Data Visualization

Interaction in Data Viz

M126 | Maria Roussou

Why do we need interaction (in general)?

- Interaction amplifies cognition
  - We understand things better if we can “touch” them, if we can observe cause and effect
  - It helps the user answer a multitude of questions, which cannot be answered just by looking at a single chart

- Interaction feeds motivation
  - We are more likely to explore if we are able to do something ourselves rather than just look

Why do we need interaction (in data viz)?

- Too much data to show in one view
- Too complex data to show at once
  - giving a sense of the complexity of the data
  - explore data with different representations
- Different audiences with different questions
- Active learning, increase involvement

- Flexible, powerful, intuitive
  - exploratory data analysis: change as you go during the 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

Why do we need interaction (in data viz)?

In short, interaction matters:

- Static = passive
- Interactive = exploration
- Supports insight generation

Key take aways:

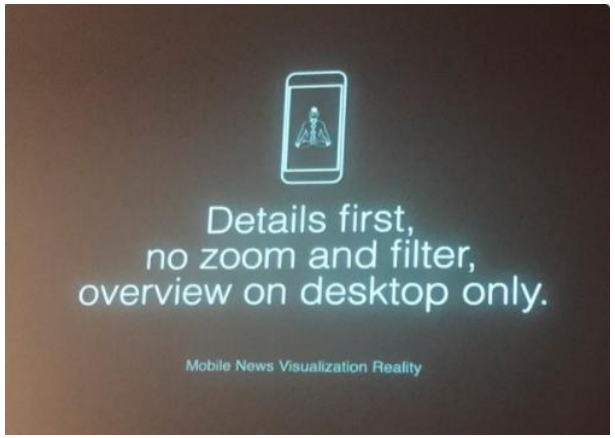
- Interaction enables insight
- Keep it simple
- Design for users

Issues with interaction (in general and in data viz)

- Takes time to learn
- Takes time to use
- Getting lost
  - remembering previous state imposes cognitive load (hard to compare visible item to memory of what you saw)
  - maintaining context/orientation when navigating
  - tracking complex changes during animation
- 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) – see next slide

Challenges with various interaction display

- What do we 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)

I Hate Tom Cruise – Alex Kauffmann (5 min)

slide by Tamara Munzner, inspired by: Alexander Lex, Utah

Shneiderman's Visual Information-Seeking Mantra

Overview first,
zoom and filter,
then details-on-demand.

Shneiderman, 1996

Shneiderman’s Visual Information-Seeking Mantra

Ben Shneiderman with Katerina Mania, 17/4/2026

What are you trying to do with data viz?

- Reveal patterns
- Provide context
- Compare scales
- Describe geography

Let people look up stuff

Amanda Cox, Visualizing data at the NY Times

See also *Talk to the Newsroom: Interactive News Collaborative*

Interaction

Interaction techniques for information visualisation are essentially a form of selection, selecting a subset of objects.

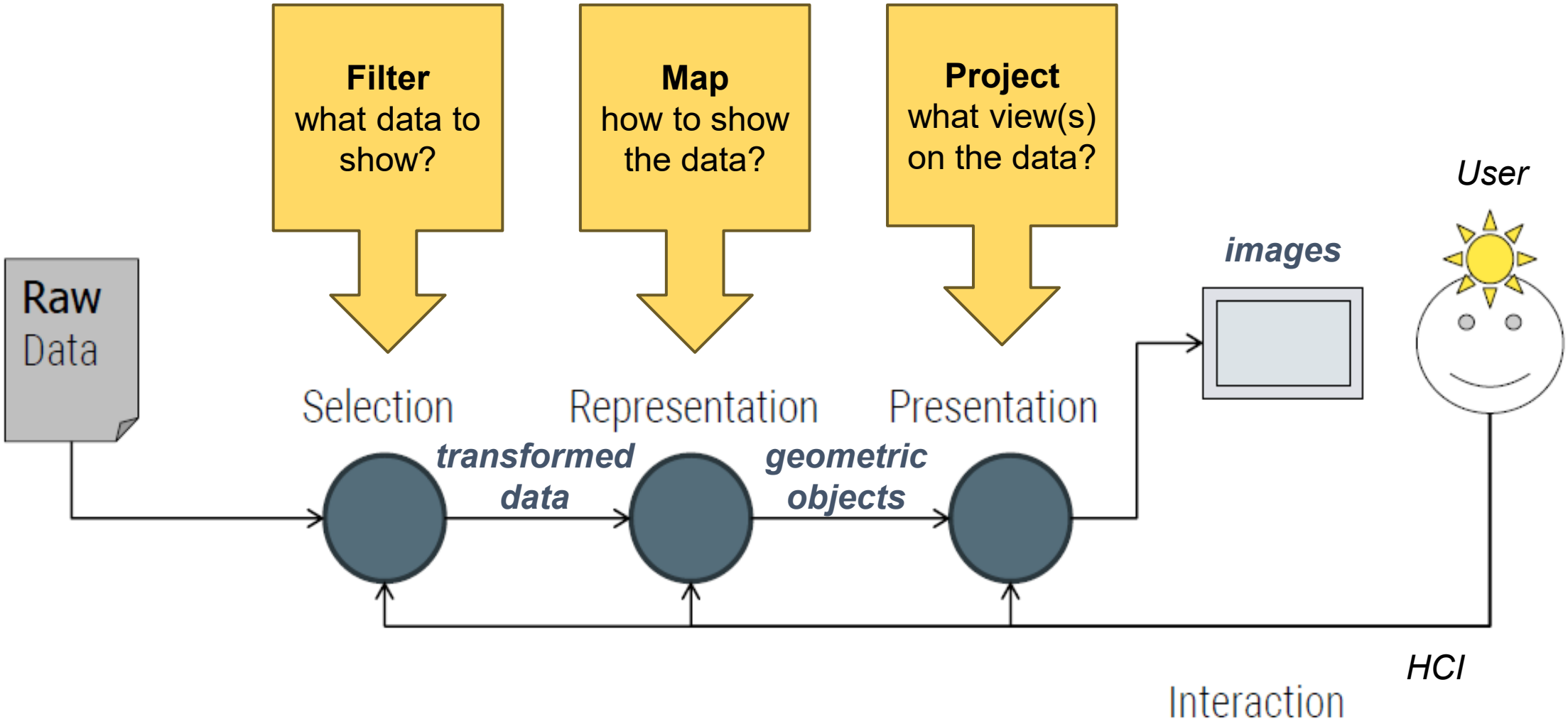
This allows them to be used to locate data, to reveal patterns in data, or to select the arguments of other transformations.

Shneiderman's Visual Information-Seeking Mantra

Overview first,
zoom and filter,
then details-on- demand.

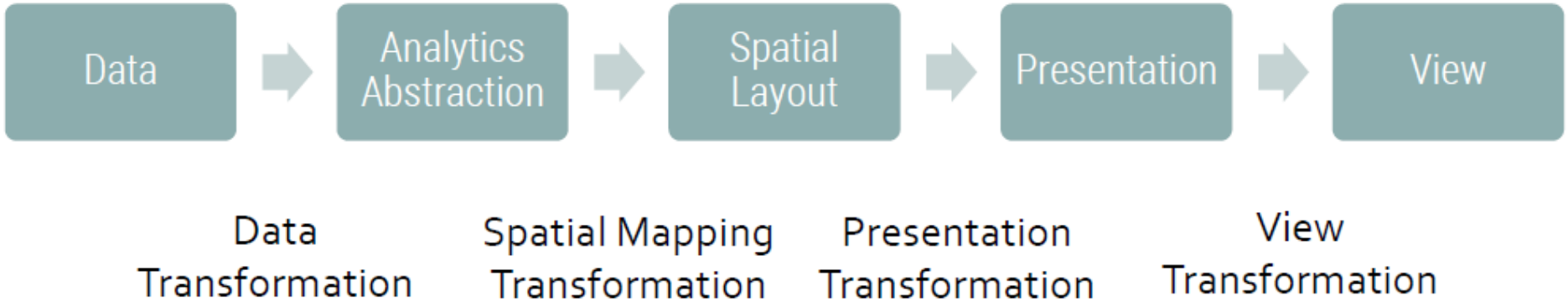
- Overview: Gain an overview of the entire collection.
- Zoom: Zoom in on items of interest
- Filter: filter out uninteresting items.
- Details-on-demand: Select an item or group and get details when needed.
- Relate: View relationships among items.
- History: Keep a history of actions to support undo, replay, and progressive refinement.
- Extract: Allow extraction of sub-collections and of the query parameters

Visualization pipeline



The Visualization Pipeline (Spence, 2000)

Visualization Reference Model



Visualization Reference Model (Card et al.)

(also a pipeline but a bit more expanded)

Types of Interactive Visual Representations

- Static representations
  - don’t allow users to perform any type of interaction, and only a single, unmodifiable view is generated
- Transformable representations
  - allow users to manipulate, in the preprocessing phase, the input data of the representations, e.g. through data filtering.
  - These manipulations usually influence and modify the images that are generated.
- Manipulable representations
  - allow users to manipulate the process that generates the view, via zooming, rotation, panning, etc.

Types of interaction (Card et al., 1999)

- Interaction with data transformations
- Interaction with the type of graphic representation
- Interaction with the geometric transformations

Table 1: Interaction techniques (Card et al., 1999).

Modifies Data Transformation	Modifies Statistical Transformations	Modifies View Transformation
Dynamic queries	Dataflow	Direct selection
Direct walk	Pivot tables	Camera movement
Details-on-demand		Magic lens
Attribute walk		Overview + detail
Brushing		Zoom & pan
Direct manipulation		

Interaction taxonomy (categories)

- Indicate: show me where I am pointing at
- Select: mark something as interesting
- Explore: show me something else
- Reconfigure: show me a different arrangement
- Encode: show me a different representation
- Abstract/Elaborate: show me more or less detail
- Filter: show me something conditionally
- Connect: show me related items
- Activate: trigger action
- Modify: manipulate elements

Soo Yi et al. (2007) & Raskin (2000)

Main interactions you should know about, in short

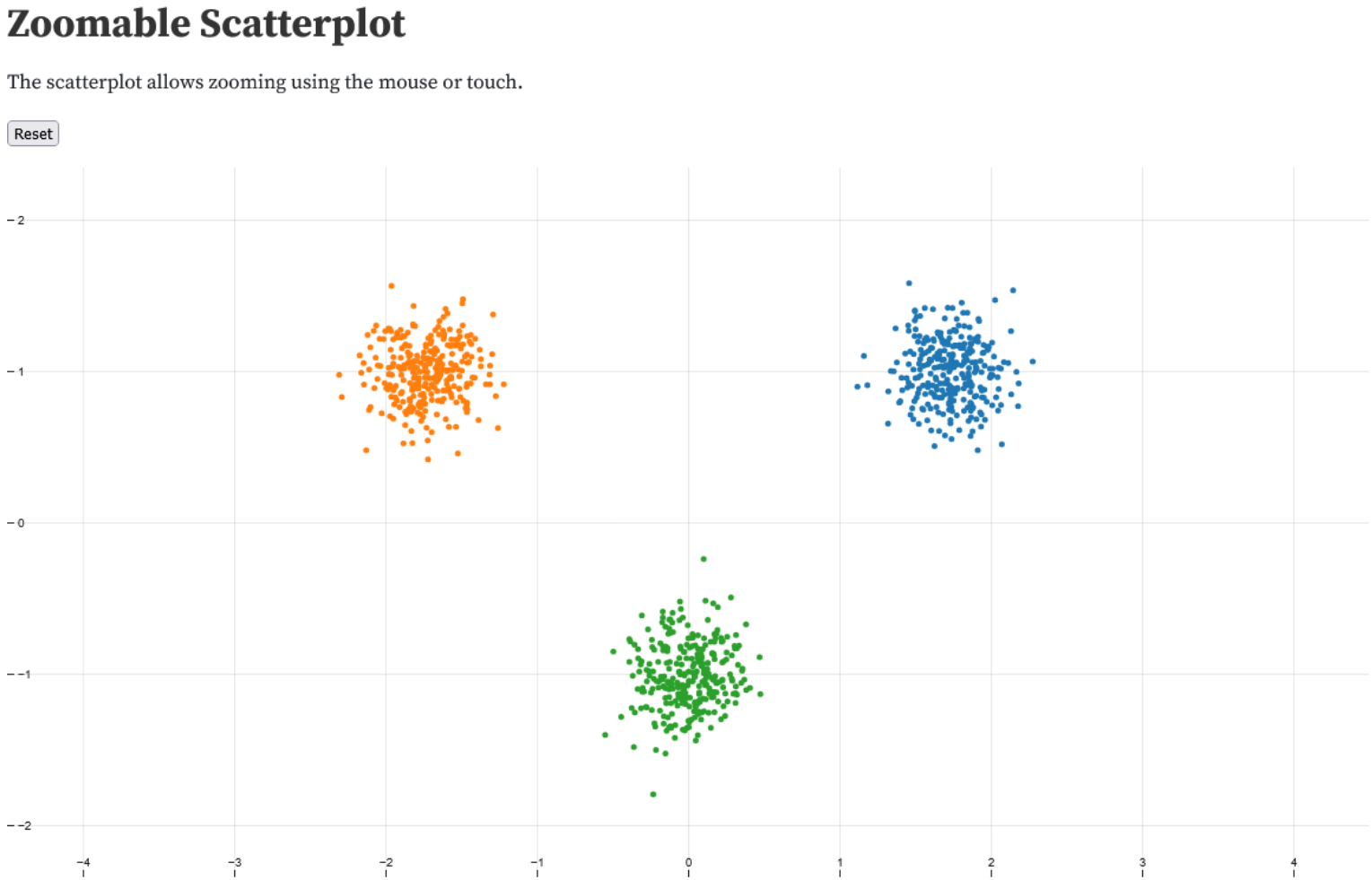
- Brushing & Linking
- Zoom & Pan
- Filtering
- Details-on-Demand
- Tooltips

Brushing & Linking

- Select data in one view
- Highlights in others
- Useful for pattern discovery

Zoom & Pan

- Navigate large datasets
- Focus on detail
- Maintain context



Zoom & Pan

- Navigate large datasets
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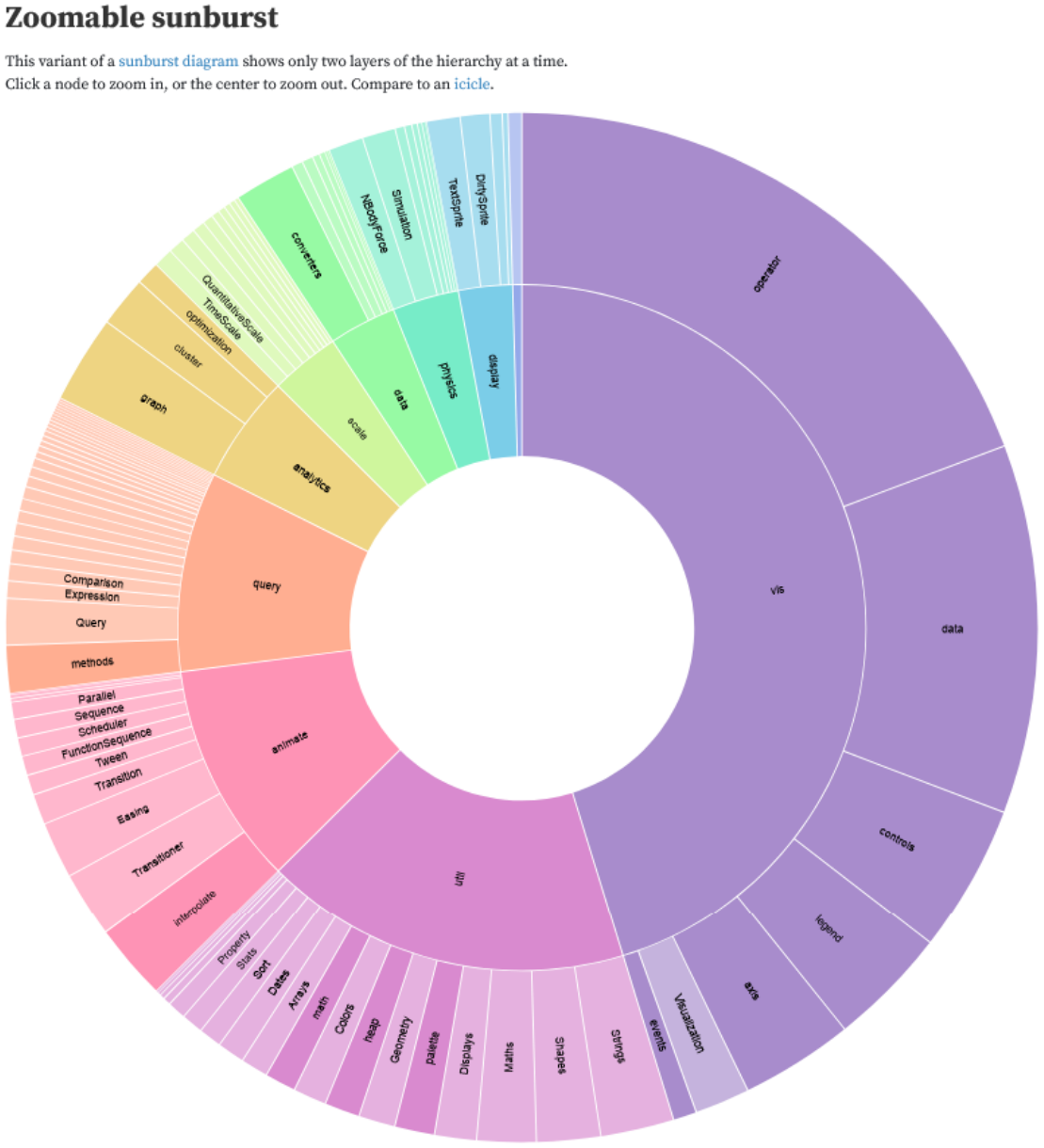
- Maintain context



Filtering

- Reduce data shown
- Focus on relevant subset
- Can be dynamic

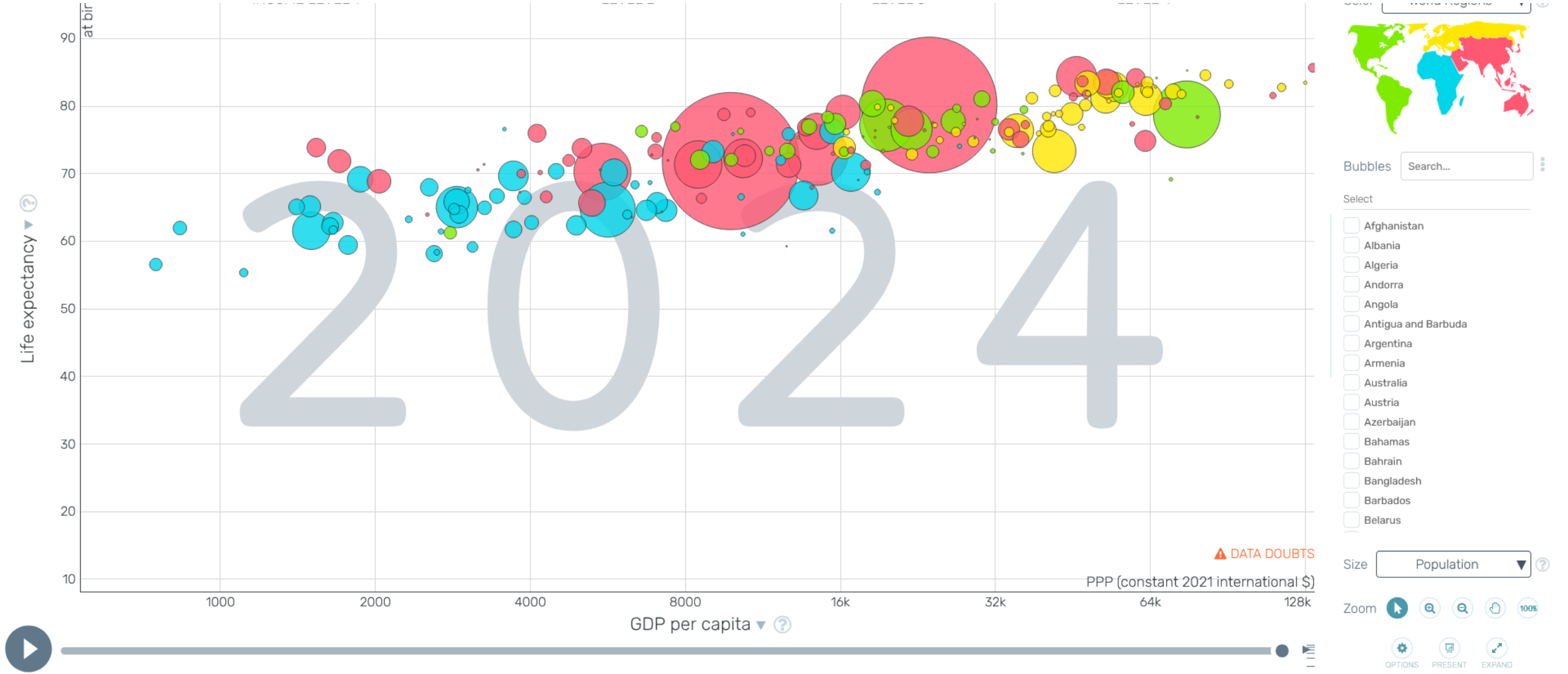
Details-on-Demand

- Show extra info when needed
- Avoid clutter
- Supports exploration

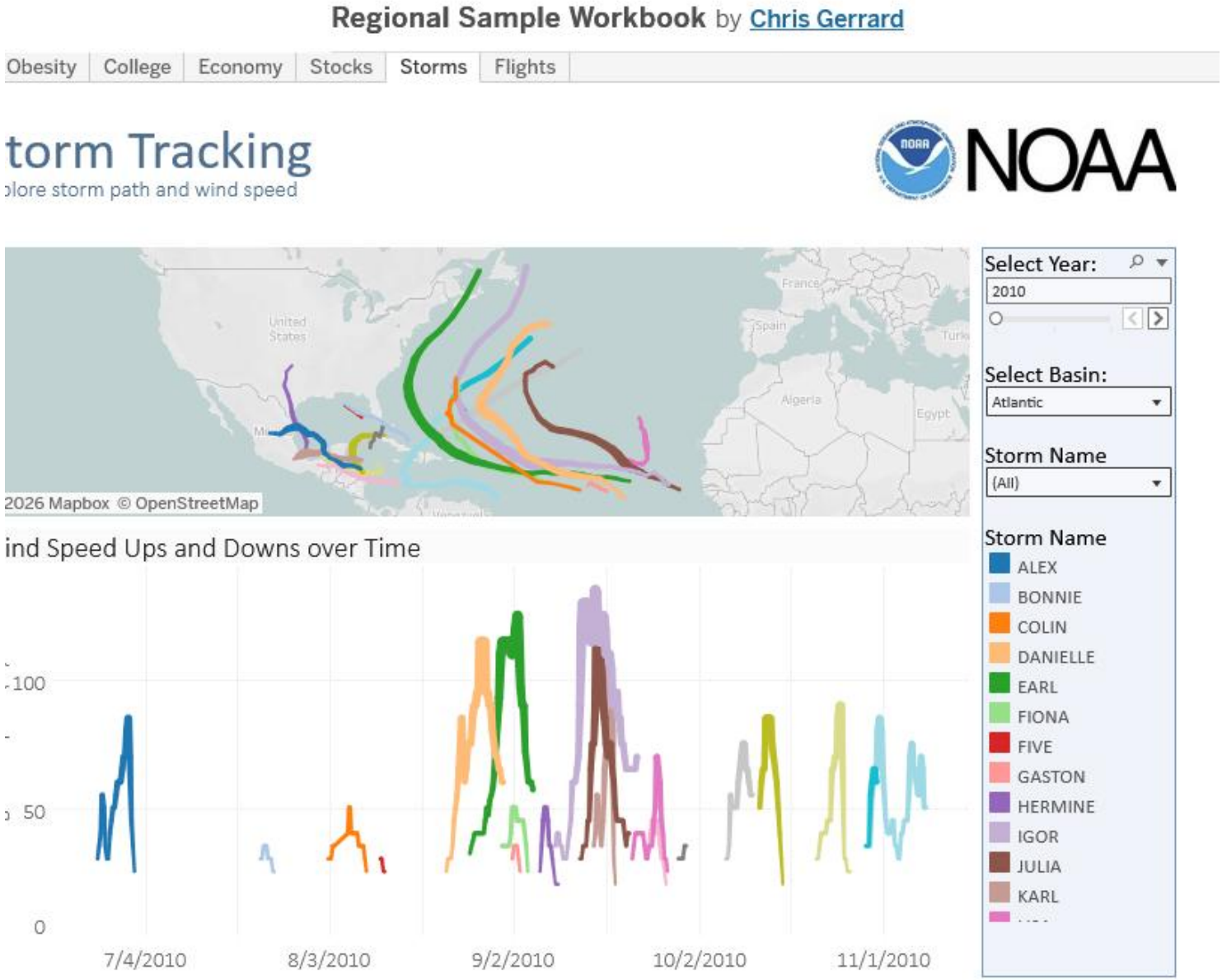
Tooltips

- Hover interaction
- Quick data insight
- Should be concise

Examples


Life expectancy
90
80
70
60
50
40
30
20
10
2024
DATA DOUBTS
PPP (constant 2021 international $)
1000
2000
4000
8000
16k
32k
64k
128k
GDP per capita
Bubbles
Search...
Select
Afghanistan
Albania
Algeria
Andorra
Angola
Antigua and Barbuda
Argentina
Armenia
Australia
Austria
Azerbaijan
Bahamas
Bahrain
Bangladesh
Barbados
Belarus
Size
Population
Zoom
100%
OPTIONS
PRESENT
EXPAND

