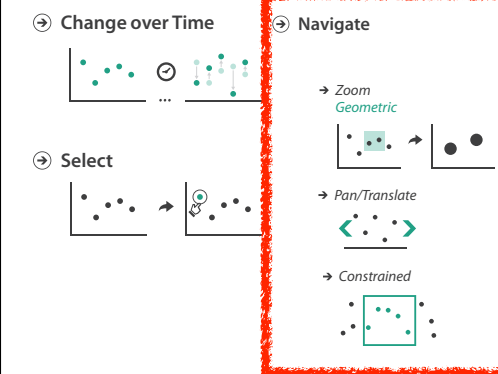


Manipulate



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Manipulate



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Navigate: Changing viewpoint/visibility

- **change viewpoint**
 - changes which items are visible within view
- **camera metaphor**
 - pan/translate/scroll
 - move up/down/sideways

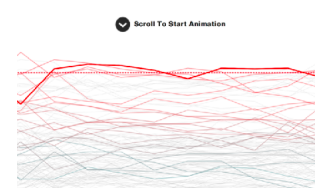
→ Navigate



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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



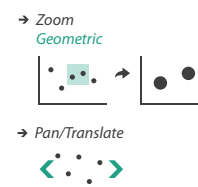
[How to Scroll, Bostock] (<https://bost.ocks.org/mike/scroll/>)
<https://eagereyes.org/blog/2016/the-scrollytelling-scourge>

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Navigate: Changing viewpoint/visibility

- **change viewpoint**
 - changes which items are visible within view
- **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

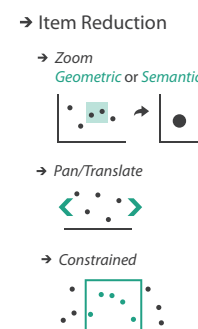


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Navigate: Unconstrained vs constrained

- **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



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Idiom: Animated transition + constrained navigation

- **example**: geographic map
 - simple zoom, only viewport changes, shapes preserved

Zoom to Bounding Box

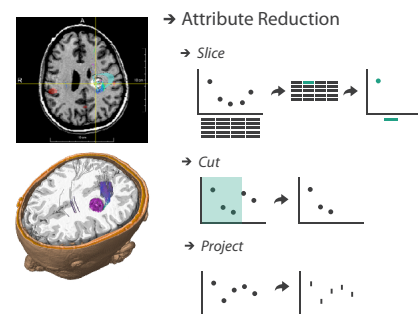


[Zoom to Bounding Box] <https://observablehq.com/@d3/zoom-to-bounding-box>

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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, ...



[Interactive Visualization of Multimodal Volume Data for Neurosurgical Tumor Treatment. Rieder, Ritter, Raspe, and Peitgen. Computer Graphics Forum (Proc. EuroVis 2008) 27:3 (2008), 1055–1062.]

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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

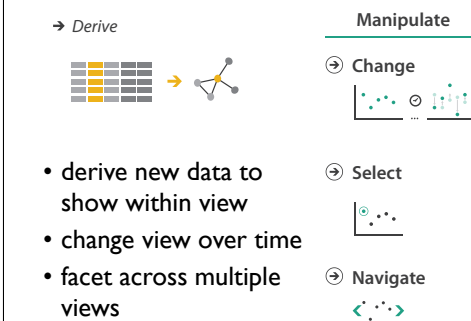
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Interaction limitations

- **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

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How to handle complexity: 1 previous strategy + 2 more



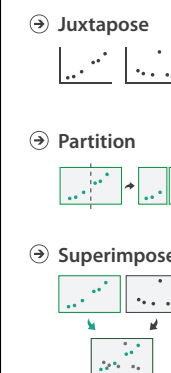
- **derive** new data to show within view
- **change** view over time
- **facet** across multiple views

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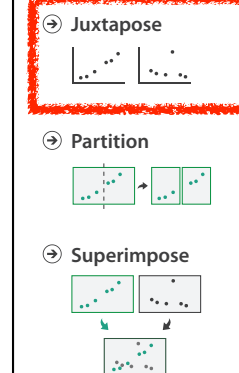
Multiple Views