Examples


Regional Sample Workbook by Chris Gerrard
Obesity
College
Economy
Stocks
Storms
Flights
torm Tracking
plore storm path and wind speed
NOAA
United States
France
Spain
Algeria
Egypt
2026 Mapbox © OpenStreetMap
ind Speed Ups and Downs over Time
100
50
0
7/4/2010
8/3/2010
9/2/2010
10/2/2010
11/1/2010
Select Year:
2010
Select Basin:
Atlantic
Storm Name
(All)
Storm Name
ALEX
BONNIE
COLIN
DANIELLE
EARL
FIONA
FIVE
GASTON
HERMINE
IGOR
JULIA
KARL

Interaction taxonomy (Munzner)

- How to handle complexity: 1 + 3 strategies

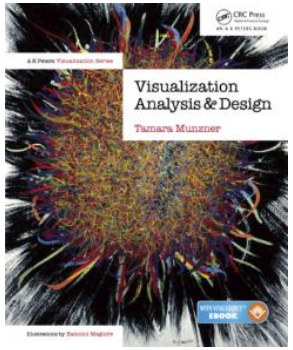
derive new data to show within view

change view over time

facet across multiple views

reduce items/attributes within single view

➔ *Derive*



Tamara Munzner

Manipulate	Facet	Reduce
Change 	Juxtapose 	Filter 
Select 	Partition 	Aggregate 
Navigate 	Superimpose 	Embed 

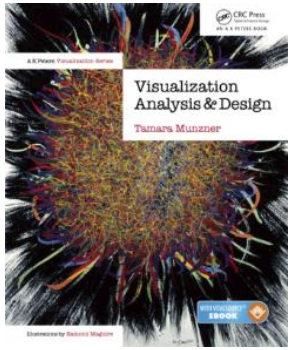
slide by Tamara Munzner

Interaction taxonomy (Munzner)

- How to handle complexity: 1 + 3 strategies

derive new data to show within view

→ *Derive*



Tamara Munzner

change view over time

Manipulate

- Change

- Select

- Navigate

facet across multiple views

Facet

- Juxtapose

- Partition

- Superimpose

reduce items/attributes within single view

Reduce

- Filter

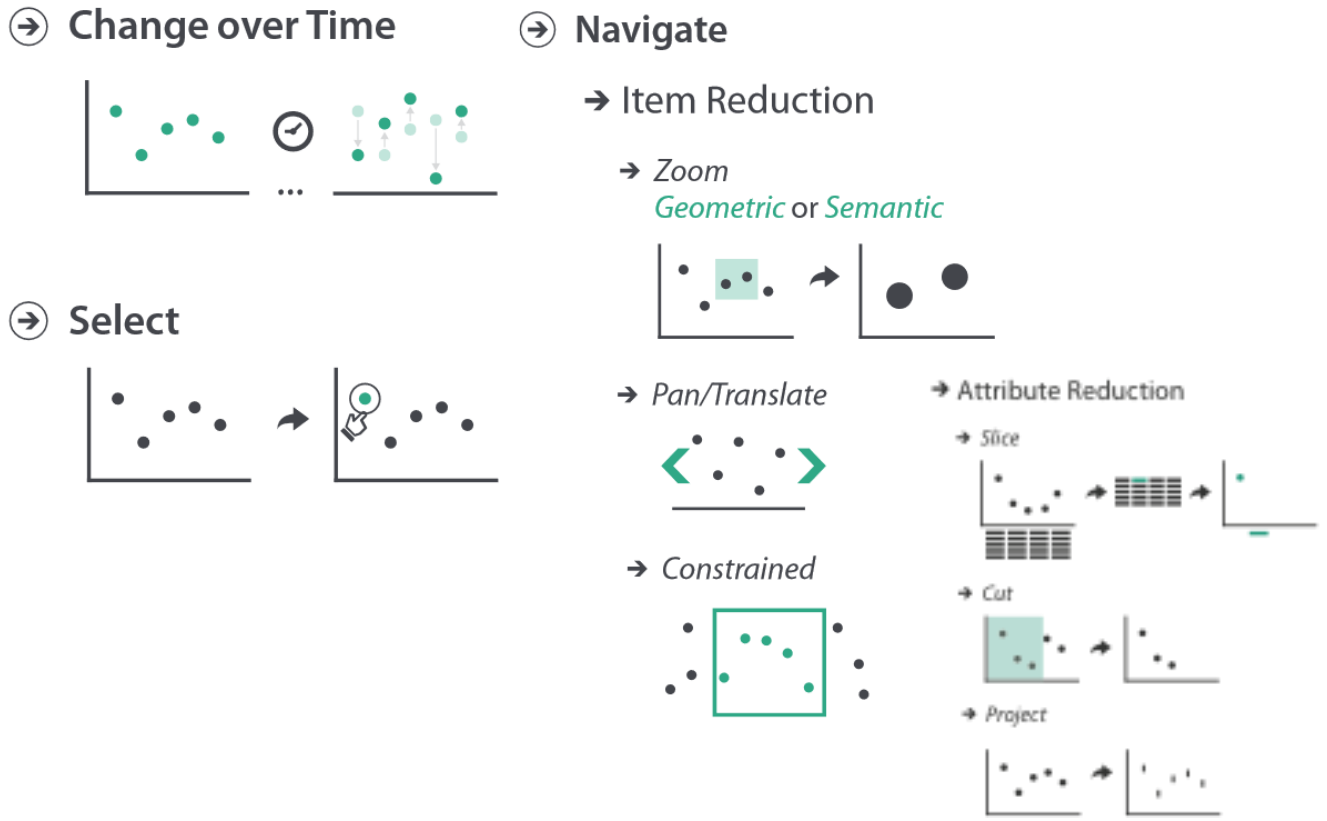
- Aggregate

- Embed

slide by Tamara Munzner

Interaction taxonomy (Munzner)

- **Manipulate**
  - **Change**
  - Select
  - Navigate
- Facet
  - Juxtapose
  - Partition
  - Superimpose
- Reduce
  - Filter
  - Aggregate
  - Embed



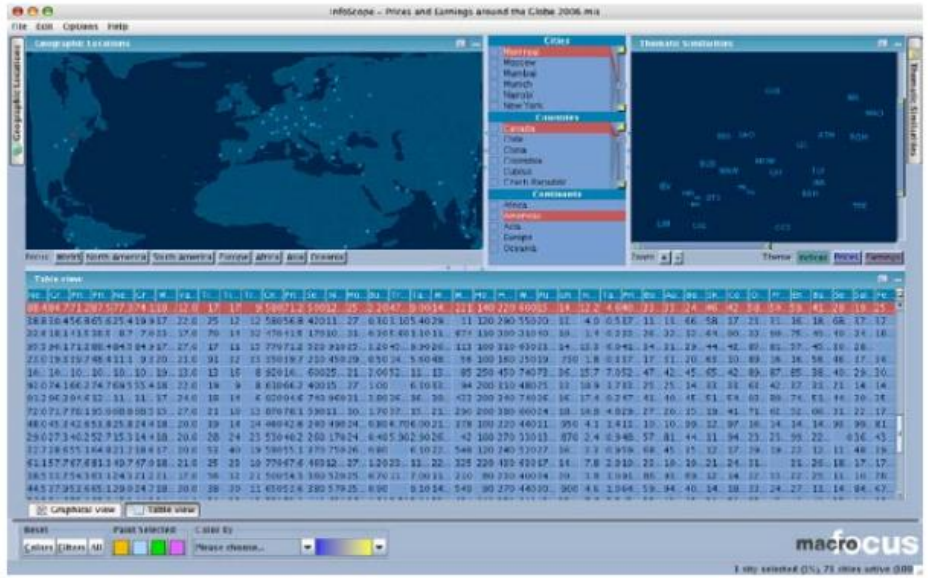
Manipulate > Change over time

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

slide by Tamara Munzner

Manipulate > Change: Re-encode

- Change representation
  - e.g., from histogram to scatterplot



InfoScope https://infoscope.informer.com/

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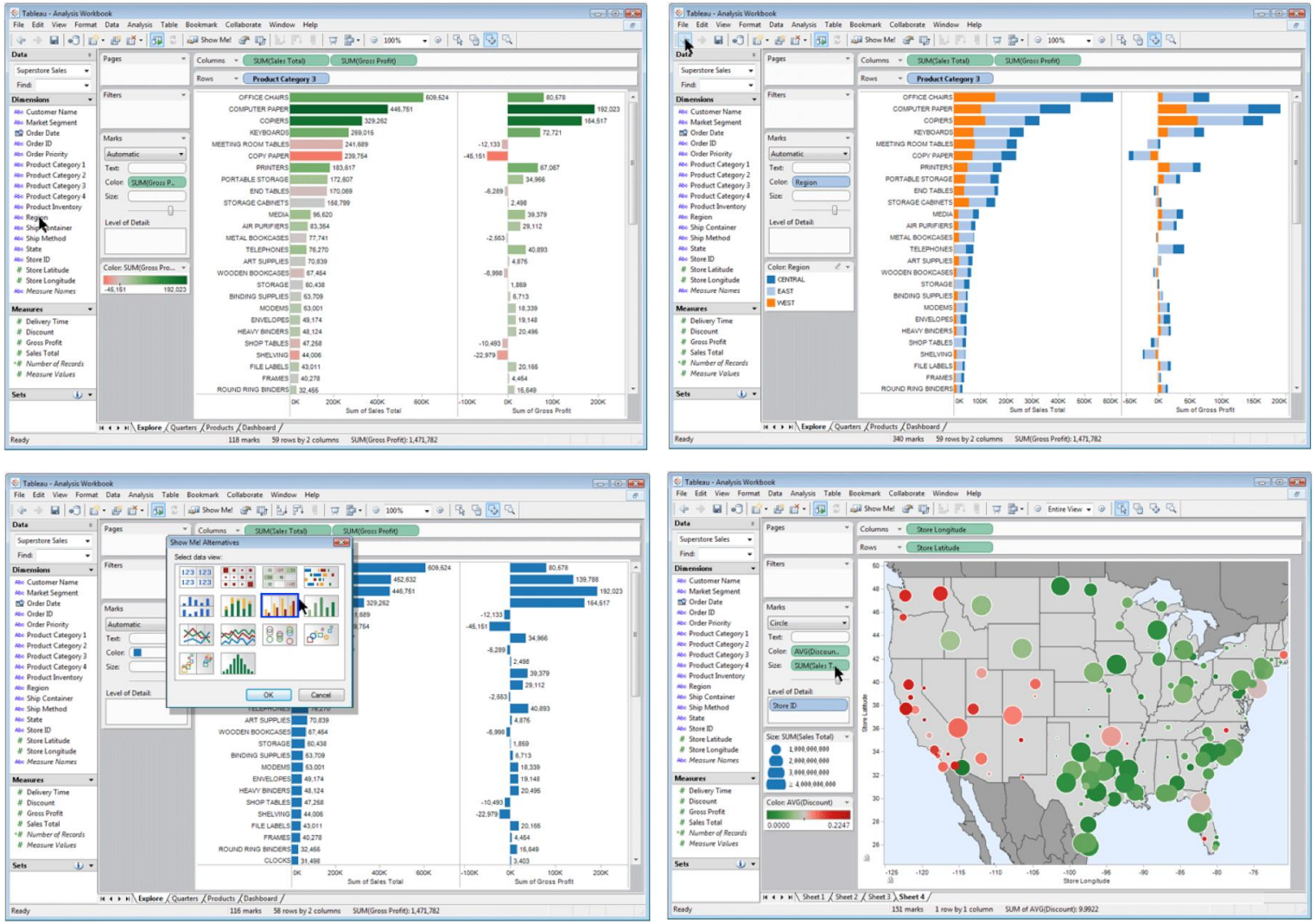
Manipulate > Change: Re-encode



made using Tableau

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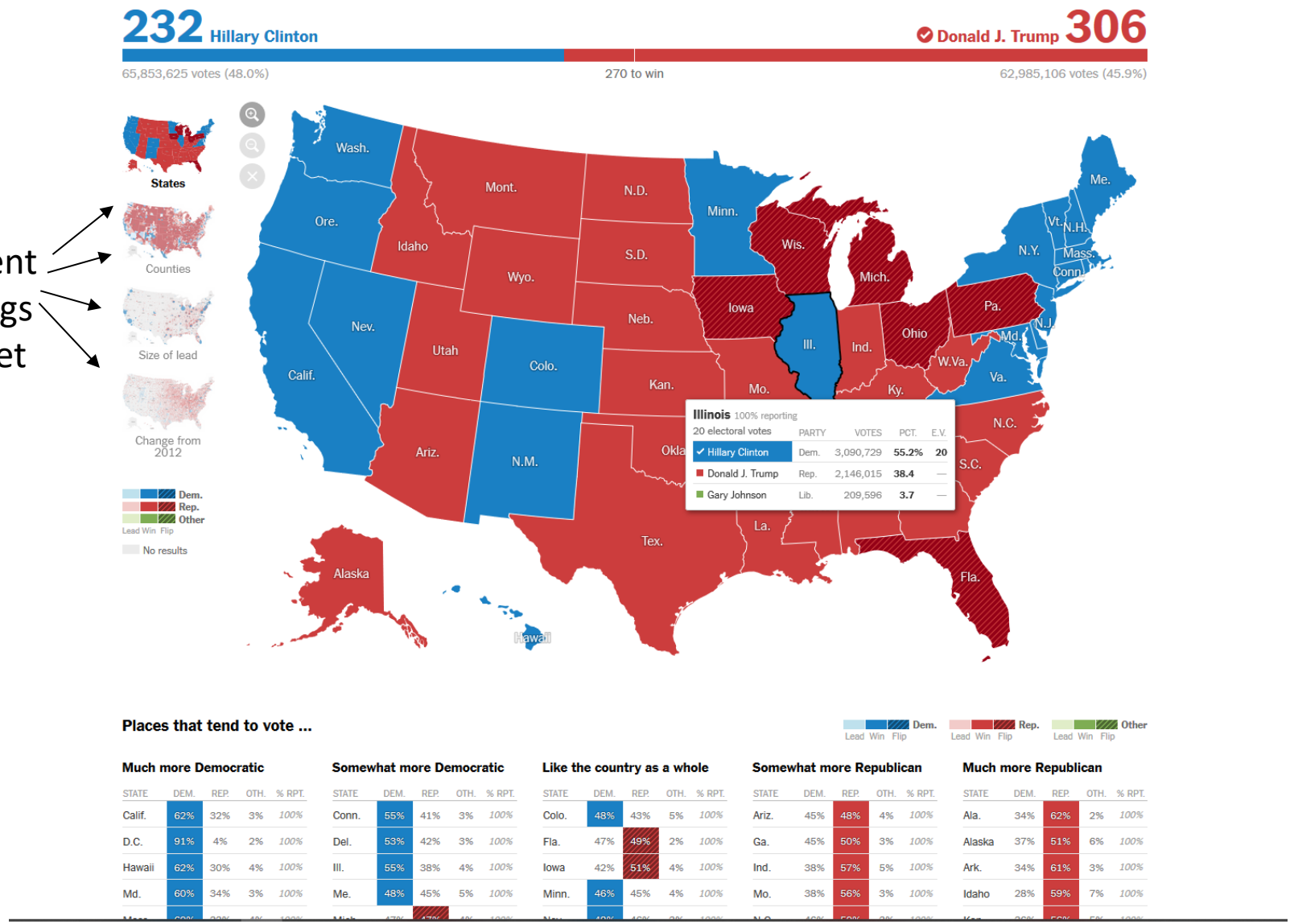
Manipulate > Change: Re-encode

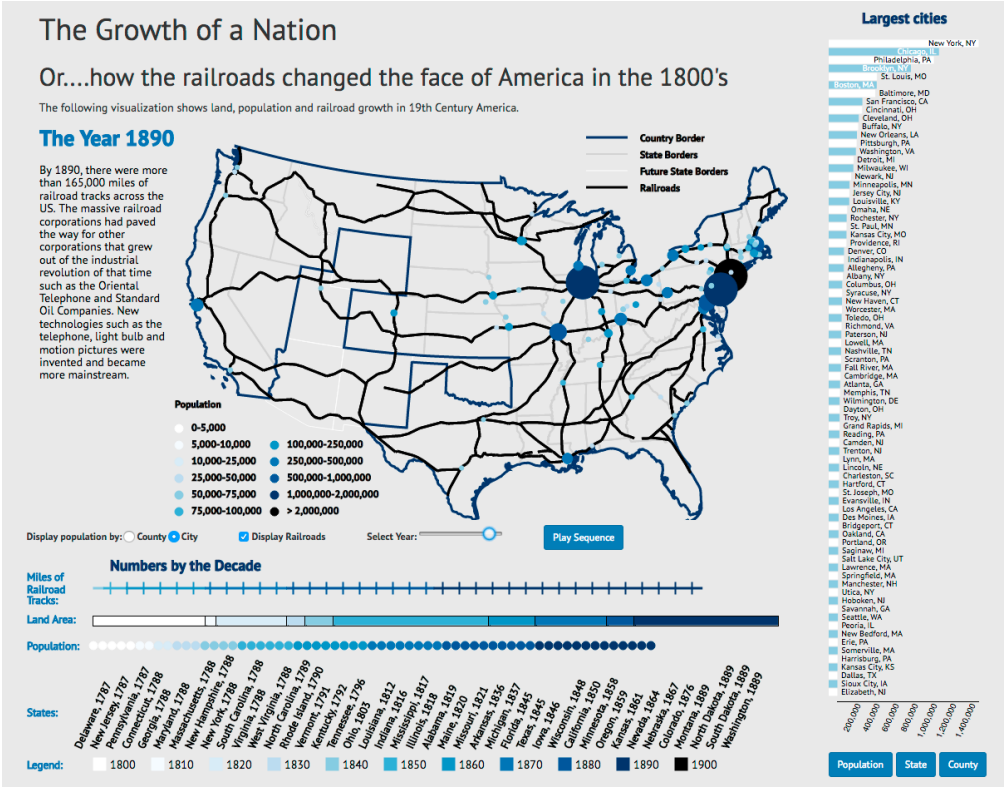
Choose different visual encodings of same dataset



NY Times Interactive

Manipulate > Change: 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

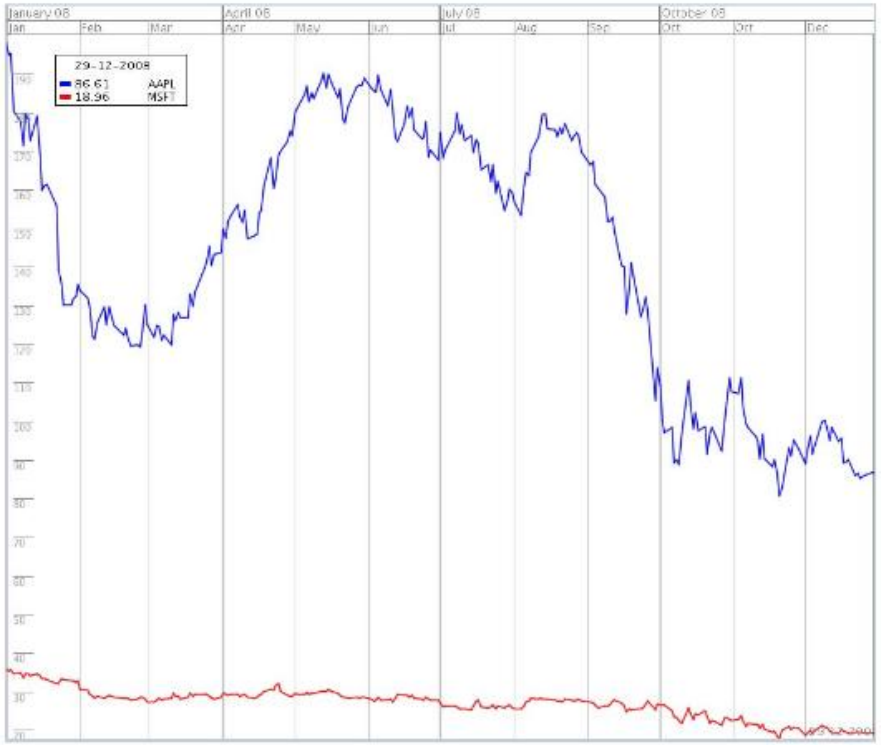


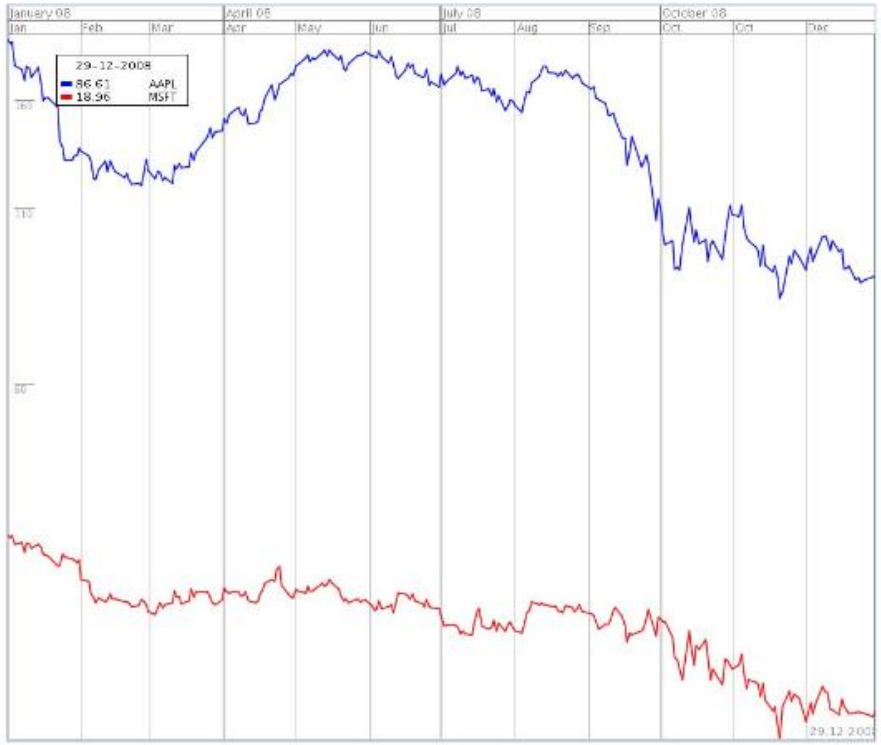
Growth of a Nation http://laurenwood.github.io/

slide by Tamara Munzner, inspired by: Alexander Lex, Utah

Manipulate > Change: Change order/arrangement

- Reconfigure to show a different arrangement
  - e.g., move view position, sorting items in a table, switch scale on axes