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Facet



Facet

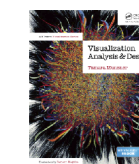


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Visualization Analysis & Design

Interactive Views (Ch 11/12) II

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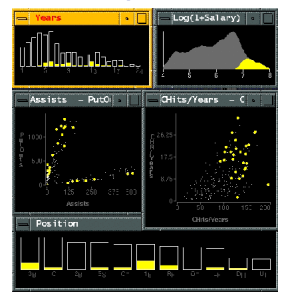
Juxtapose and coordinate views

- Share Encoding: Same/Different
 - **Linked Highlighting**
- Share Data: All/Subset/None
- Share Navigation

Idiom: **Linked highlighting**

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

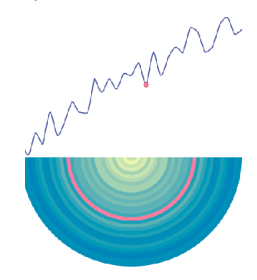
System: **EDV**



[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!



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

Idiom: **Overview-detail views**

System: **Google Maps**

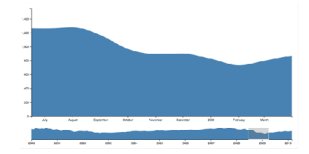
- encoding: same or different
 - ex: same (birds-eye map)
- data: subset shared
 - viewpoint differences: subset of data items
- navigation: shared
 - bidirectional linking
- other differences
 - (window size)



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

Idiom: **Overview-detail navigation**

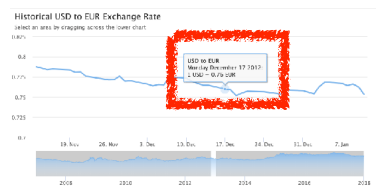
- encoding: same or different
- data: subset shared
- navigation: shared
 - unidirectional linking
 - select in small overview, change extent in large detail view



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

Idiom: **Tooltips**

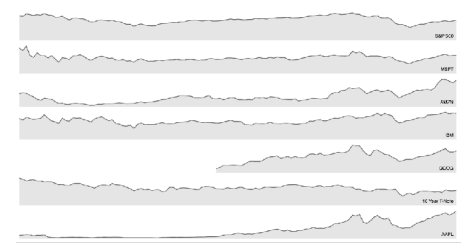
- popup information for selection
 - hover or click
 - specific case of detail view: provide useful additional detail on demand
 - beware: does not support overview!
 - always consider if there's a way to visually encode directly to provide overview
 - "If you make a rollover or tooltip, assume nobody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



<https://www.highcharts.com/demos/dynamic-master-detail/>

Idiom: **Small multiples**

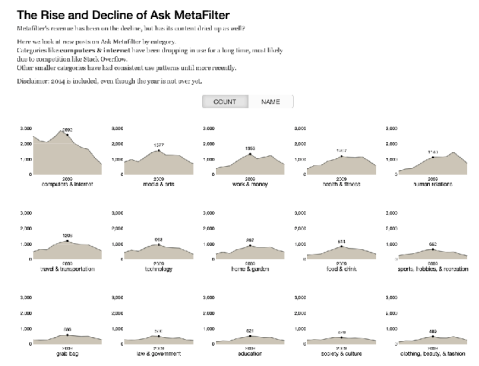
- encoding: same
 - ex: line charts
- data: none shared
 - different slices of dataset
 - items or attributes
 - ex: stock prices for different companies



<https://blocks.org/mbostock/1157787/>

Interactive small multiples

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



<https://blocks.org/ColinEberhardt/3c780088c363d1515403f50a87a87121/>
<https://blog.scottlogic.com/2017/04/05/interactive-responsive-small-multiples.html/>
http://projects.flowingdata.com/tut/linked_small_multiples_demo/

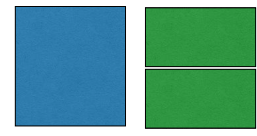
Example: Combining many interaction idioms System: **Buckets**

- multiform
- multidirectional linked highlighting of small multiples
- tooltips

<http://buckets.peterbeshai.com/>

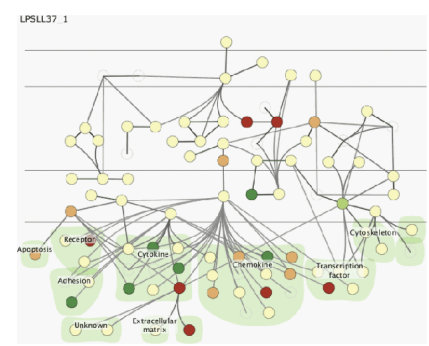
Juxtapose views: tradeoffs

- 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

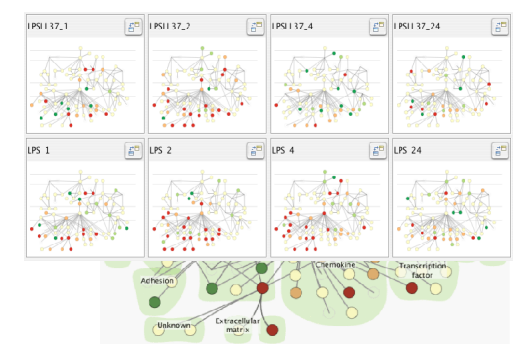
- animate: hard to follow if many scattered changes or many frames
 - vs easy special case: animated transitions



[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)



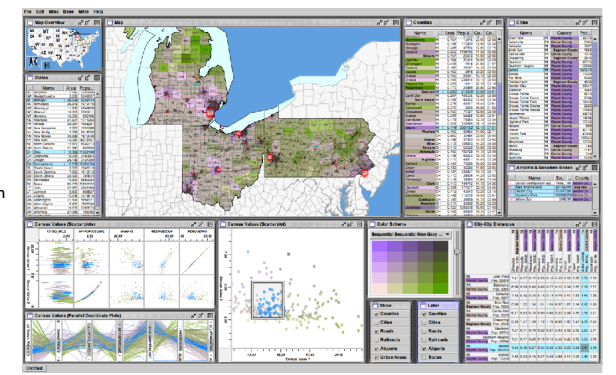
[Cerebral: Visualizing Multiple Experimental Conditions on a Graph with Biological Context. Barsky, Munzner, Gardy, and Kincaid. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14:6 (2008), 1253–1260.]

View coordination: Design choices

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

Idiom: **Reorderable lists**

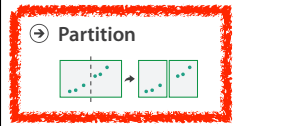
- list views
 - easy lookup
 - useful when linked to other views
- how many views is ok vs too complex?
 - open research question



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

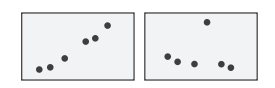
Facet

- Juxtapose
- **Partition**
- Superimpose



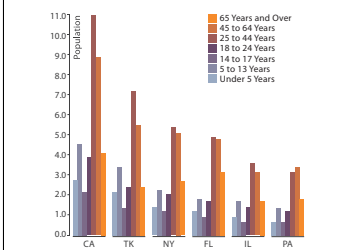
Partition into views

- how to divide data between views
 - Partition into Side-by-Side Views
 - split into regions by attributes
 - encodes association between items using spatial proximity
 - order of splits has major implications for what patterns are visible

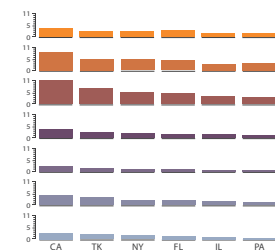


Partitioning: Grouped vs small-multiple bars

- 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



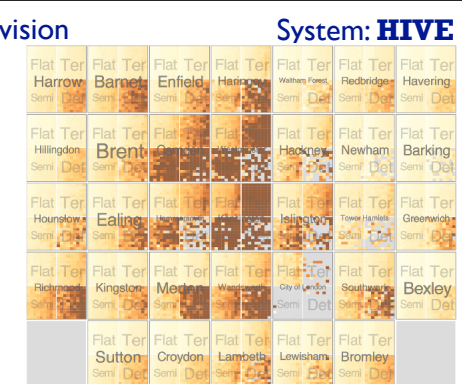
[https://observablehq.com/@d3/grouped-bar-chart]