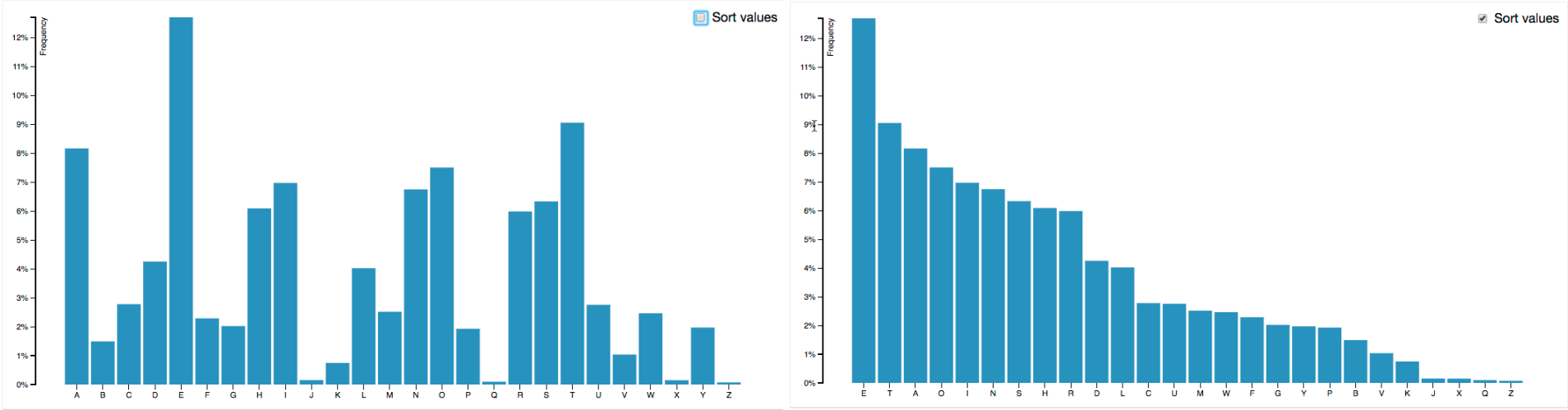




InfoScope https://infoscope.informer.com/

Manipulate > Change: Change order/arrangement

- Reconfigure to show a different arrangement
  - e.g. data-driven reordering of a simple table to find extreme values, trends



Sortable Bar Chart, https://bl.ocks.org/mbostock/3885705

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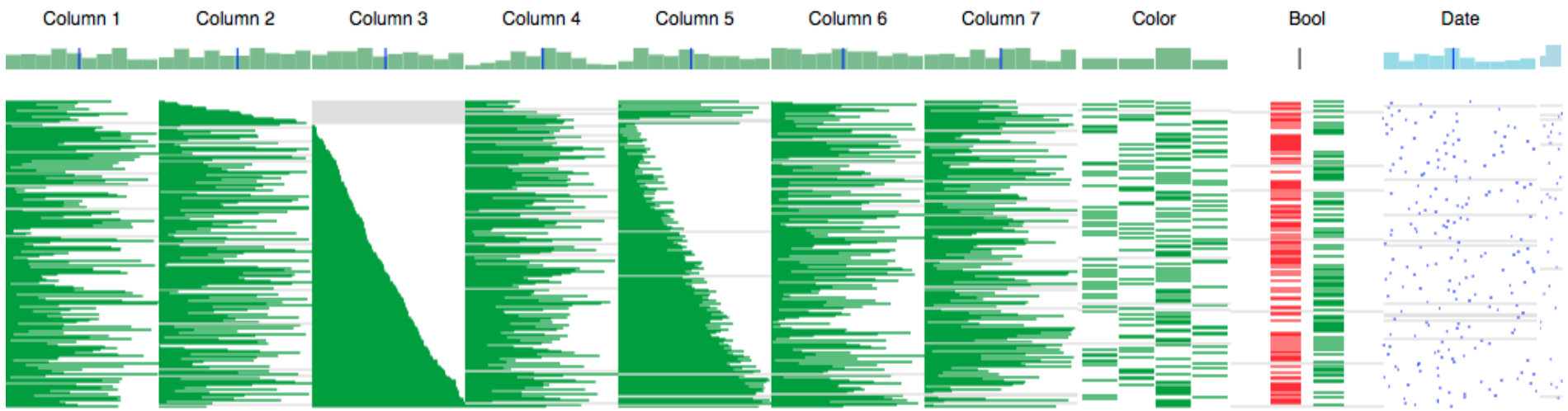
Manipulate > Change: Reorder

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



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

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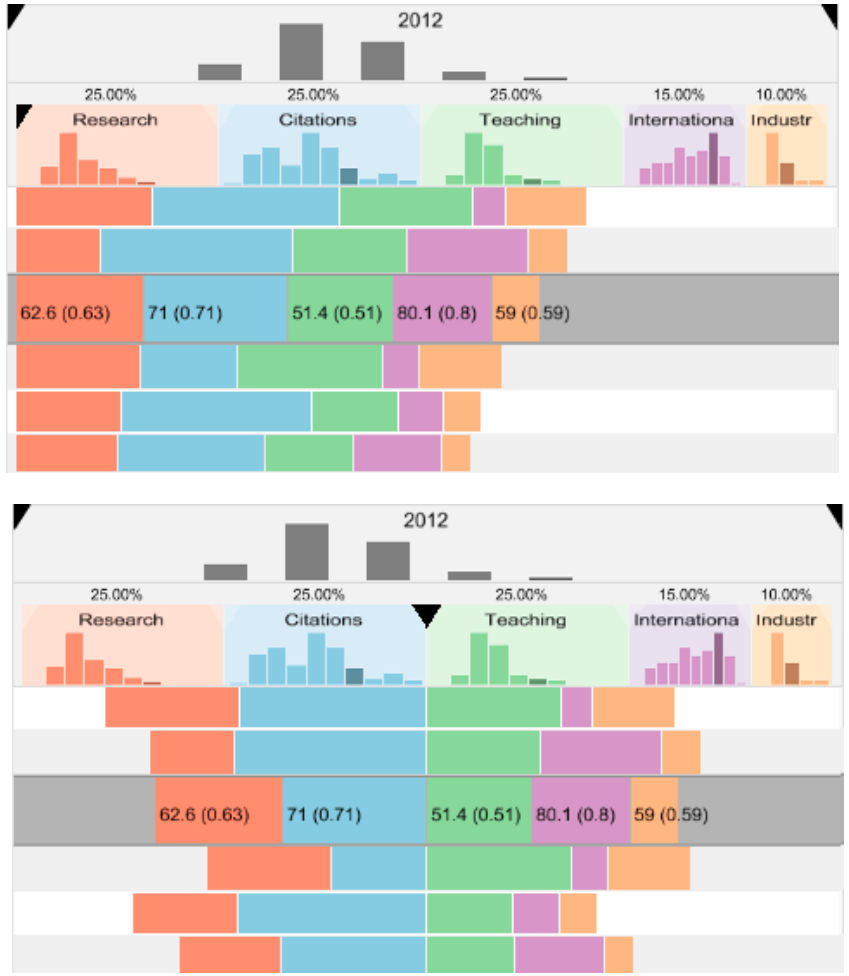
Manipulate > Change: Change alignment

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



Gratzlet al. LineUp: visual analysis of multi-attribute rankings, 2013

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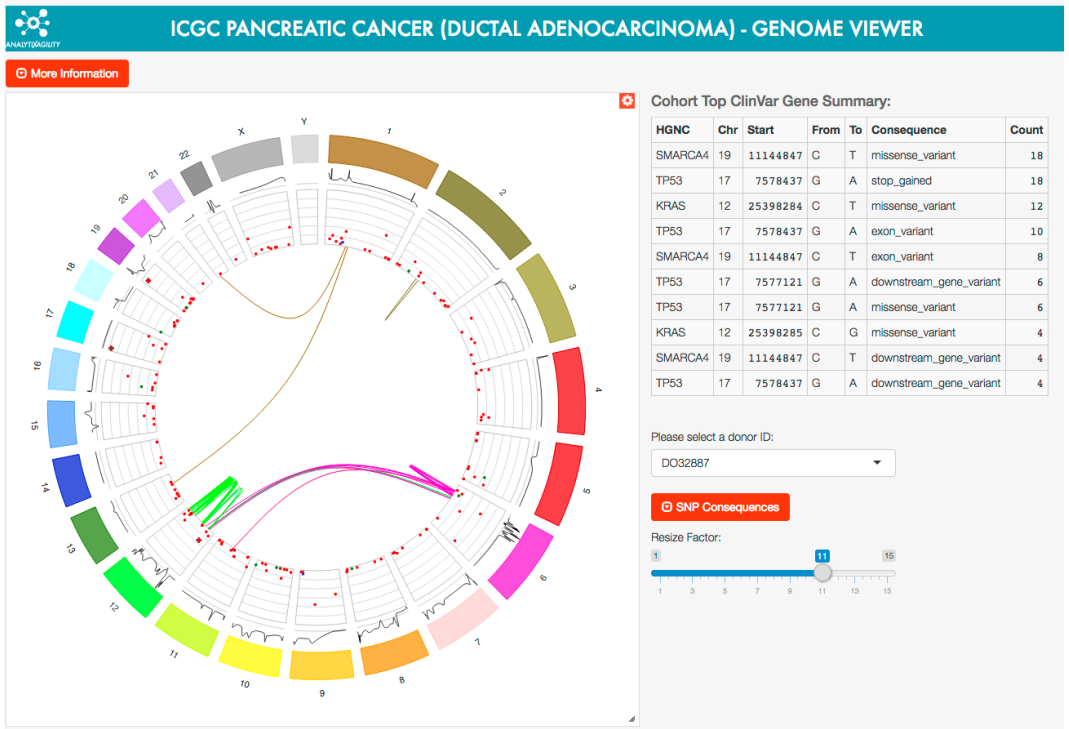
Manipulate > Change

- APGI genome browser (tooling: R/Shiny)
  - tooltip detail on demand on hover
  - expand/contract chromosomes
  - expand/contract control panes



https://gallery.shinyapps.io/genome_browser/

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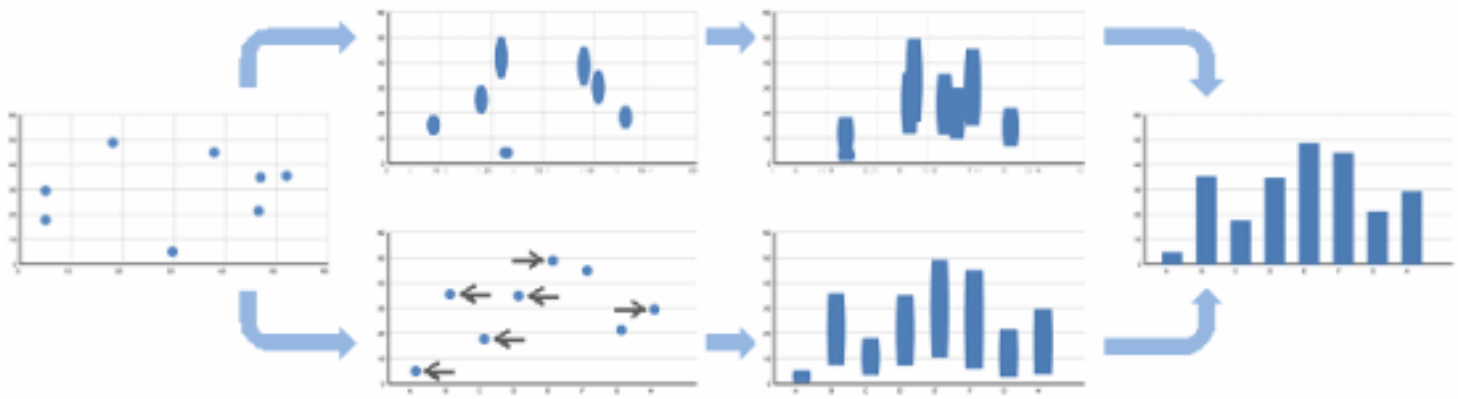
Manipulate > Change: Animated transitions

- smooth interpolation from one state to another
  - alternative to jump cuts, supports item tracking best case for animation
  - staging to reduce cognitive load
- example: animated transitions in statistical data graphics



Animated Transitions in Statistical Data Graphics. Heer and Robertson. IEEE TVCG (Proc InfoVis 2007) 13(6):1240-1247, 2007

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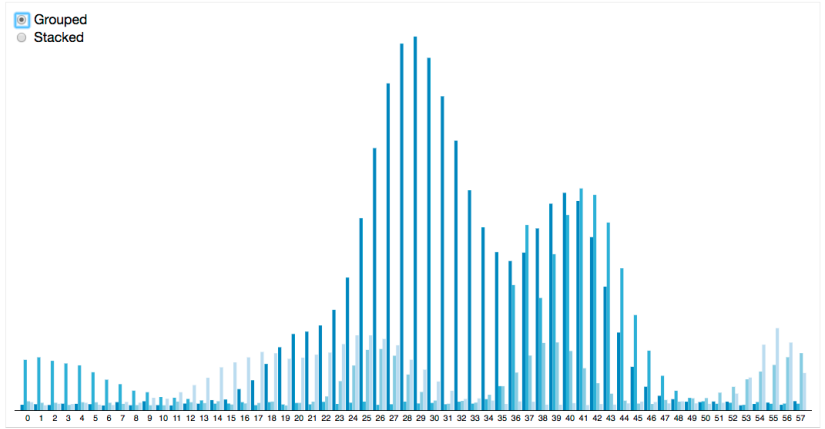
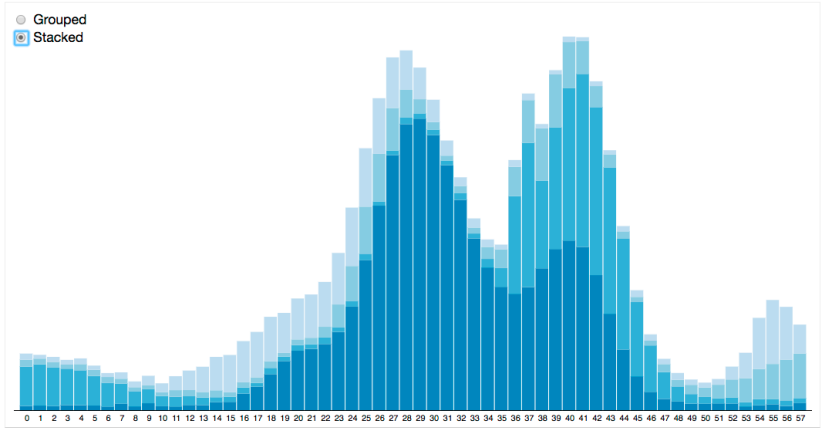


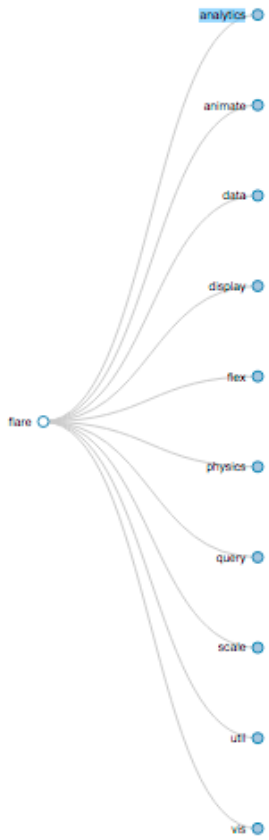


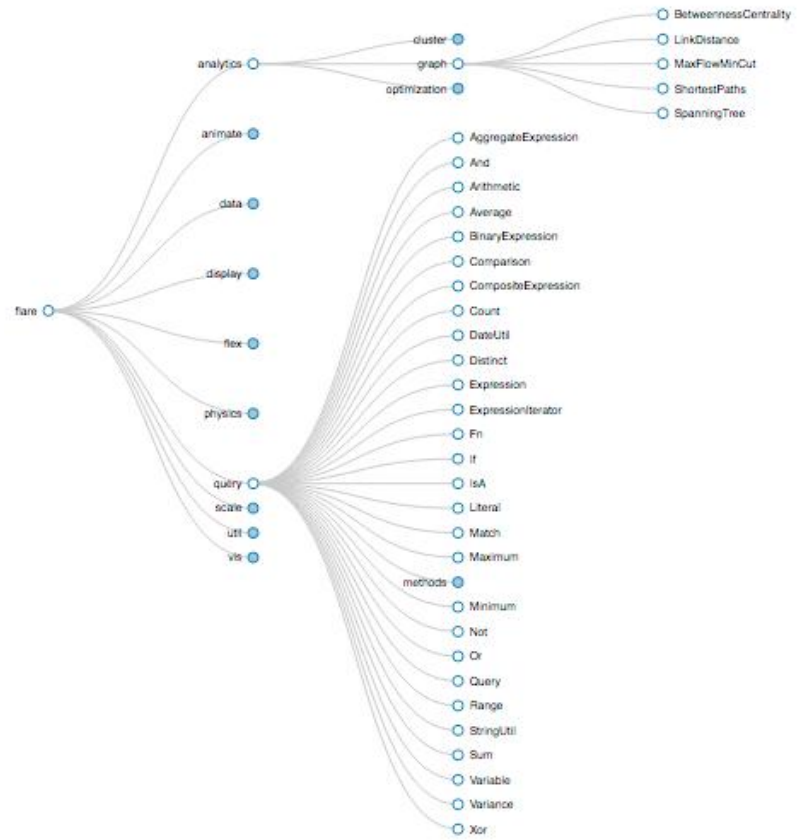
Stacked to Grouped Bars *http://bl.ocks.org/mbostock/3943967*

slide by Tamara Munzner

Manipulate > Change: Animated transition - tree detail

- animated transition
  - network drilldown/rollup



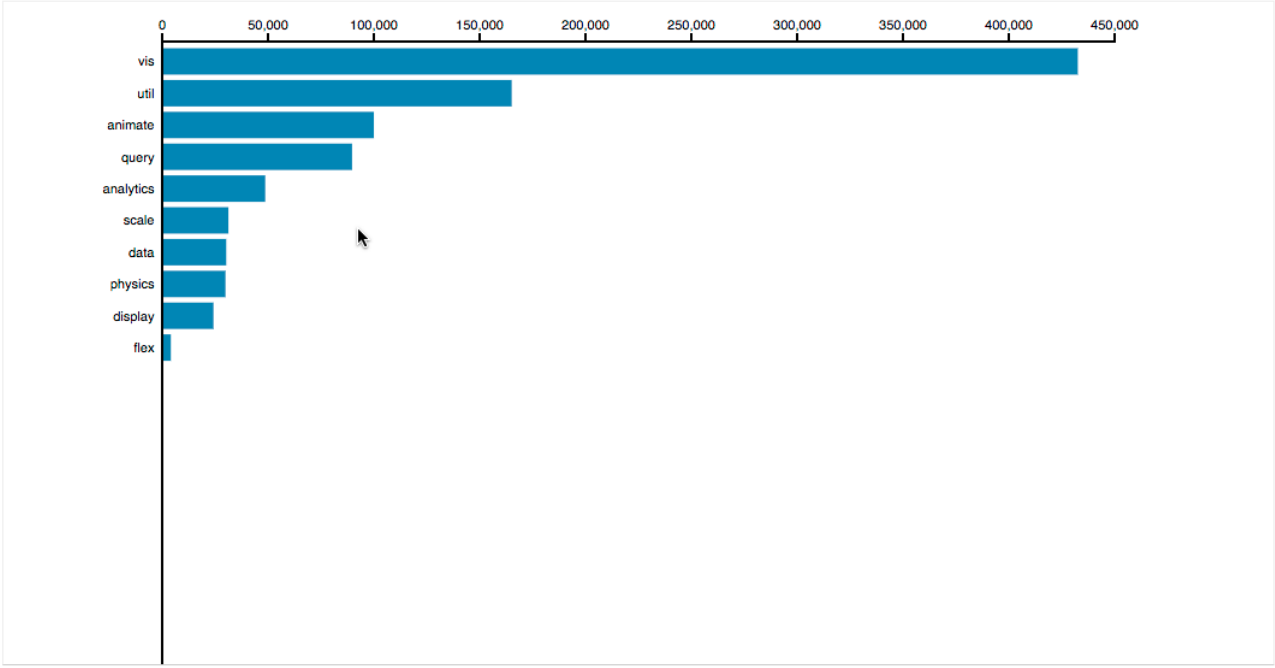


Collapsible Treehttps://bl.ocks.org/mbostock/4339083

slide by Tamara Munzner

Manipulate > Change: Animated transition - bar detail

- example: hierarchical bar chart
  - add detail during transition to new level of detail



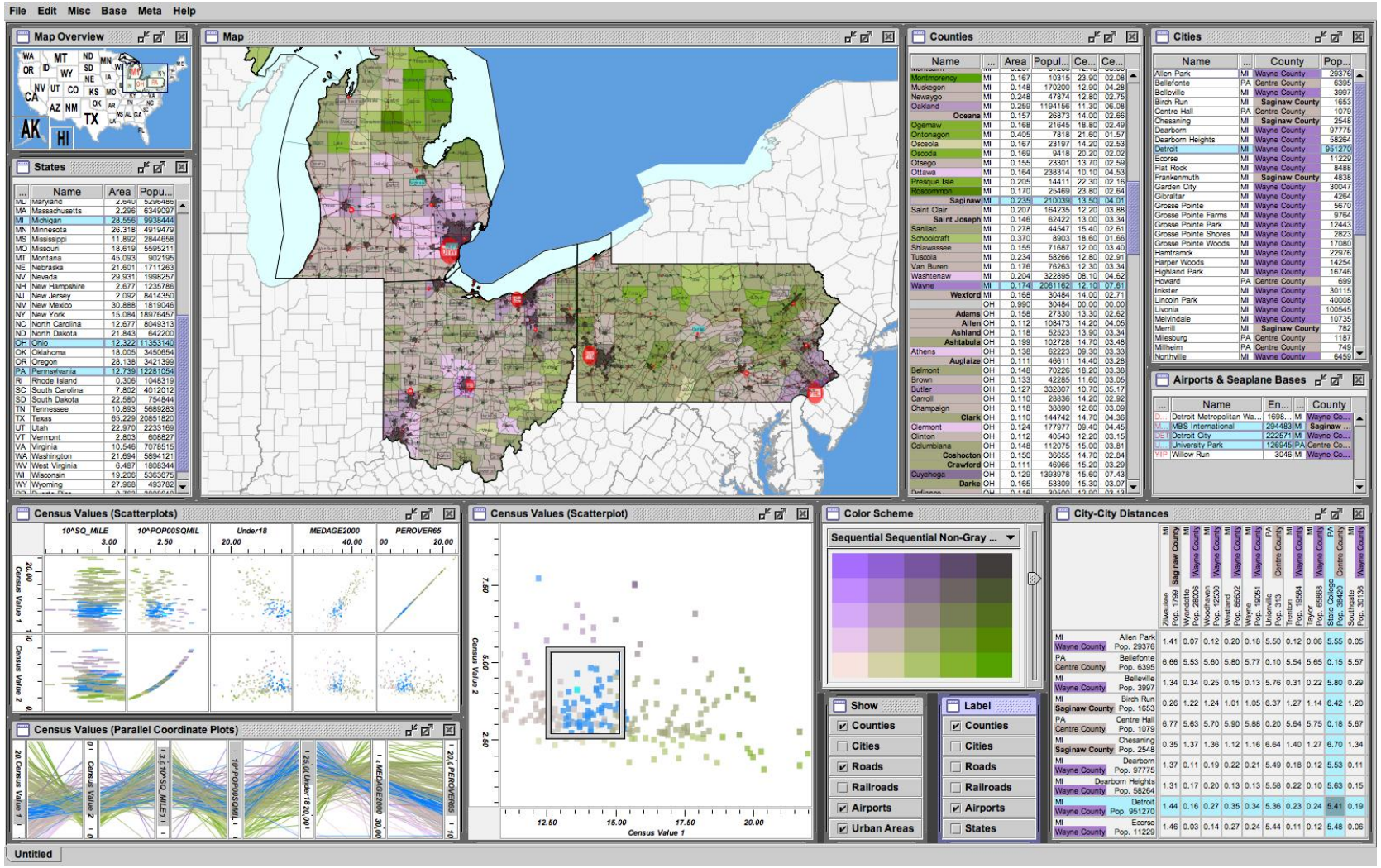
Hierarchical Bar Chart https://bl.ocks.org/mbostock/1283663

slide by Tamara Munzner

Manipulate > Change: multiple views

- Linked views, multiple views, coordinated views, coupled views
- Vary:
  - what is shown
  - how it is shown
- per view

Manipulate > Change: multiple, coordinated views



Chris Weaver. "Patterns of Coordination in Improvise Visualizations". *Proc. of the IS&T/SPIE Conf. on Visualization and Data Analysis*, San Jose, CA, January 2007.

Manipulate > Change: multiple views

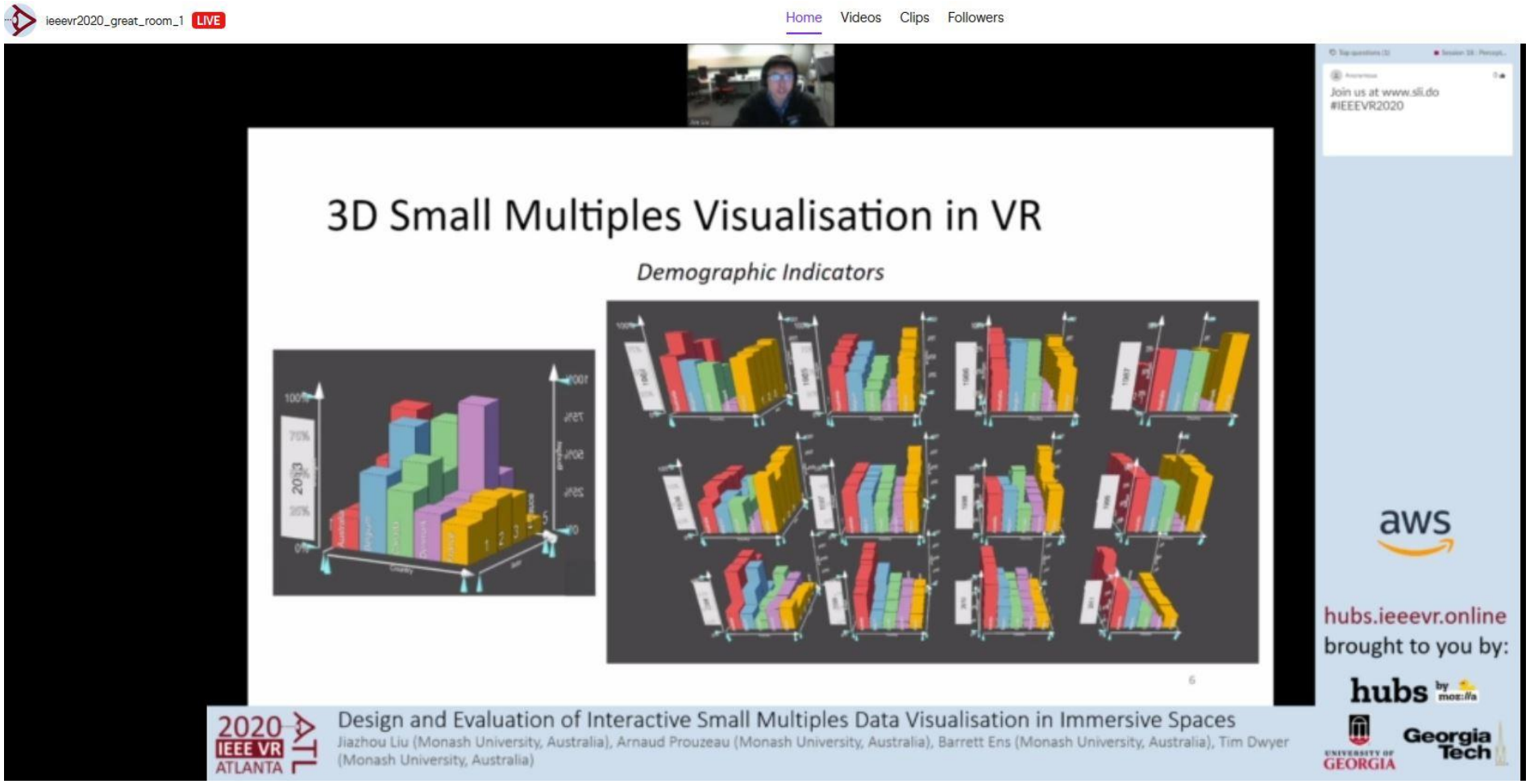
- Small multiples: same visual encoding, shared navigation

Jim Vallandingham

http://vallandingham.me/small_mults_talk/

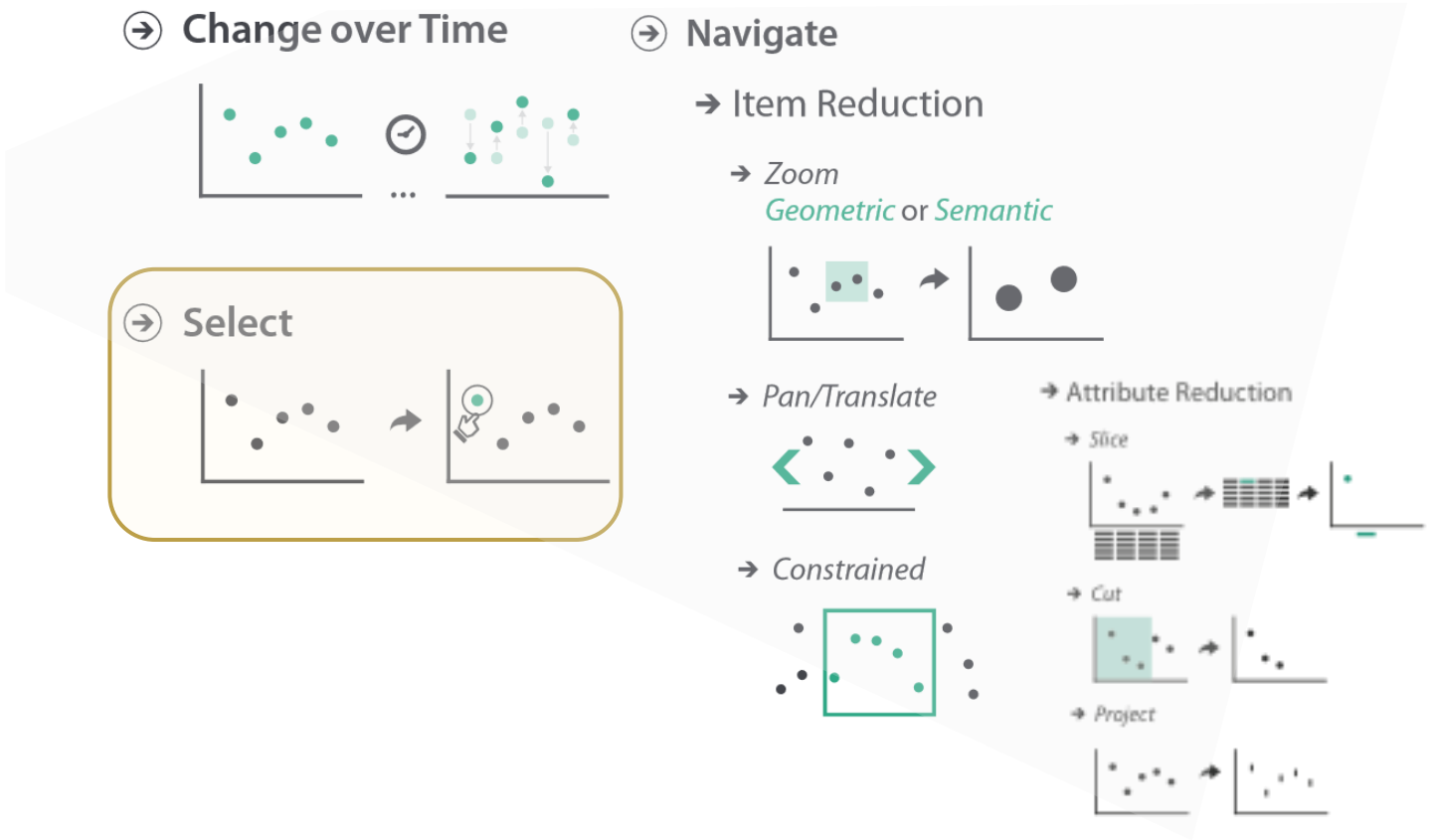
Manipulate > Change: multiple views

- Small multiples: same visual encoding, shared navigation



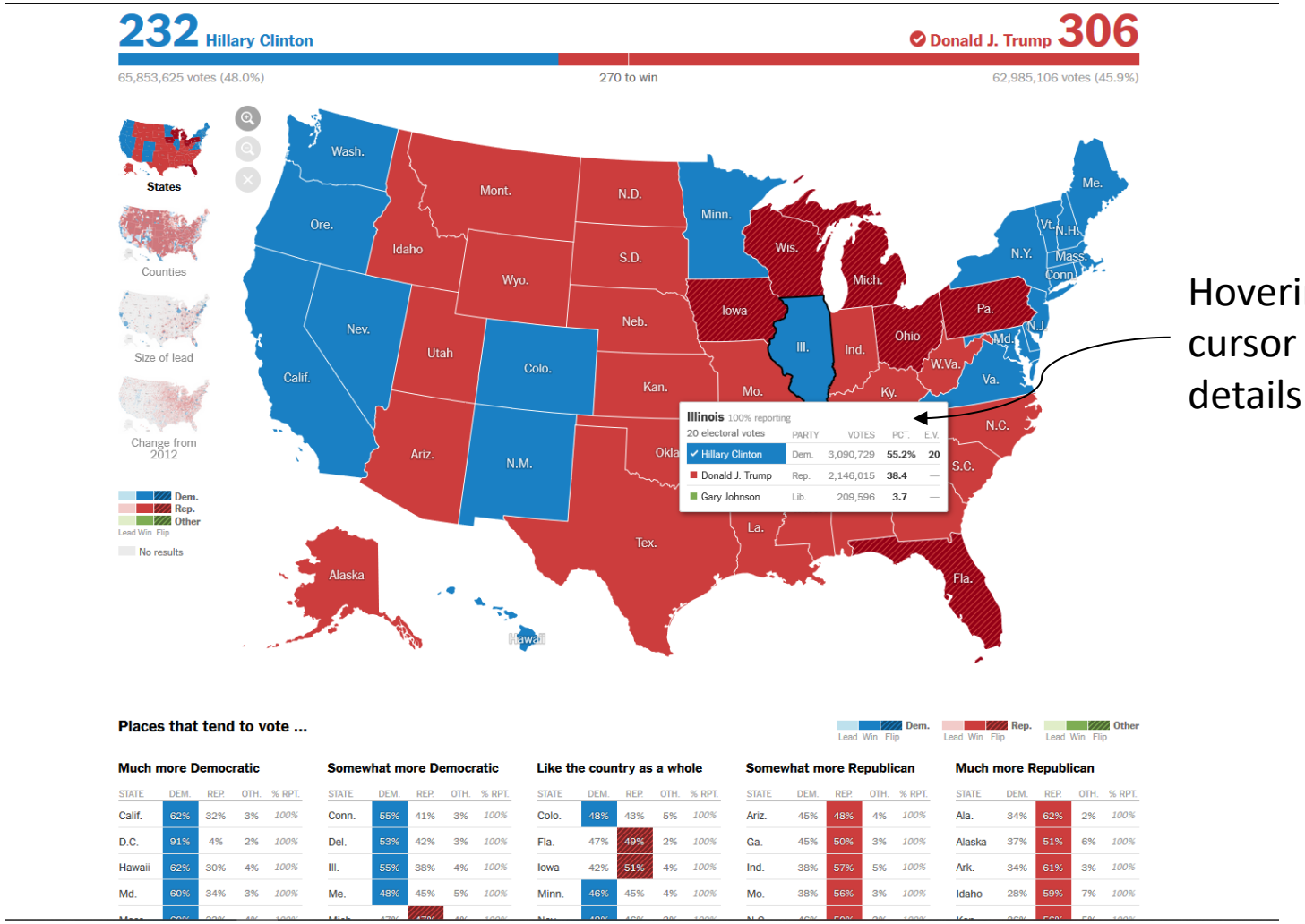
Interaction taxonomy (Munzner)

- **Manipulate**
  - Change
  - **Select**
  - Navigate
- Facet
  - Juxtapose
  - Partition
  - Superimpose
- Reduce
  - Filter
  - Aggregate
  - Embed



Indicate (show me where I am pointing at)

- Visual Feedback, pop-up tooltips (mouse over)



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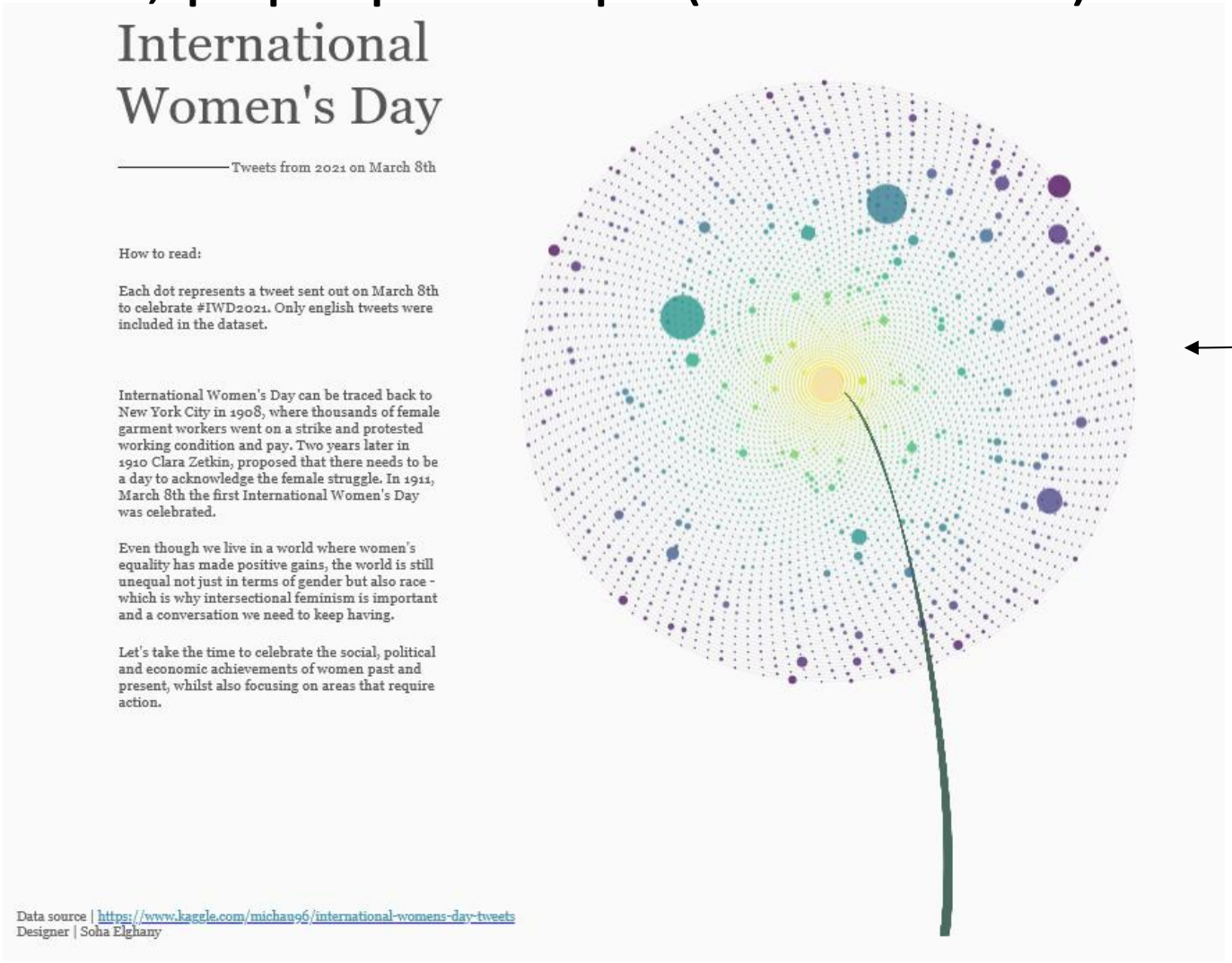

Hovering mouse cursor over each dot brings up details of item

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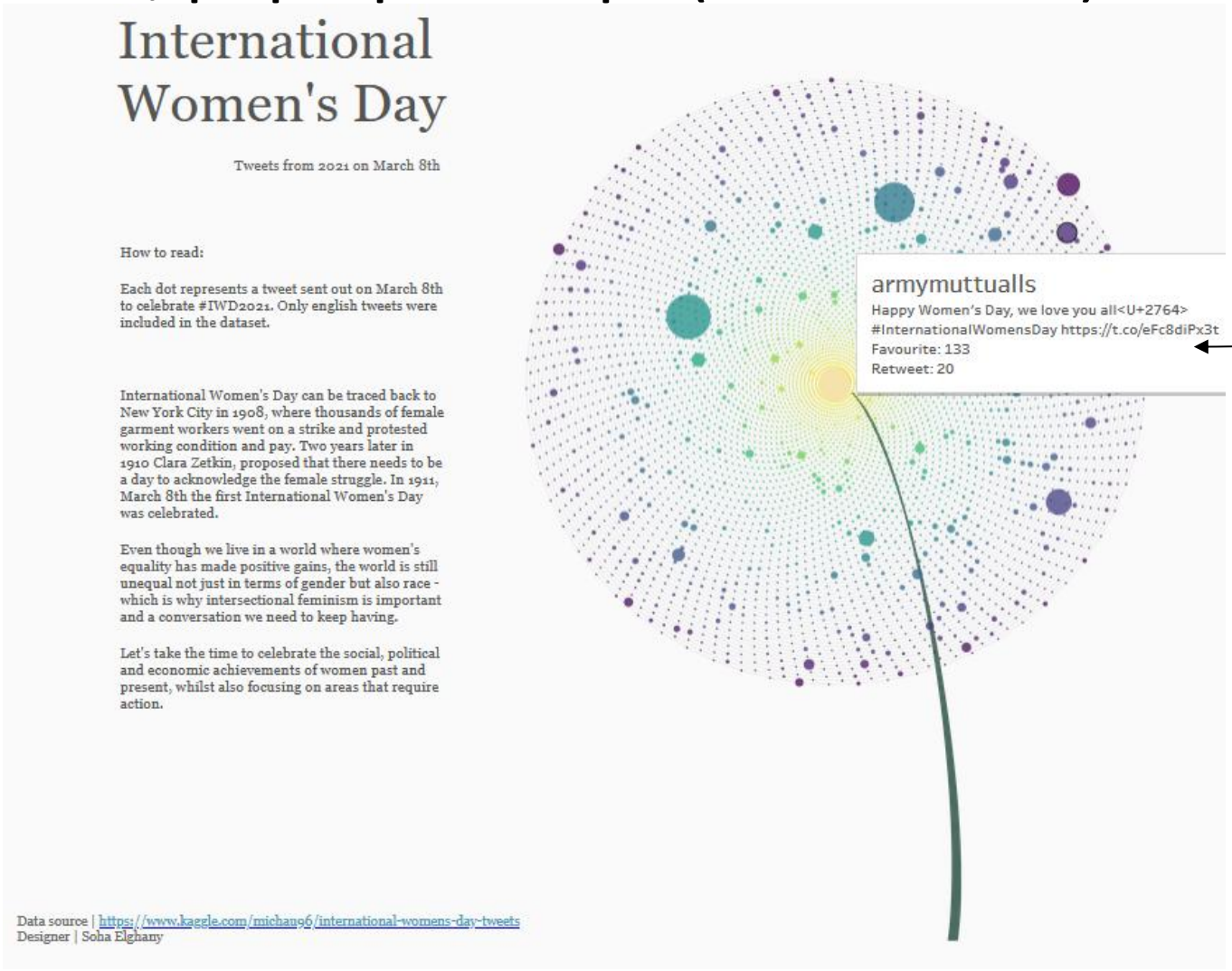
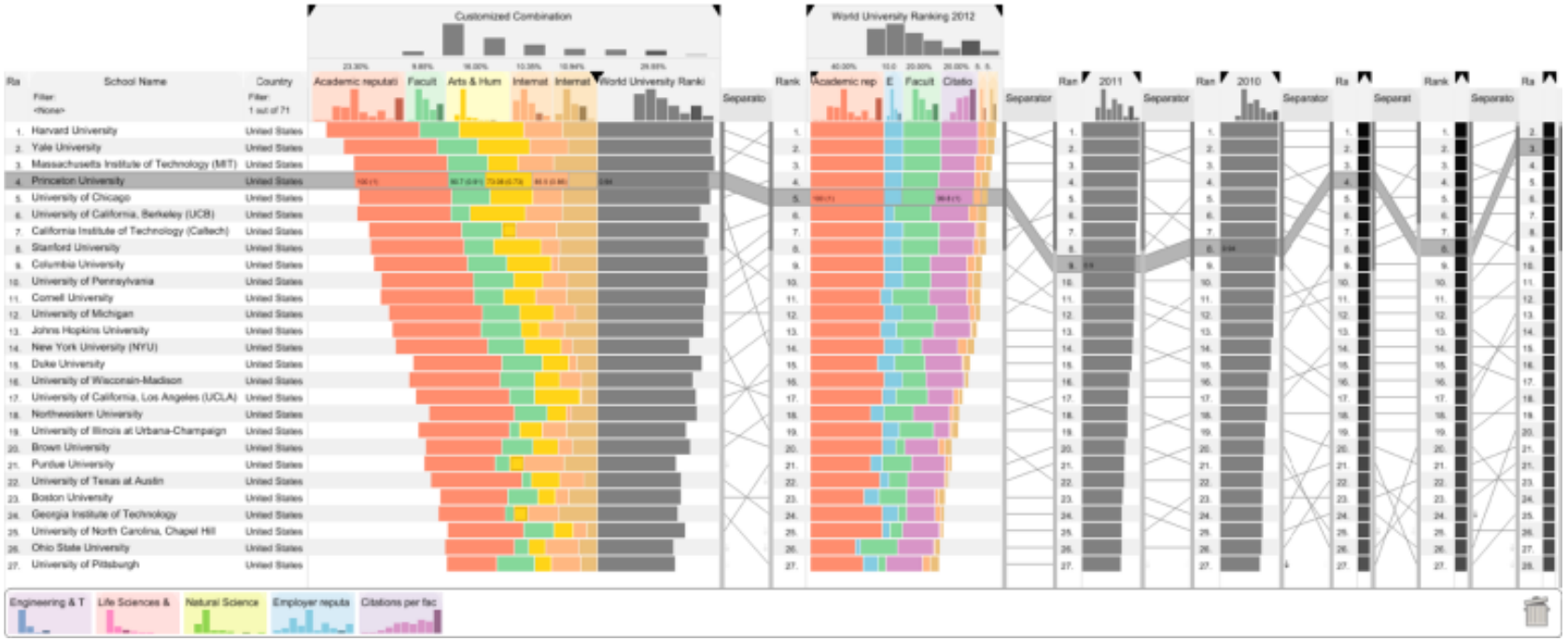