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

Partitioning: Recursive subdivision

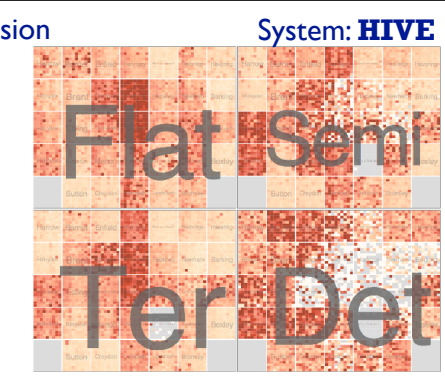
- split by neighborhood
- then by type
 - flat, terrace, semi-detached, detached
- then time
 - years as rows
 - months as columns
- color by price
- neighborhood patterns
 - where it's expensive
 - where you pay much more for detached type



[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

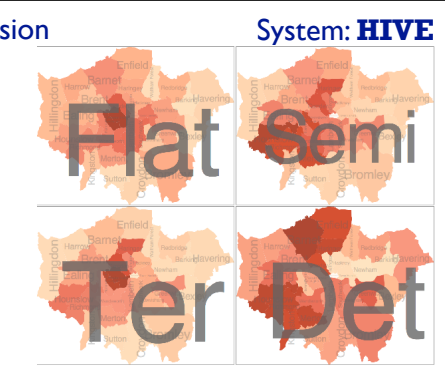
- switch order of splits
 - type then neighborhood
- switch color
 - by price variation
- type patterns
 - within specific type, which neighborhoods inconsistent



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

Partitioning: Recursive subdivision

- different encoding for second-level regions
 - choropleth maps



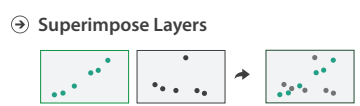
[Configuring Hierarchical Layouts to Address Research Questions. Slingsby, Dykes, and Wood. IEEE Transactions on Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 977-984.]

Facet

- Juxtapose
 - Two separate scatter plots side-by-side.
- Partition
 - A single scatter plot divided into two sections.
- Superimpose
 - Two scatter plots overlaid on top of each other.

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?



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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]

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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

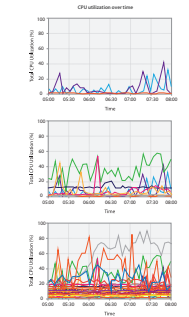


[The Visual Design and Control of Trellis Display. Becker, Cleveland, & Shyu. Journal of Computational and Graphical Statistics 5(2):123-155 1996.]

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Superimposing limits (static)

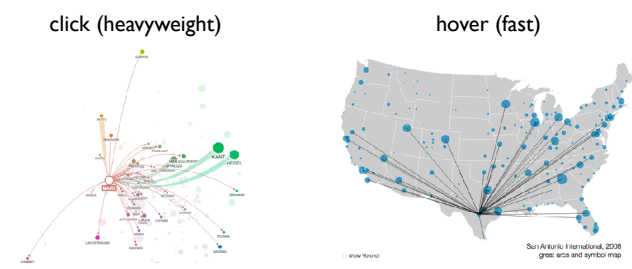
- few layers, more lines
 - up to a few dozen lines
 - but not hundreds
- superimpose vs juxtapose: empirical study
 - same size: all multiples, vs single superimposed
 - superimposed: local tasks
 - juxtaposed: global tasks, esp. for many charts



[Graphical Perception of Multiple Time Series. Javed, McDonnell, and Elmquist. 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



[https://mariandoerk.de/edgemaps/demo/ http://mbostock.github.io/d3/talk/2011/11/16/airports.html]

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How?

Encode	Manipulate	Facet	Reduce
<ul style="list-style-type: none"> Arrange <ul style="list-style-type: none"> Express Order Use 	<ul style="list-style-type: none"> Map from categorical and ordered attributes <ul style="list-style-type: none"> Color <ul style="list-style-type: none"> Hue Saturation Luminance Size, Angle, Curvature, ... Shape Motion <ul style="list-style-type: none"> Direction, Rate, Frequency, ... 	<ul style="list-style-type: none"> Juxtapose Partition Superimpose 	<ul style="list-style-type: none"> Filter Aggregate Embed

What? Why? How?

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