Hovering mouse cursor over each dot brings up details of item

Manipulate > Select: mark something as interesting

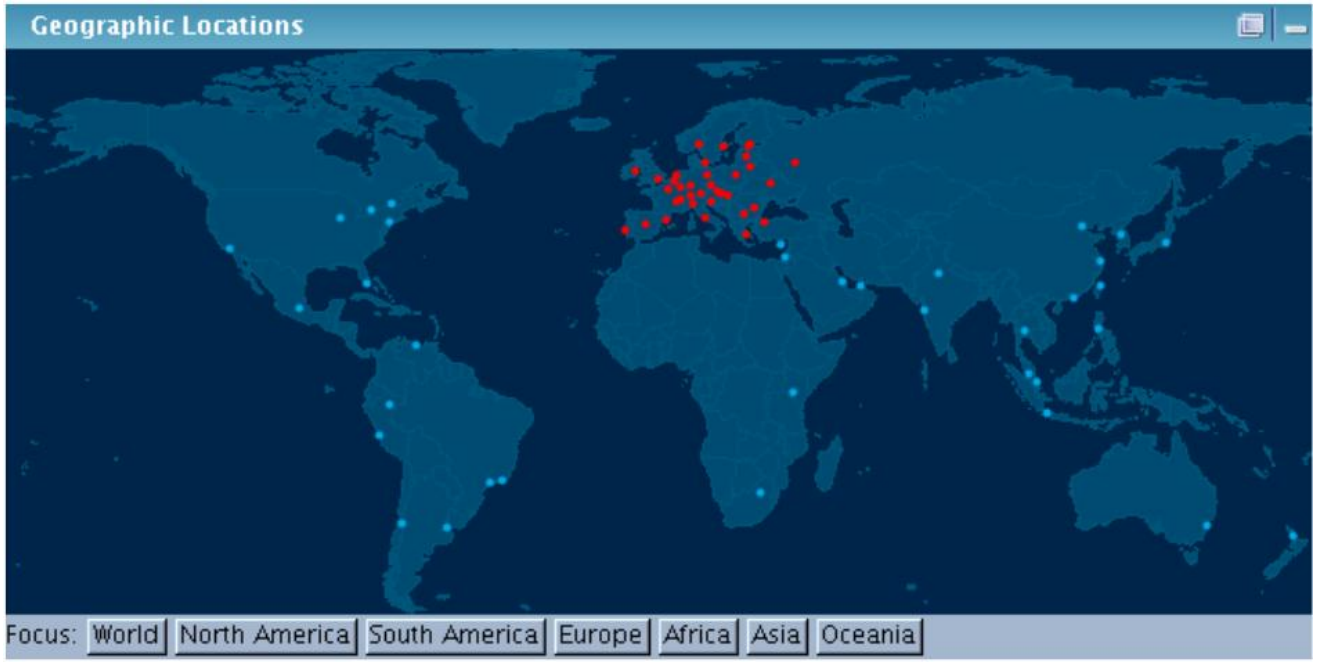
- Basic operation for all interaction
- Point + click (or double click) vs hover
- Change: color, border, or link items



Gratzlet al. LineUp: visual analysis of multi-attribute rankings, 2013

Manipulate > Select: mark something as interesting

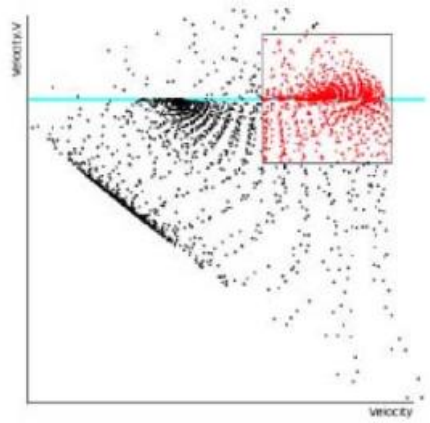
- Region selection: point + click + drag
  - Highlights a certain subset



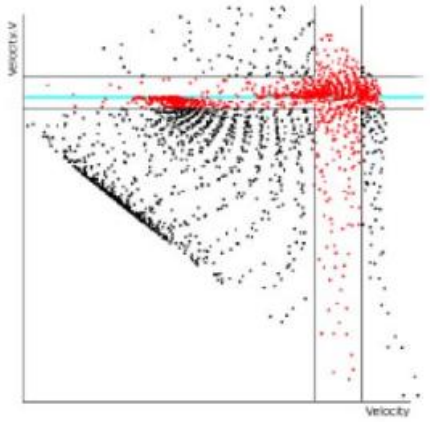
InfoScope https://infoscope.informer.com/

Manipulate > Select: Brushing

- More complex than simple selection
- Brush is an interactive interface tool to select /mark subsets of data in a single view
  - e.g. by sweeping a virtual brush across items of interest
- Usually used to visually filter data (via highlighting)
- Additional manipulation / operations may be performed on the subsets
  - e.g. masking, magnification, labeling etc.
- Different types of brushes (Hauser et al. 2002)
  - e.g. simple brush, composite brush, angular brushing, smooth brushing



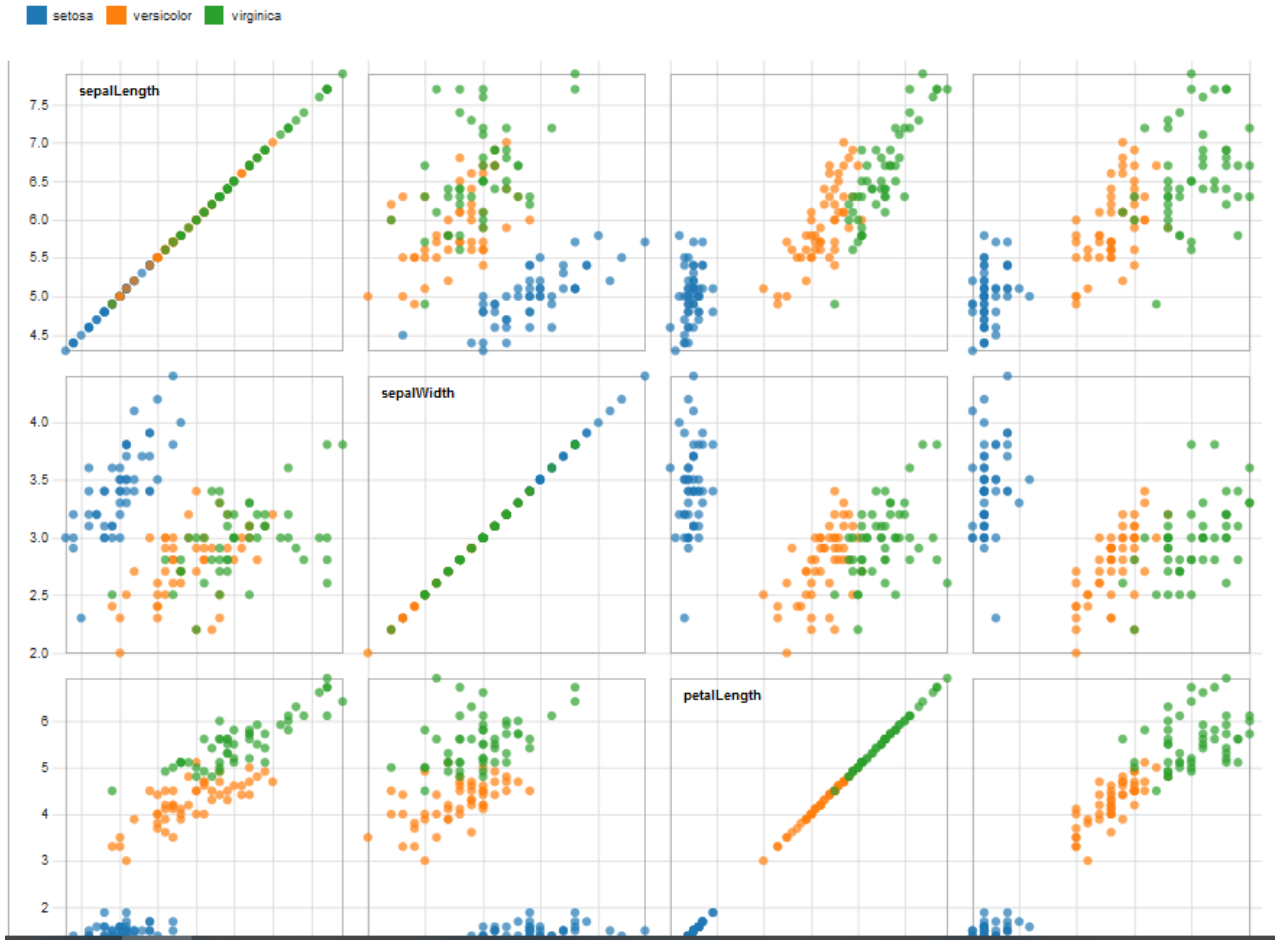
AND-brush



OR-brush

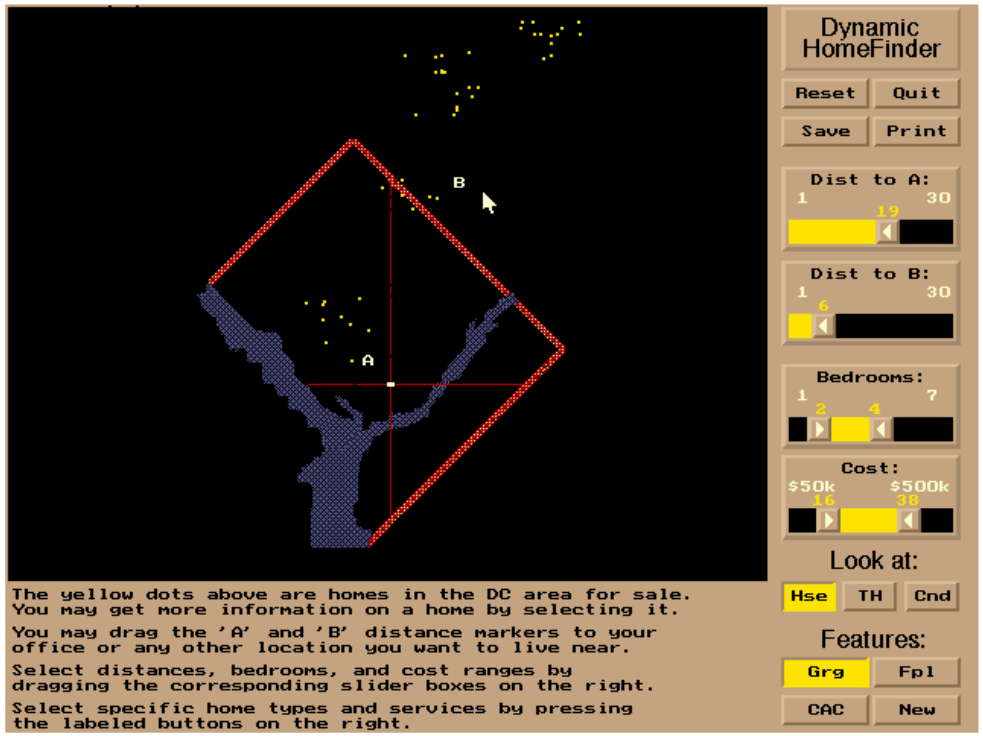
Manipulate > Select: Brushing and linking

- Common interaction technique
- Select items in one view, highlight in other views



Manipulate > Select: Dynamic query

- Selection/filtering by pointing (not typing)
- Immediate and continuous display of results
- Promote exploration

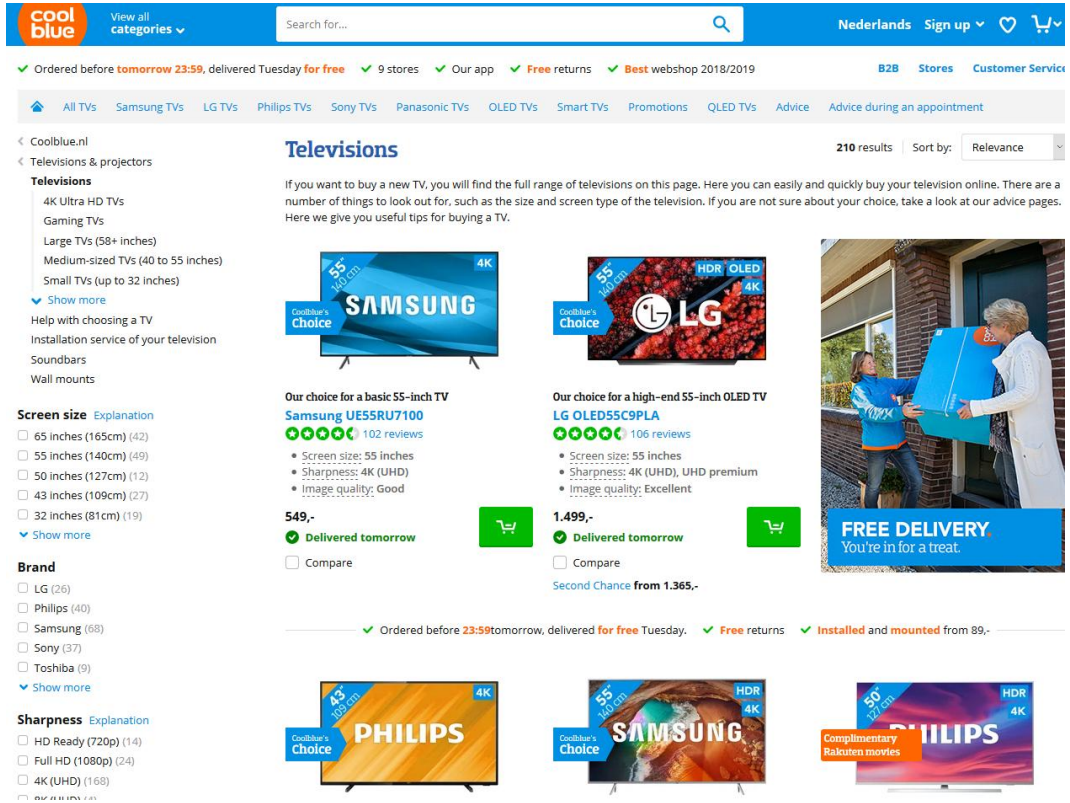


Williamson & Shneidermann:
Dynamic HomeFinder, 1992

http://www.youtube.com/watch?v=5X8XY9430fM

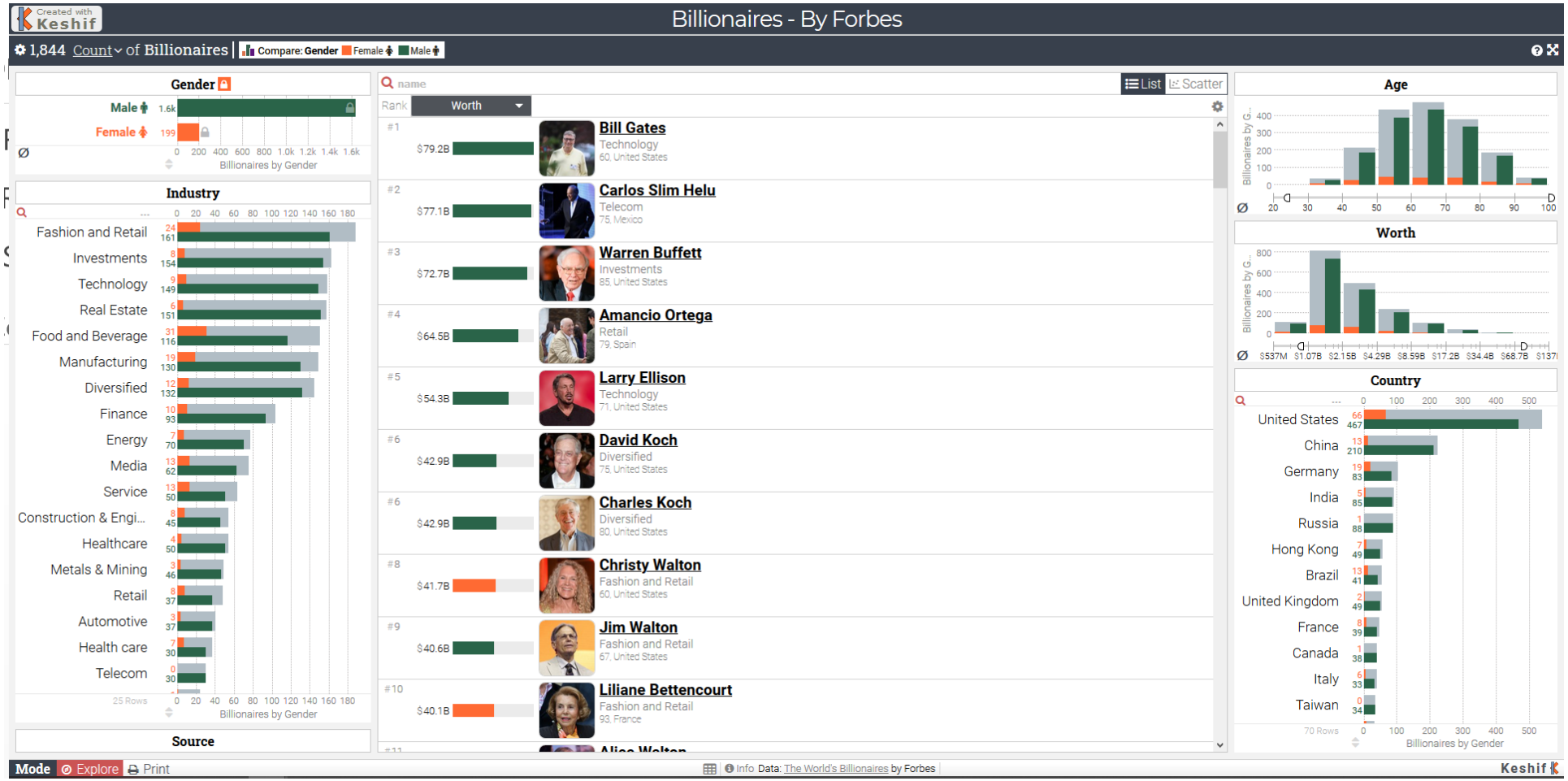
Manipulate > Select: Facetted Search

- Selection/filtering by pointing (not typing)
- Immediate and continuous display of results
- Promote exploration
- Ubiquitous!



Manipulate > Select

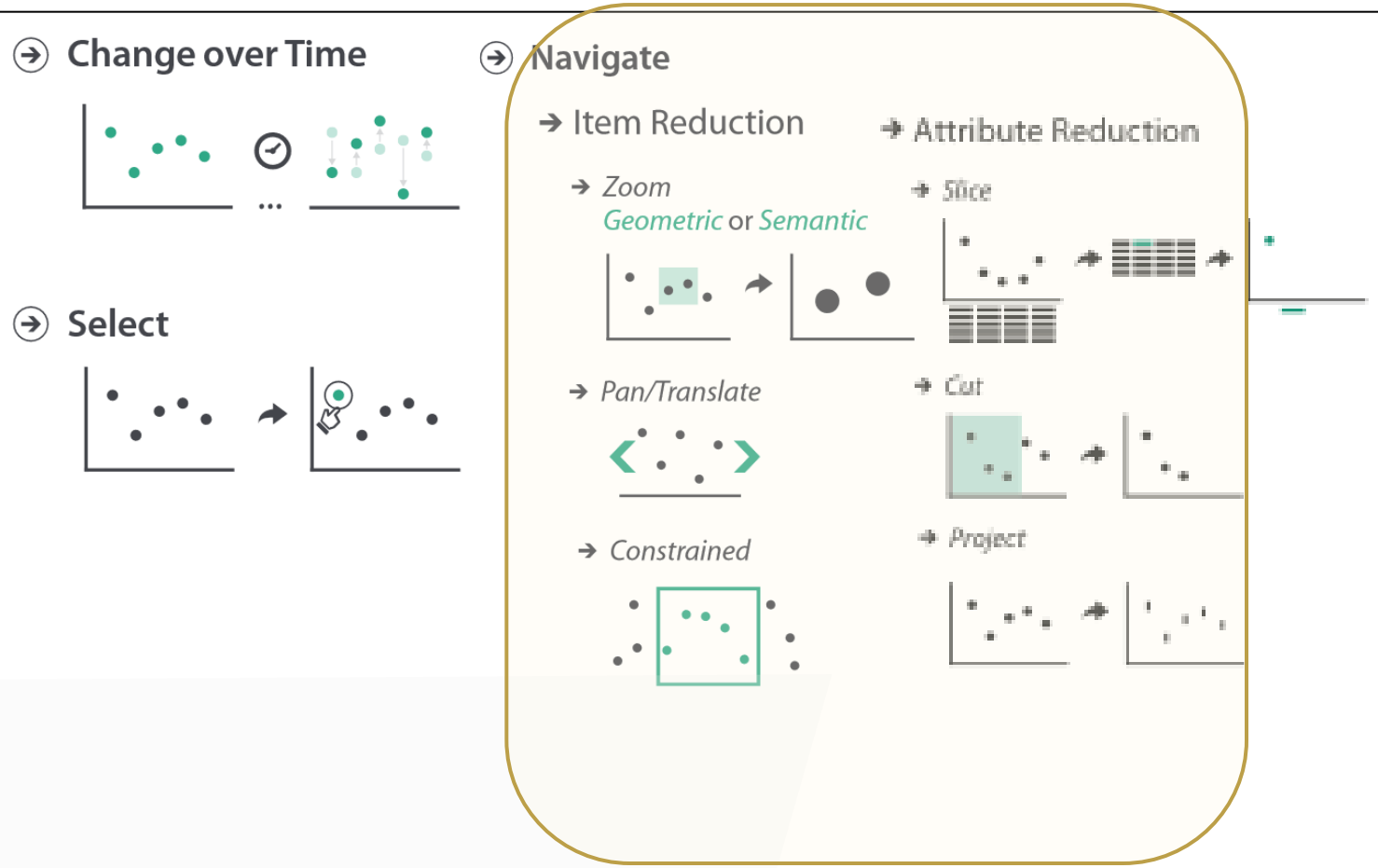
- Combine selection, brushing, filtering



Keshif.me (M. Adil Yalçın et al.)

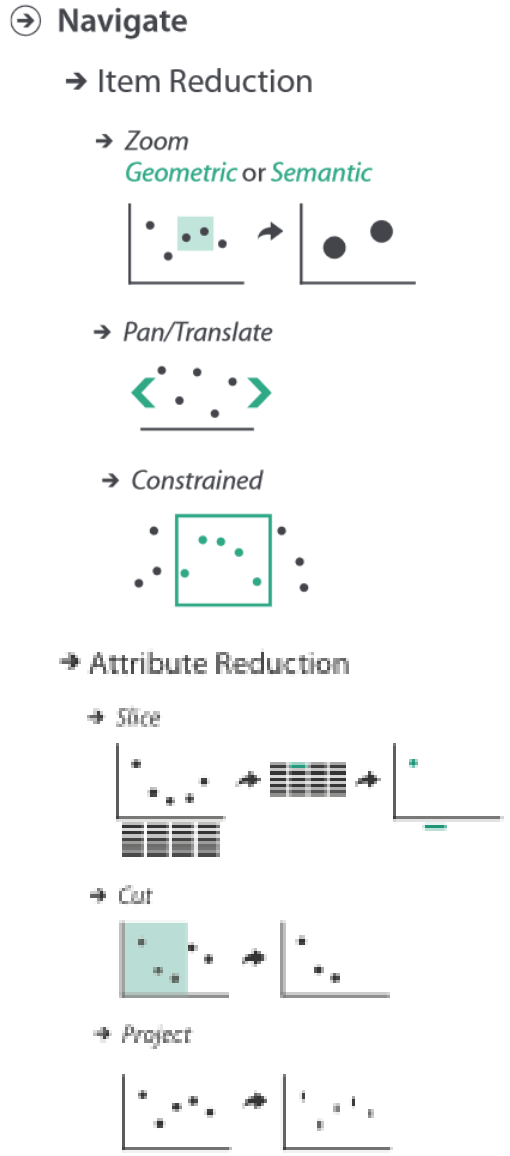
Interaction taxonomy (Munzner)

- **Manipulate**
  - Change
  - Select
  - **Navigate**
- Facet
  - Juxtapose
  - Partition
  - Superimpose
- Reduce
  - Filter
  - Aggregate
  - Embed



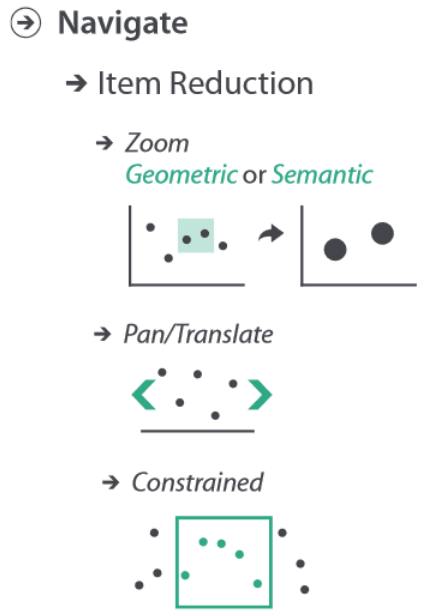
Manipulate > Navigate

- Item reduction
  - Zoom
  - Pan
  - Constrained
- Attribute reduction
  - Slice
  - Cut
  - Project



Manipulate > Navigate: Changing viewpoint/visibility

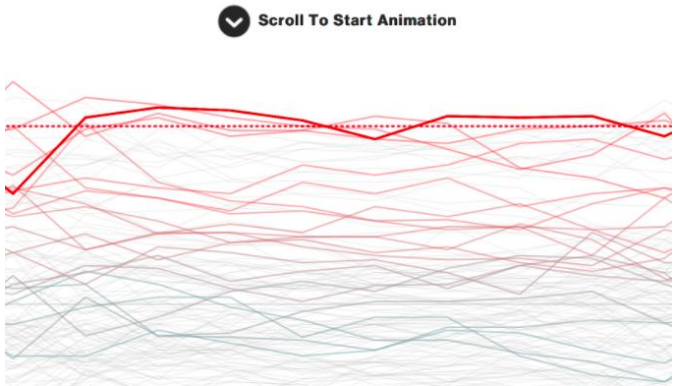
- change viewpoint
  - changes which items are visible within view
- camera metaphor
  - pan/translate/scroll
    - move up/down/sideways
  - rotate/spin
    - typically in 3D
  - zoom in/out
    - enlarge/shrink world == move camera closer/further
    - geometric zoom: standard, like moving physical object



slide by Tamara Munzner

Manipulate > Navigate: Scrollytelling

- Interaction by scrolling (panning down to navigate page)
- 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



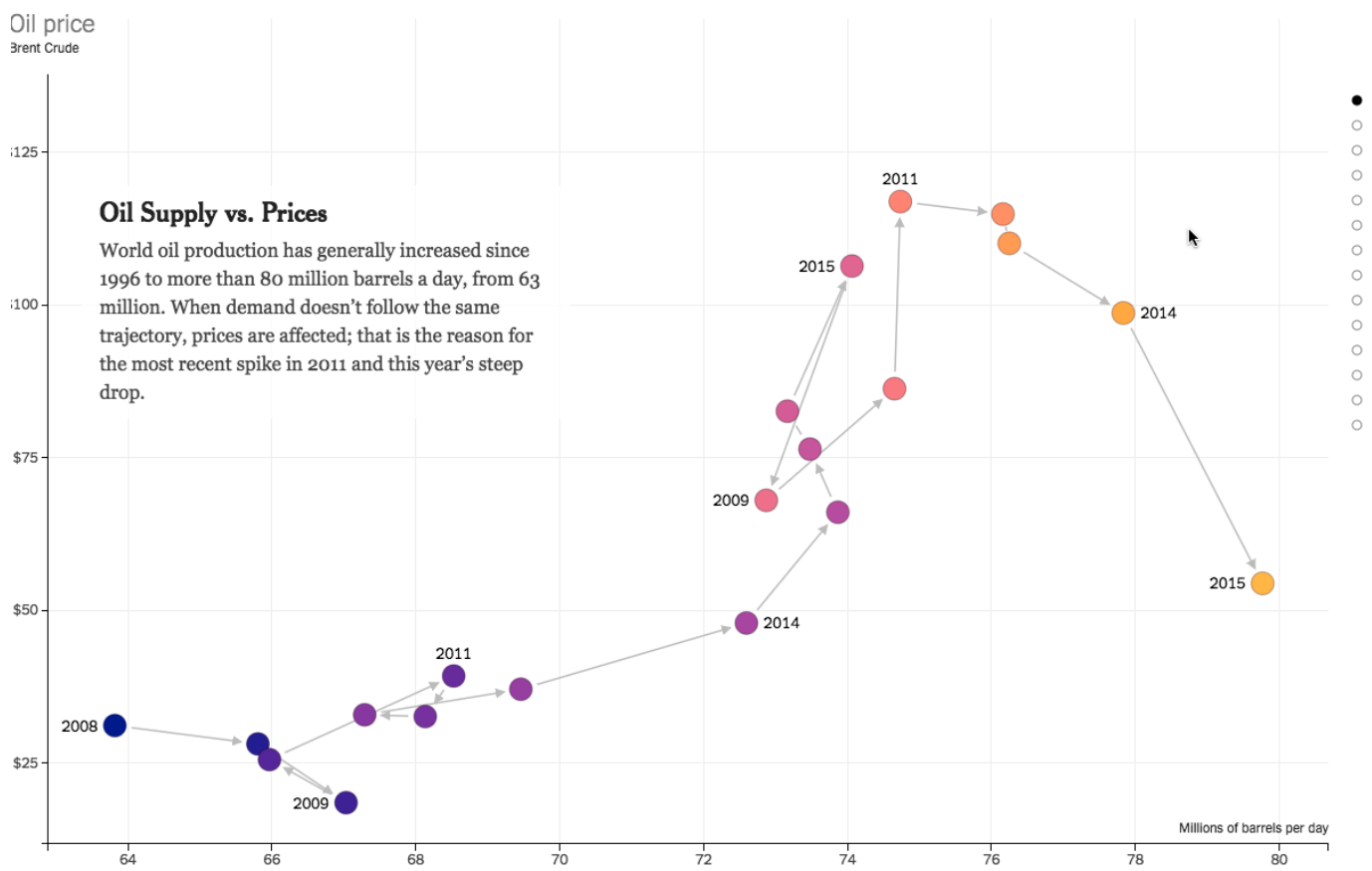
https://eagereyes.org/blog/2016/the-scrollytelling-scourge

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

slide by Tamara Munzner, inspired by: Alexander Lex, Utah

Manipulate > Navigate: Scrollytelling examples

- How the US and O.P.E.C. drive oil prices

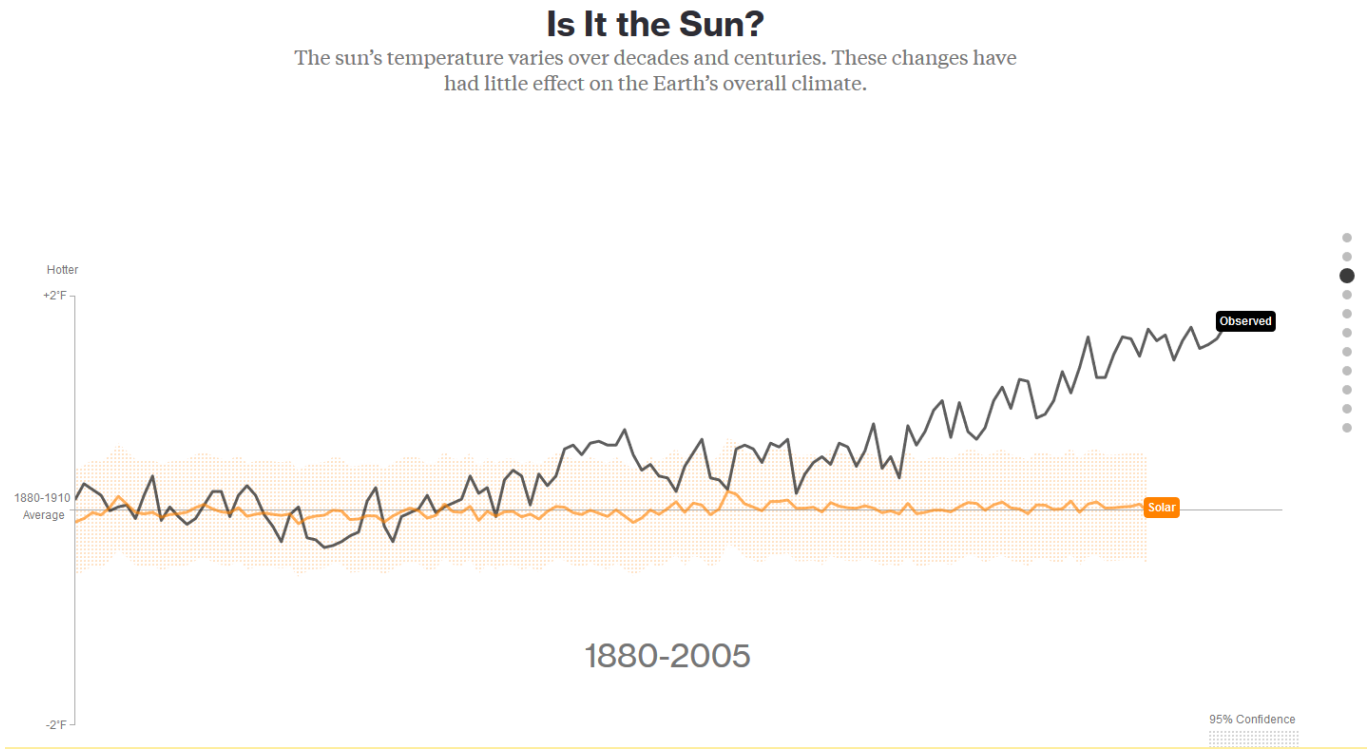


https://www.nytimes.com/interactive/2015/09/30/business/how-the-us-and-opec-drive-oil-prices.html?_r=1

slide by Tamara Munzner, inspired by: Alexander Lex, Utah

Manipulate > Navigate: Scrollytelling examples

- What's really warming the world?

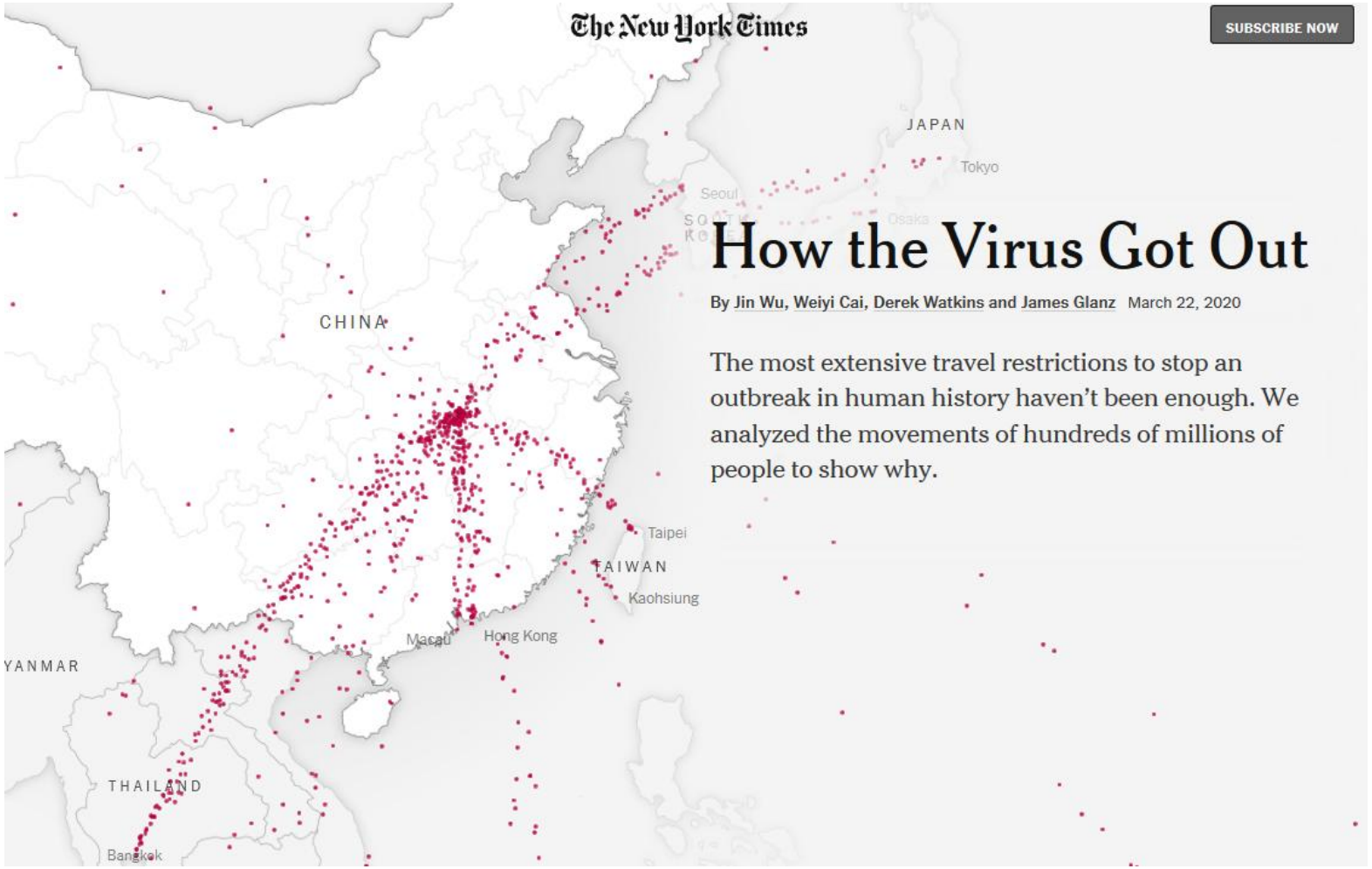


https://www.bloomberg.com/graphics/2015-whats-warming-the-world/

slide by Tamara Munzner, inspired by: Alexander Lex, Utah

Manipulate > Navigate: Scrollytelling examples

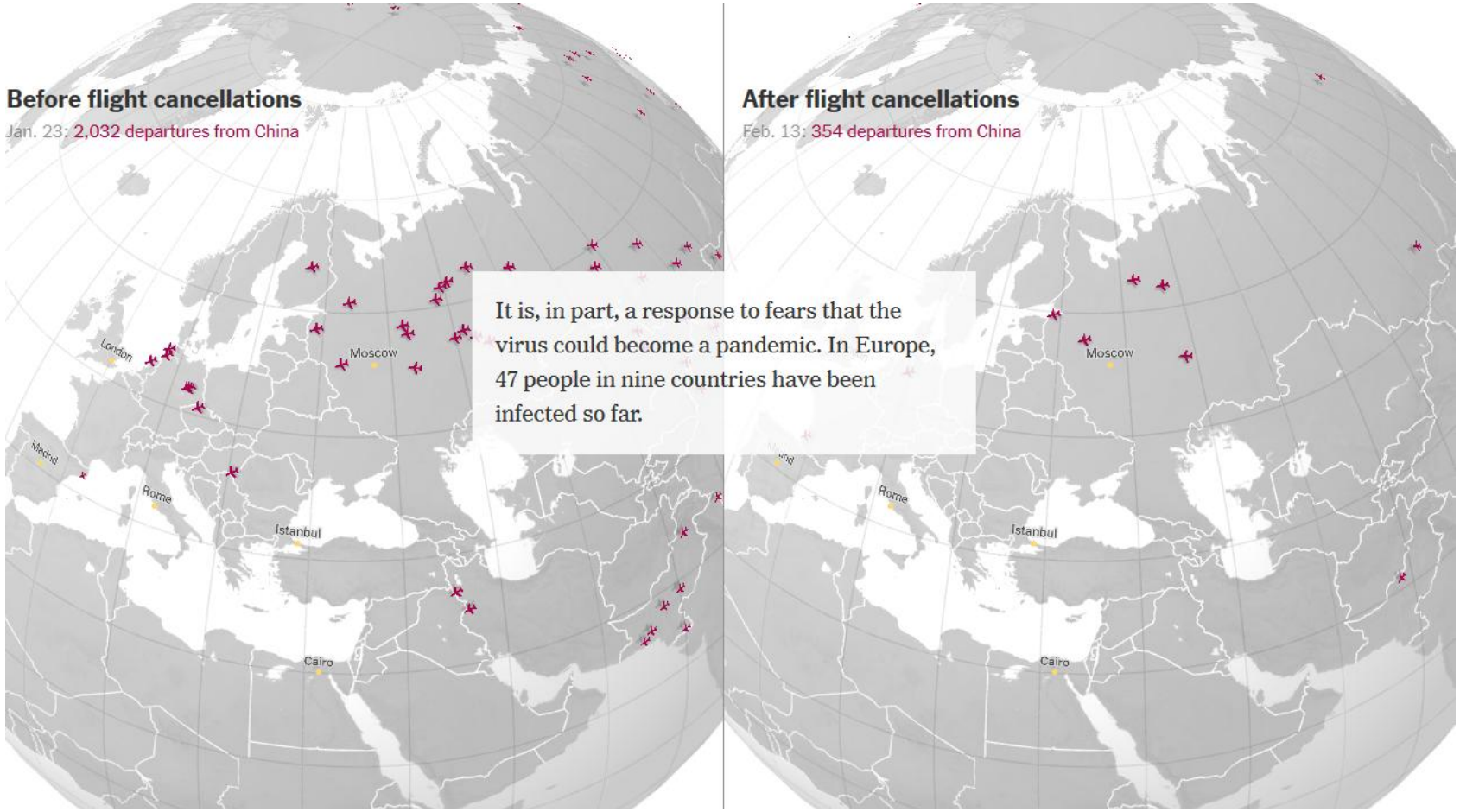
- How the Virus Got Out



New York Times Interactive, 2020

Manipulate > Navigate: Scrollytelling examples

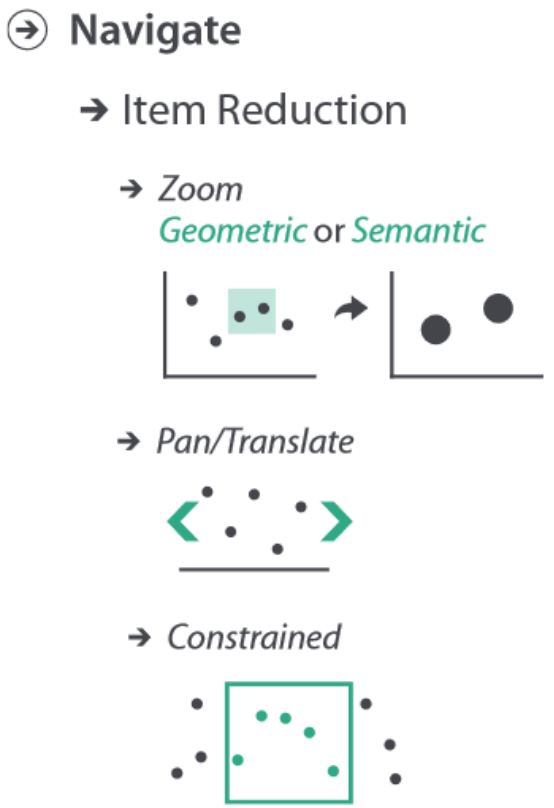
- 13,000 Missing Flights: The Global Consequences of the Coronavirus



New York Times Interactive, 2020

Manipulate > Navigate: Unconstrained vs constrained

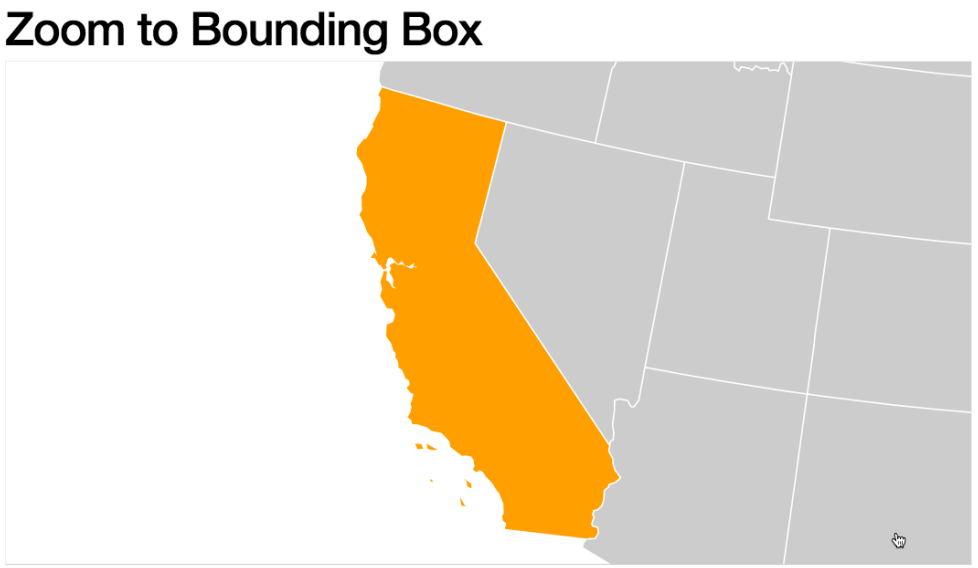
- unconstrained navigation
  - easy to implement for designer
  - hard to control for user
    - easy to overshoot/undershoot
- constrained navigation
  - typically uses animated transitions
  - trajectory automatically computed based on selection
    - just click; selection ends up framed nicely in final viewport



slide by Tamara Munzner

Manipulate > Navigate: Animated transition + constrained navigation

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

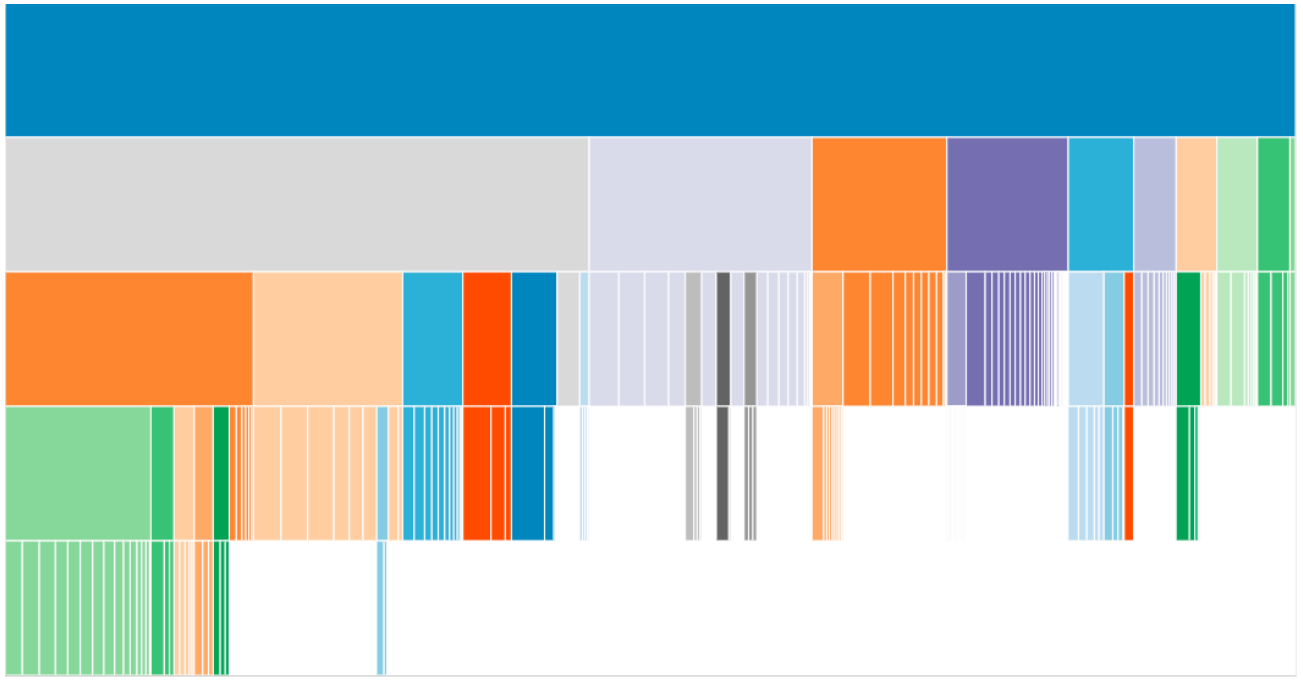


Zoom to Bounding Box
https://bl.ocks.org/mbostock/4699541

slide by Tamara Munzner

Manipulate > Navigate: Animated transition + constrained navigation

- example: icicle plot
  - transition into containing mark causes aspect ratio (shape) change

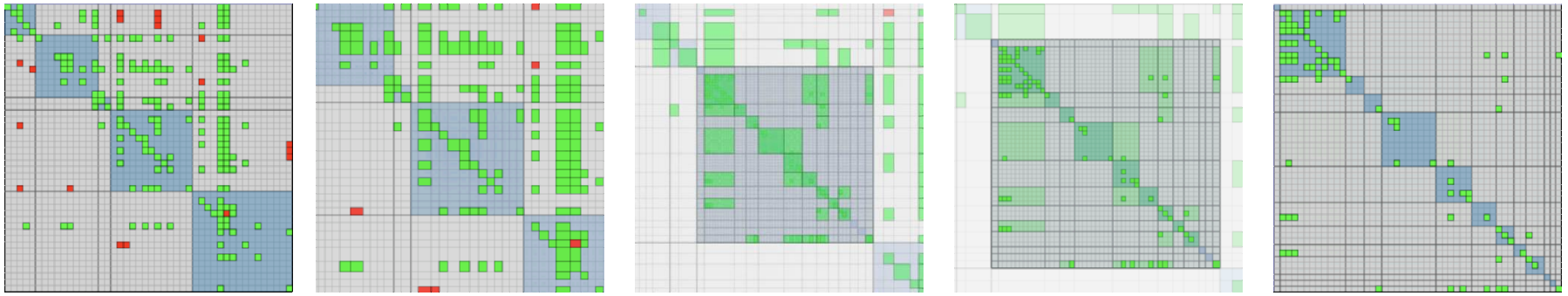


Zoomable Icicle
https://bl.ocks.org/mbostock/1005873

slide by Tamara Munzner

Manipulate > Navigate: Animated transition + constrained navigation

- example: multilevel matrix views
  - add detail during transition



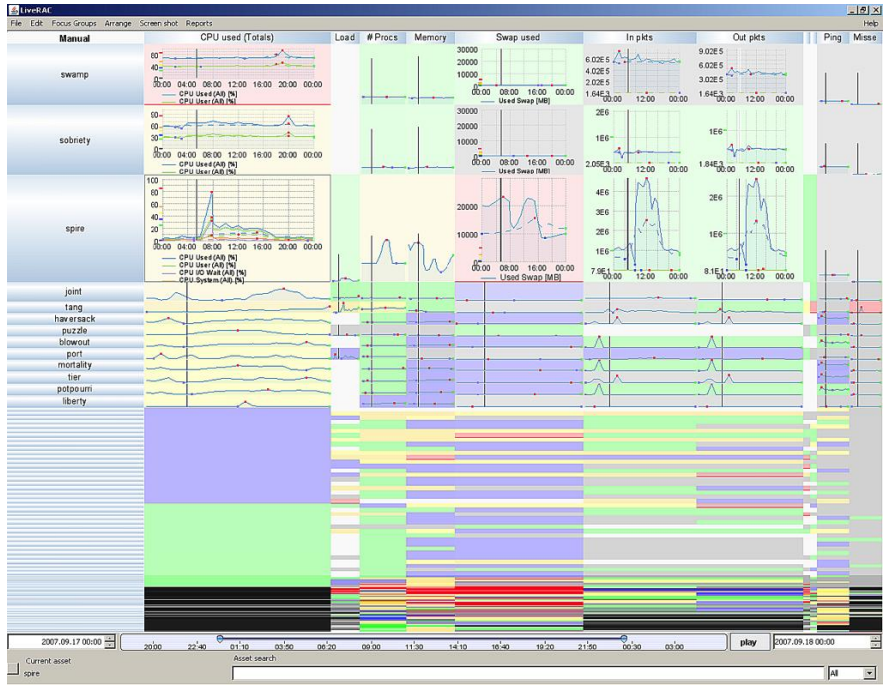
Using Multilevel Call Matrices in Large Software Projects. van Ham. Proc. IEEE Symp. Information Visualization (InfoVis), pp. 227–232, 2003.

https://www.win.tue.nl/~vanwijk/zoompan.pdf

slide by Tamara Munzner

Manipulate > Navigate: Semantic zooming

- semantic zoom: As you zoom in, content is updated
  - alternative to geometric zoom
  - resolution-aware layout adapts to available space
  - goal: legible at multiple scales
  - dramatic or subtle effects
- visual encoding change
  - colored box
  - sparkline
  - simple line chart
  - full chart: axes and tickmarks

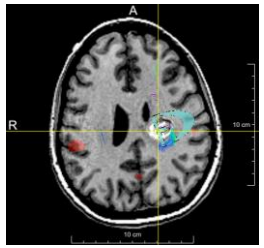


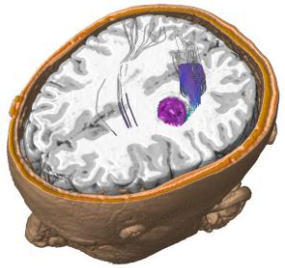
LiveRAC - Interactive Visual Exploration of System Management Time-Series Data. McLachlan, Munzner, Koutsofios, and North. Proc. ACM Conf. Human Factors in Computing Systems (CHI), pp. 1483–1492, 2008.

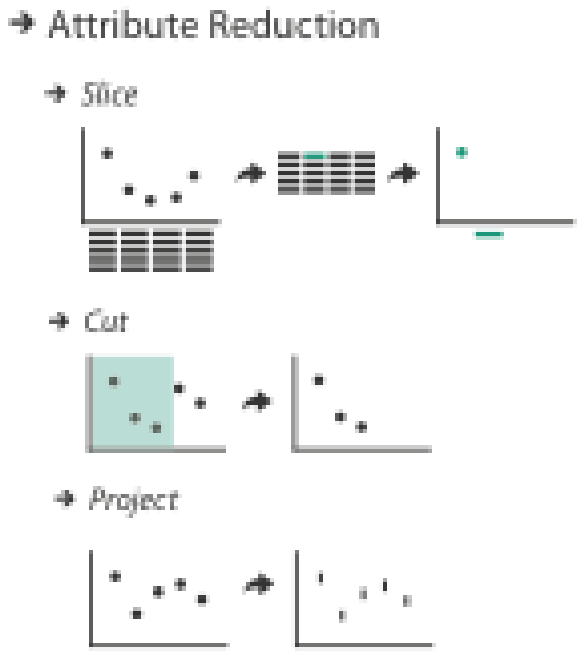
slide by Tamara Munzner

Manipulate > Navigate: Attribute reduction

- 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 (eliminate 3rd dimension)
    - perspective (foreshortening captures limited 3D information)



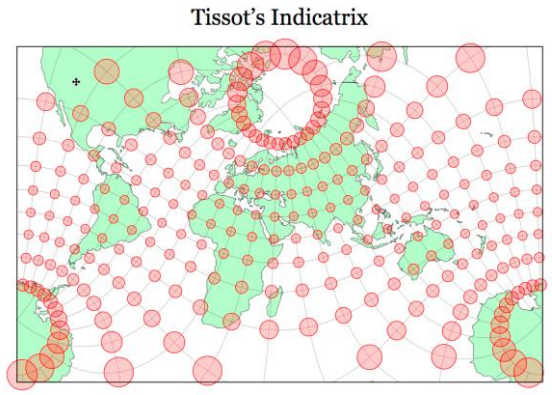




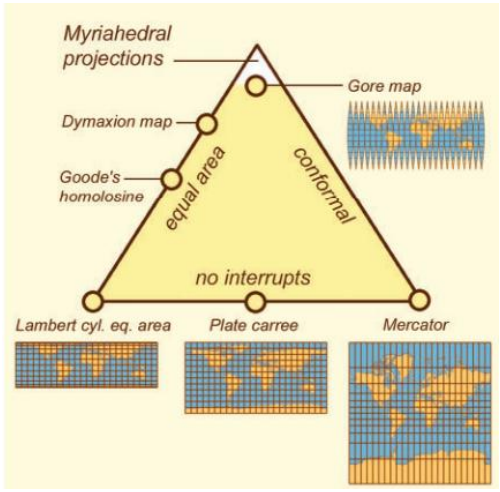
Interactive Visualization of Multimodal Volume Data for Neurosurgical Tumor Treatment. Rieder, Ritter, Raspe, and Peitgen. Computer Graphics Forum (Proc. EuroVis 2008) 27:3 (2008), 1055–1062.]

Manipulate > Navigate: Cartographic projections

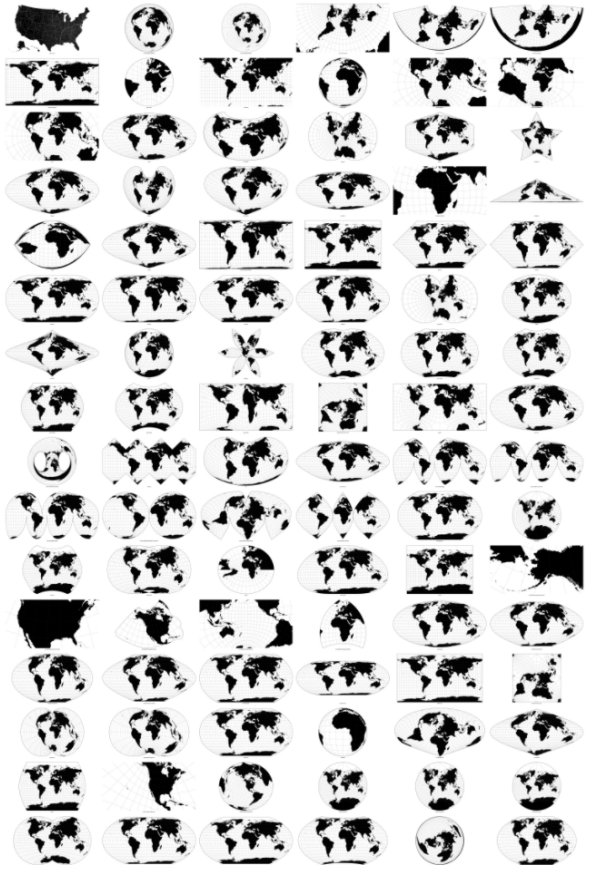
- project from 2D sphere surface to 2D plane
  - can only fully preserve 2 out of 3
    - angles: conformal
    - area: equal area
    - contiguity: no interruptions



https://www.jasondavies.com/maps/tissot/



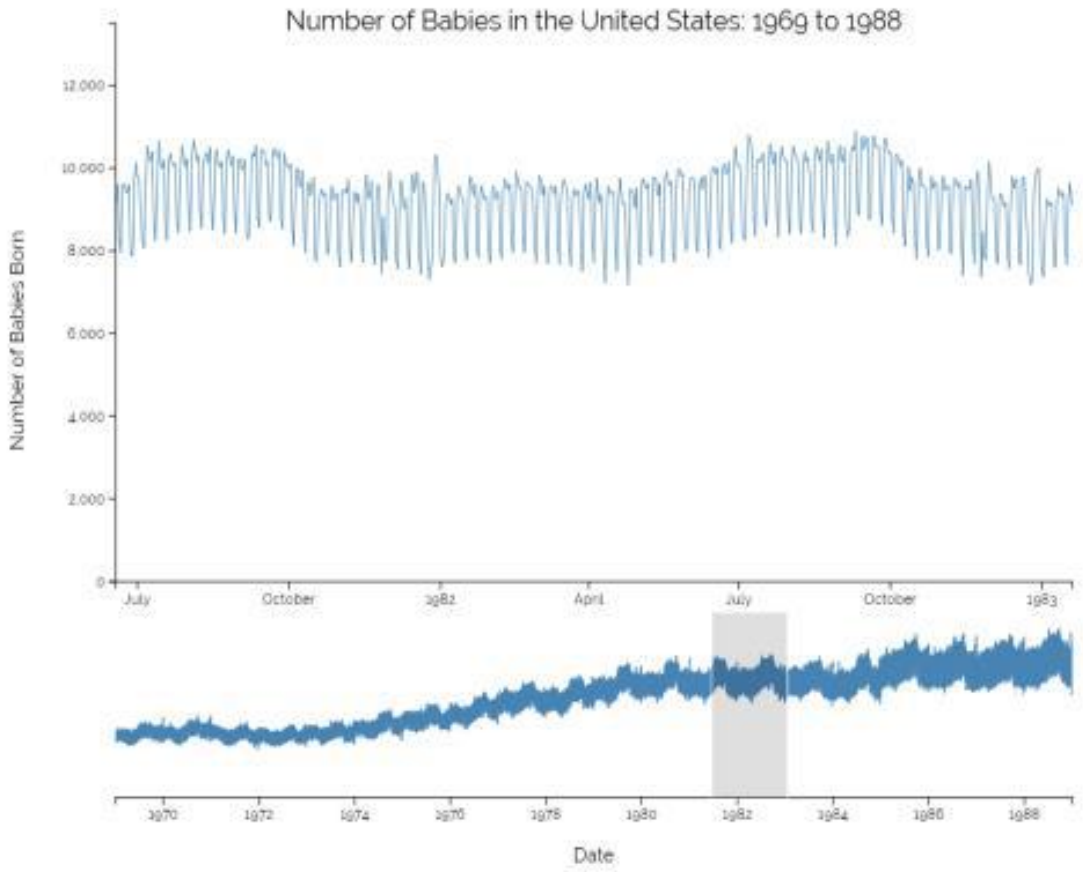
https://www.win.tue.nl/~vanwijk/myriahedral/



[Every Map Projection https://bl.ocks.org/mbostock/29cddc0006f8b98eff12e60dd08f59a7

slide by Tamara Munzner

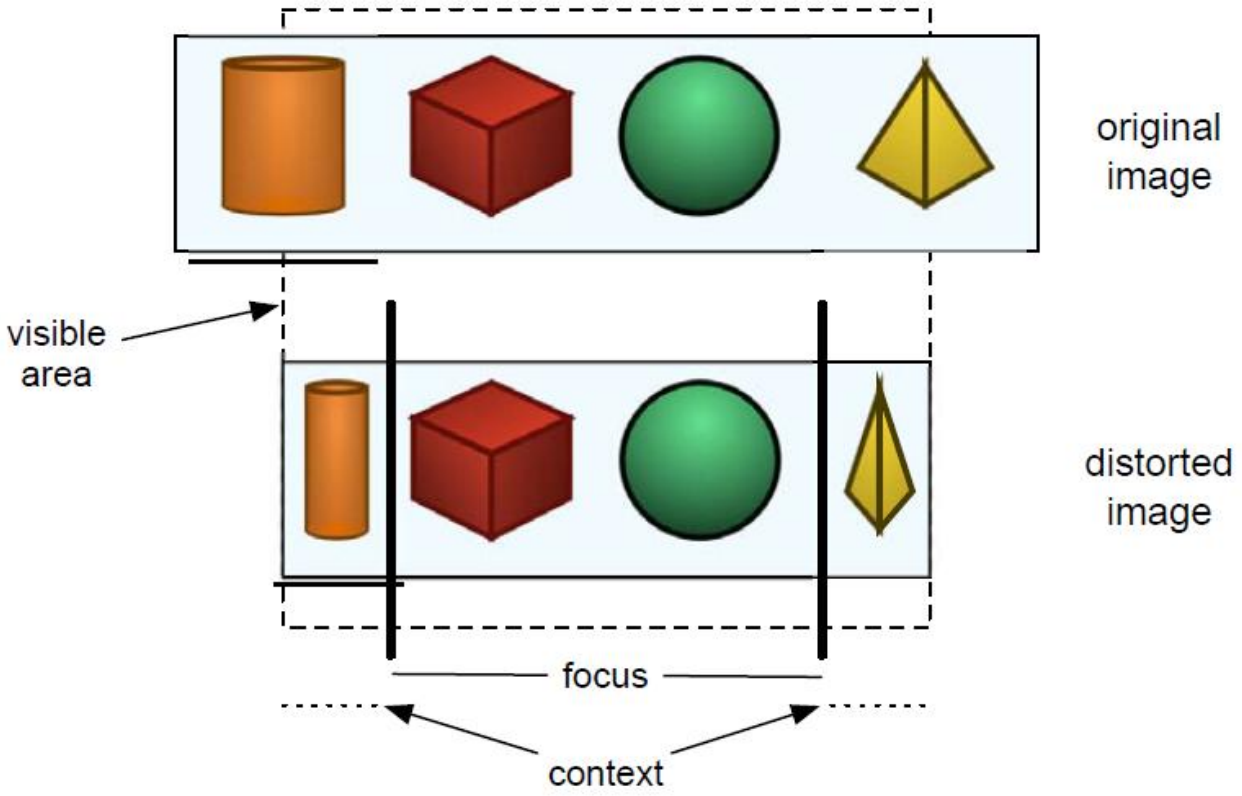
Manipulate > Navigate: Focus & Context



ɔng/raw/884bb566c84775d92b3d/

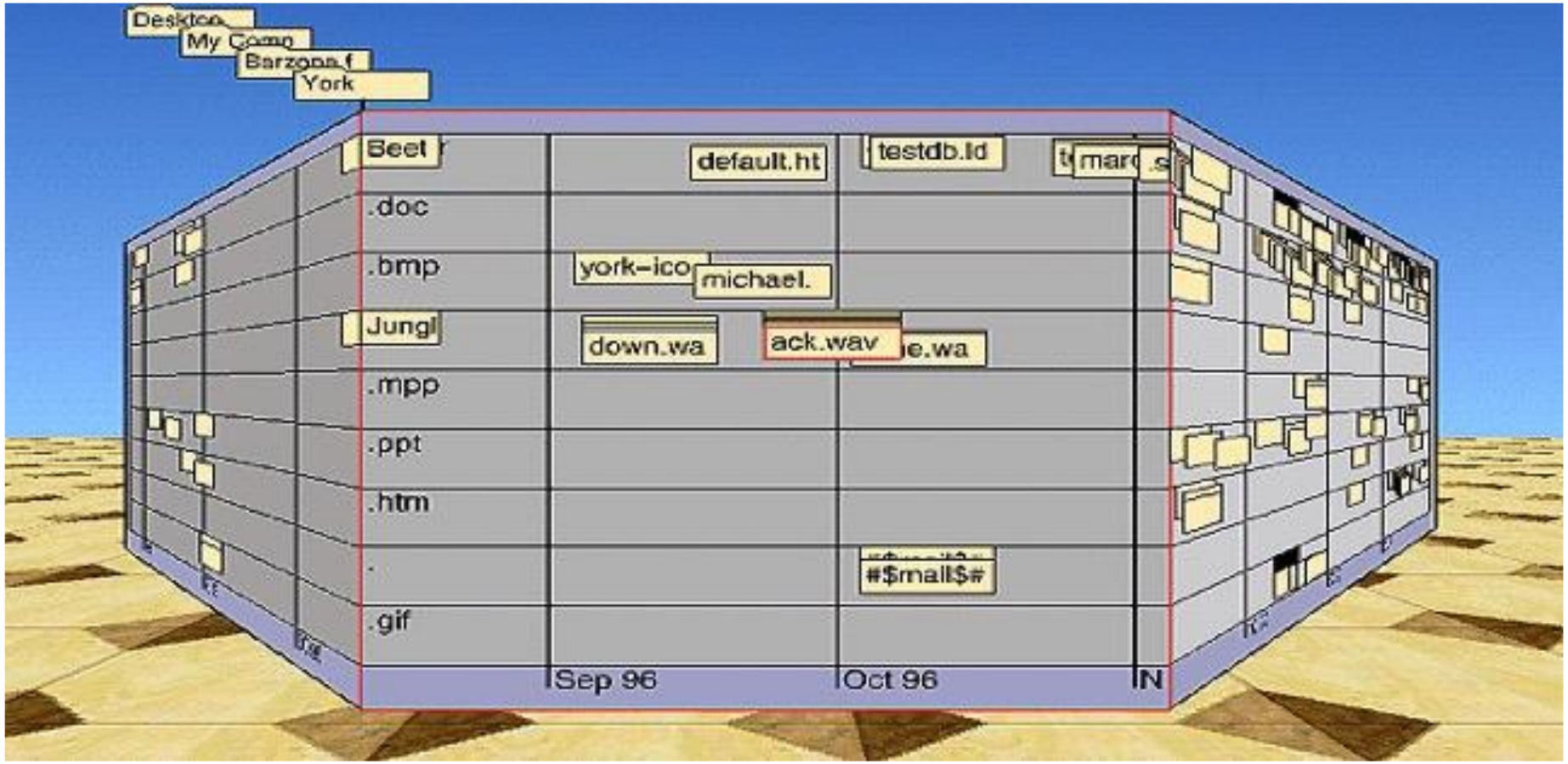
Manipulate > Navigate: Focus & Context

- Bifocal display



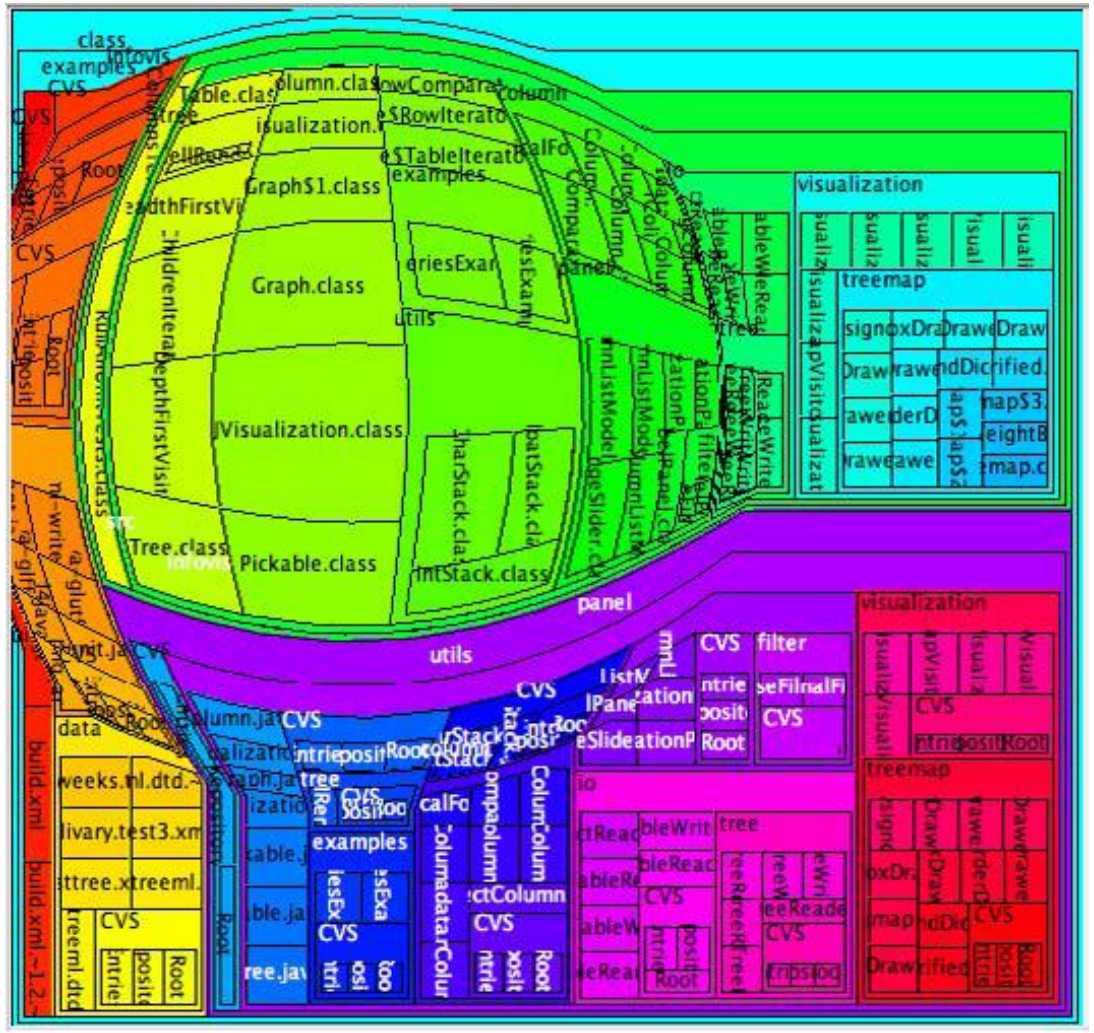
Manipulate > Navigate: Focus & Context

- The perspective wall



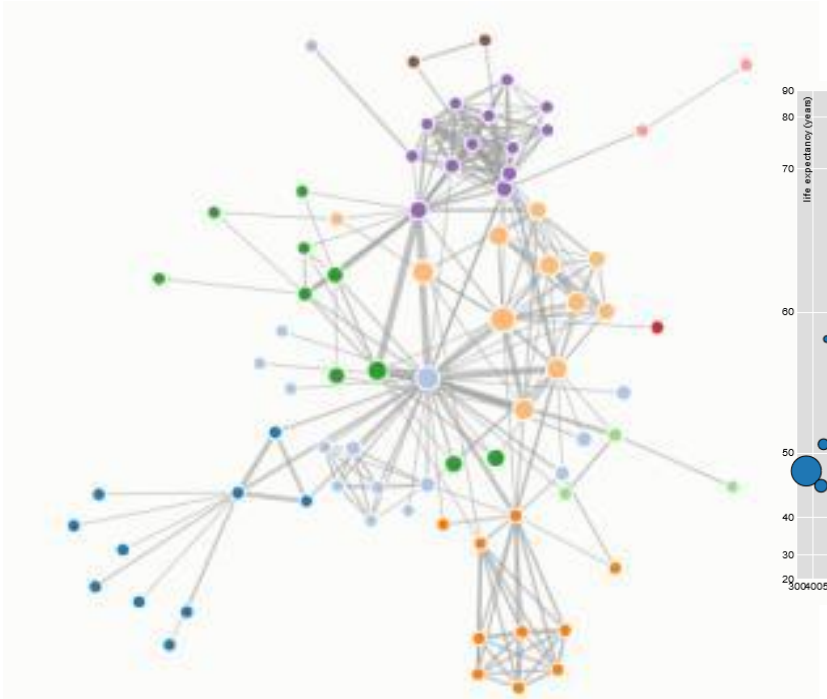
Manipulate > Navigate: Overview-detail

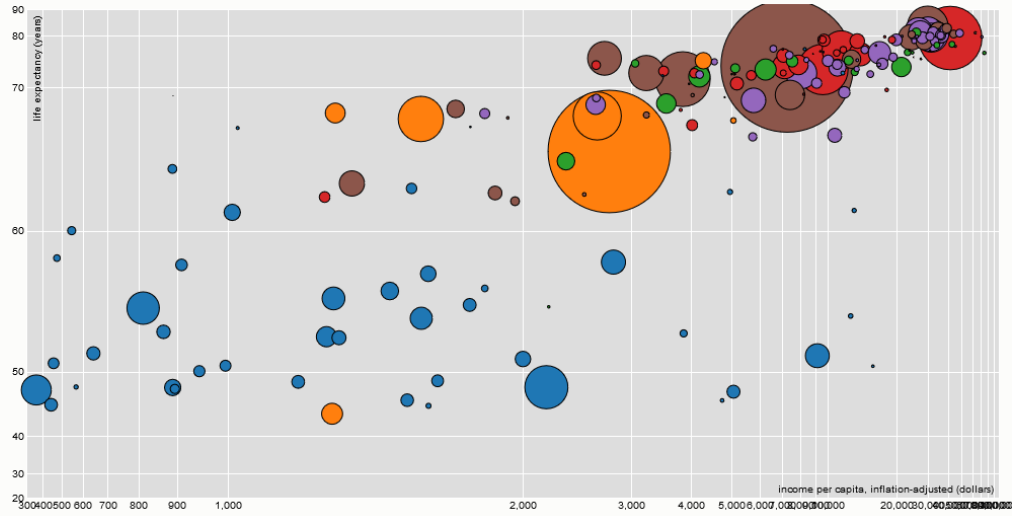
- Fisheye view

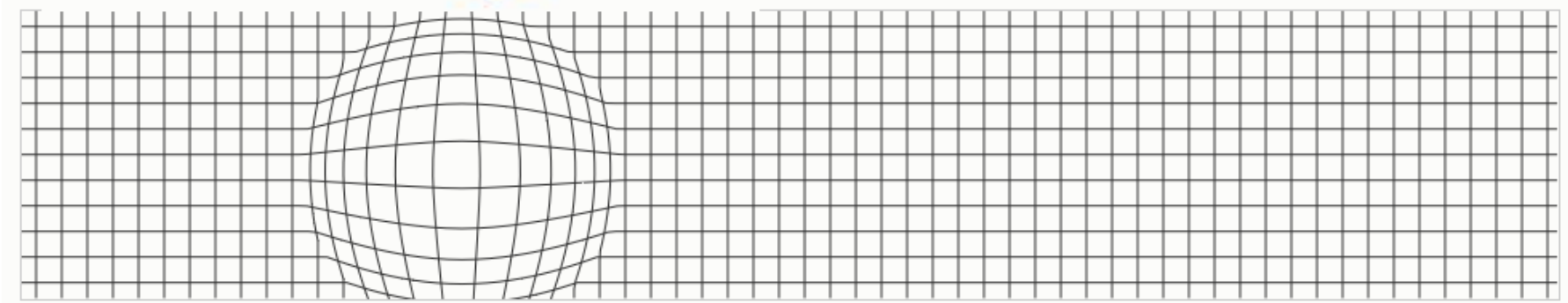


Manipulate > Navigate: Overview-detail

- Fisheye view

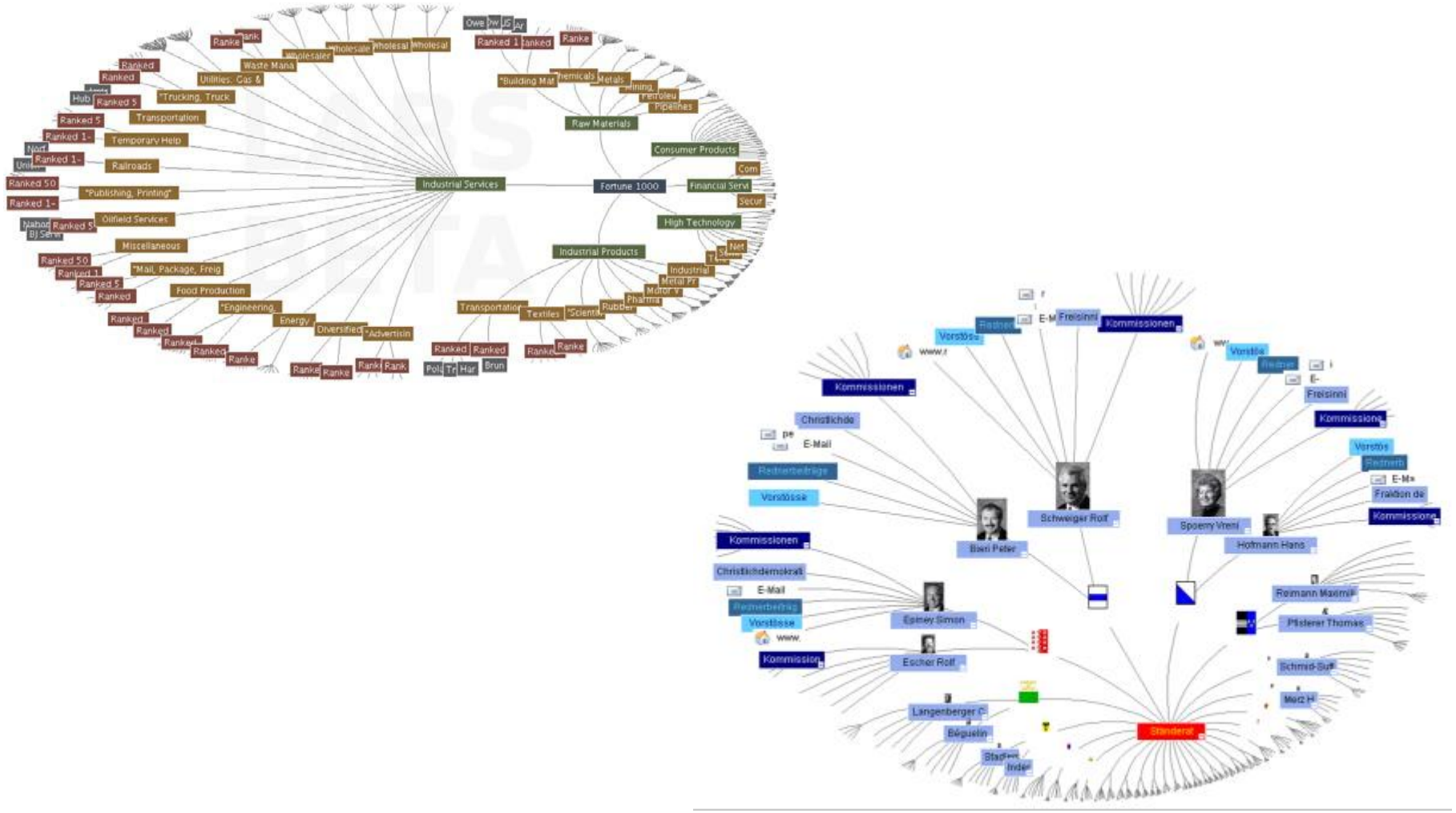






Manipulate > Navigate: Focus & Context

- Hyperbolic browser



Interaction taxonomy (Munzner)

- How to handle complexity: 1 + 3 strategies

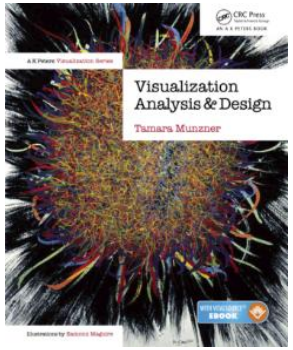
derive new data to show within view

change view over time

facet across multiple views

reduce items/attributes within single view

→ *Derive*



Tamara Munzner

Manipulate

- Change
- Select
- Navigate

Facet

- Juxtapose
- Partition
- Superimpose

Reduce

- Filter
- Aggregate
- Embed

slide by Tamara Munzner

Interaction taxonomy (Munzner)

- Manipulate
  - Change
  - Select
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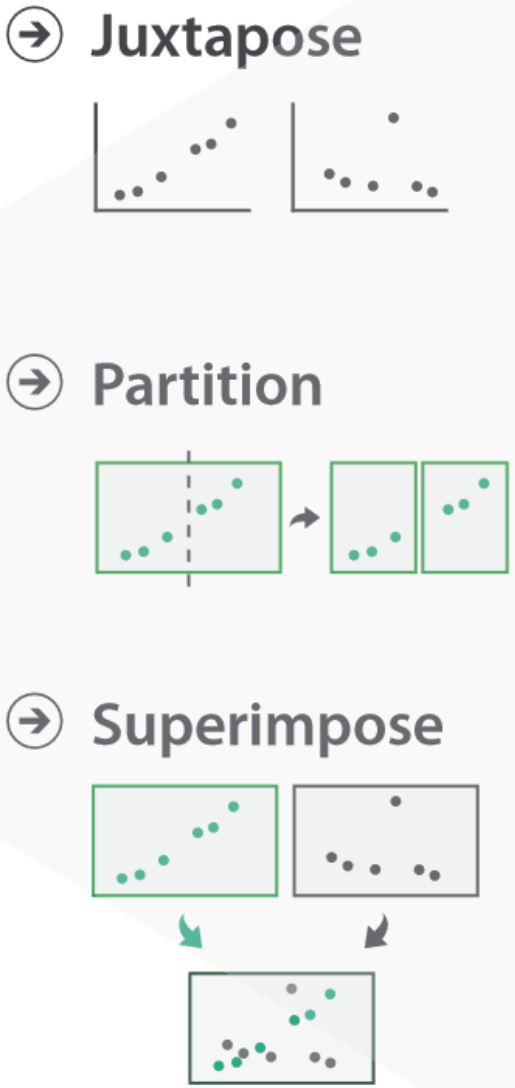
- **Facet**
  - Juxtapose
  - Partition
  - Superimpose
- Reduce
  - Filter
  - Aggregate
  - Embed



Facet > Juxtapose and coordinate views

- Juxtapose
  - Share encoding: same/different
    - Linked highlighting
  - Share data: All/subset/none
  - Share navigation

➔ Share Encoding: Same/Different

➔ *Linked Highlighting*

➔ Share Data: All/Subset/None

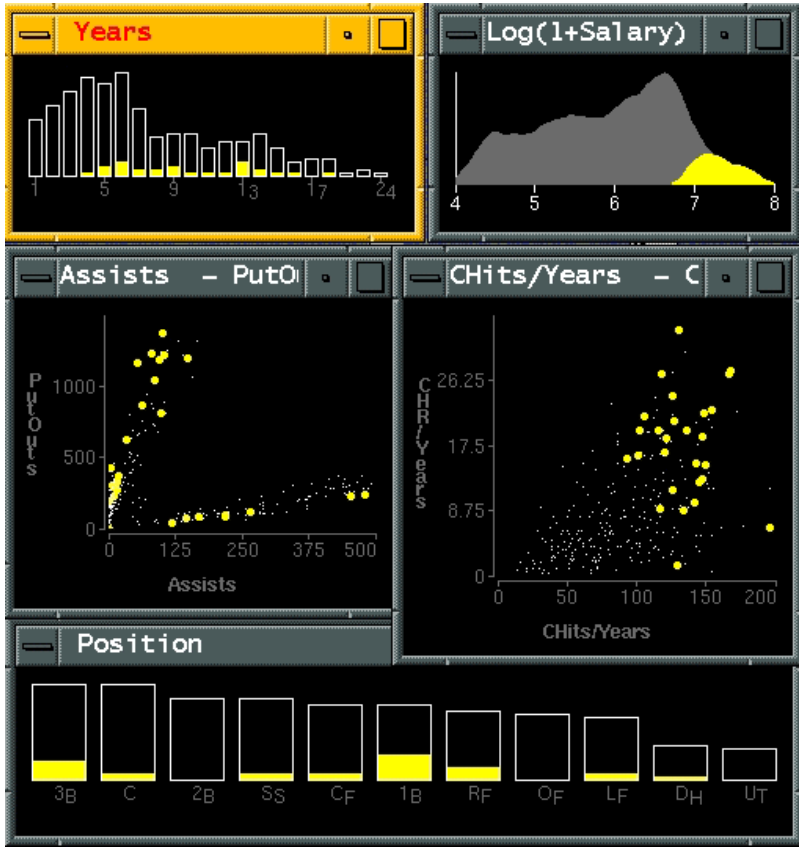
➔ Share Navigation

- Partition

- Superimpose

Facet > Juxtapose: Linked highlighting

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

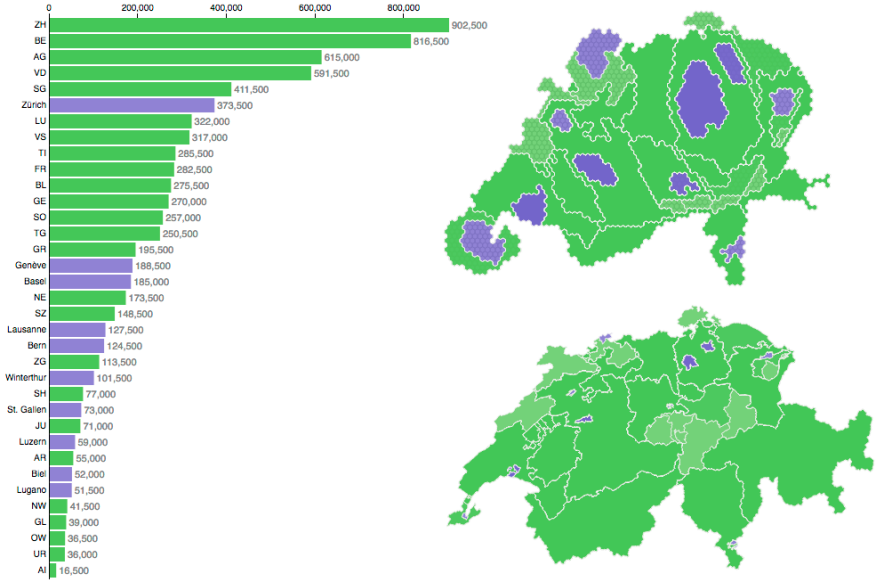


Visual Exploration of Large Structured Datasets. Wills. Proc. New Techniques and Trends in Statistics (NTTS), pp. 237–246. IOS Press, 1995.

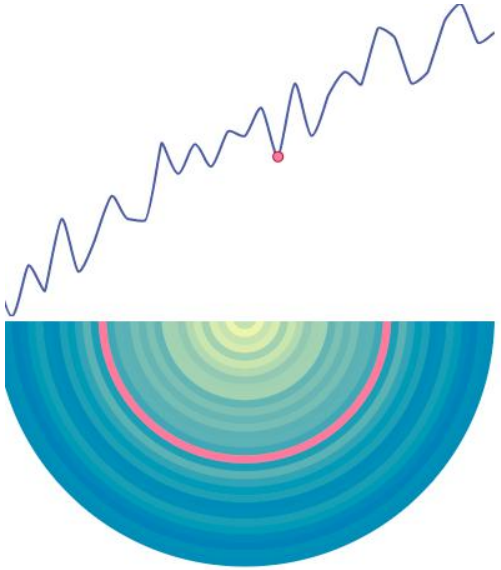
slide by Tamara Munzner

Facet > Juxtapose: Linked highlighting, linked views

- unidirectional vs bidirectional linking

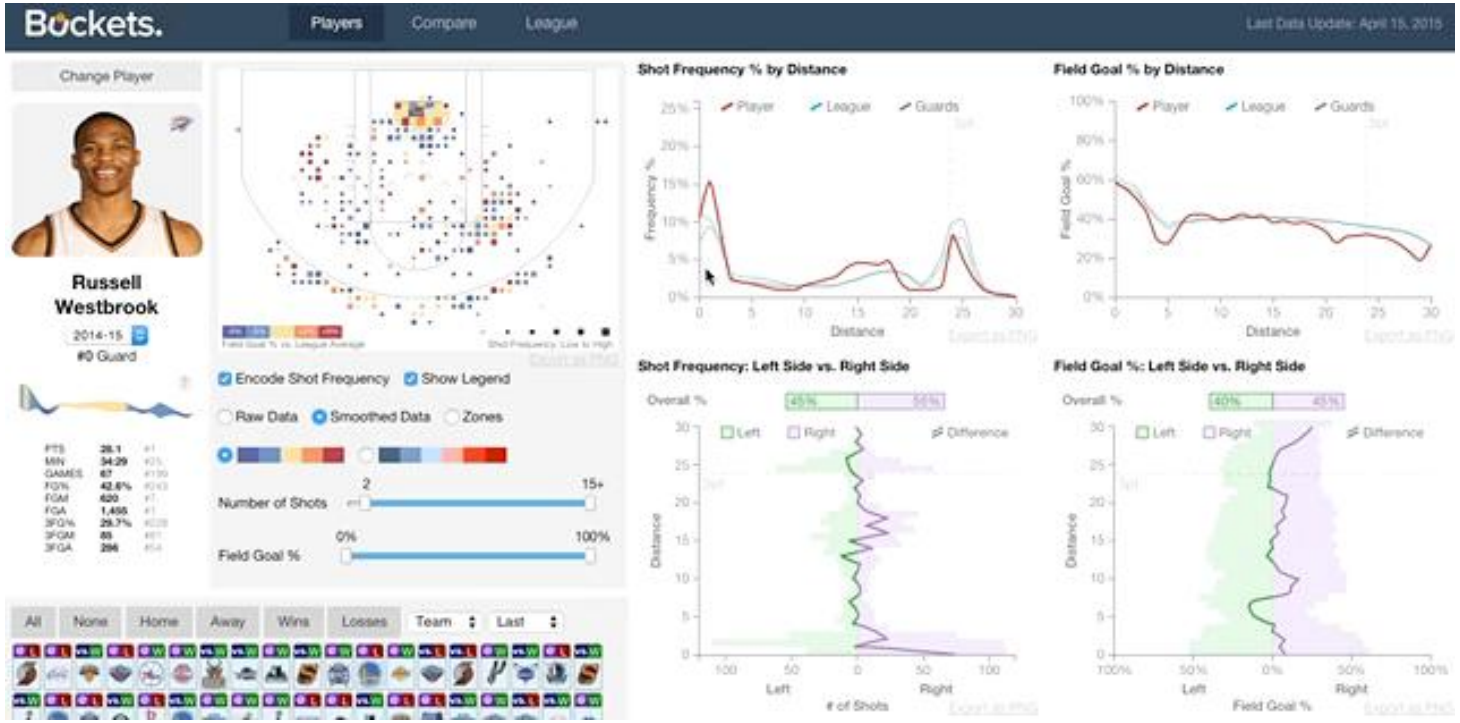


Population: les cantons et les 10 plus grandes villes de la Suisse



Example using React. D3.js and Reflux

Facet > Juxtapose: Linked views: Multidirectional linking



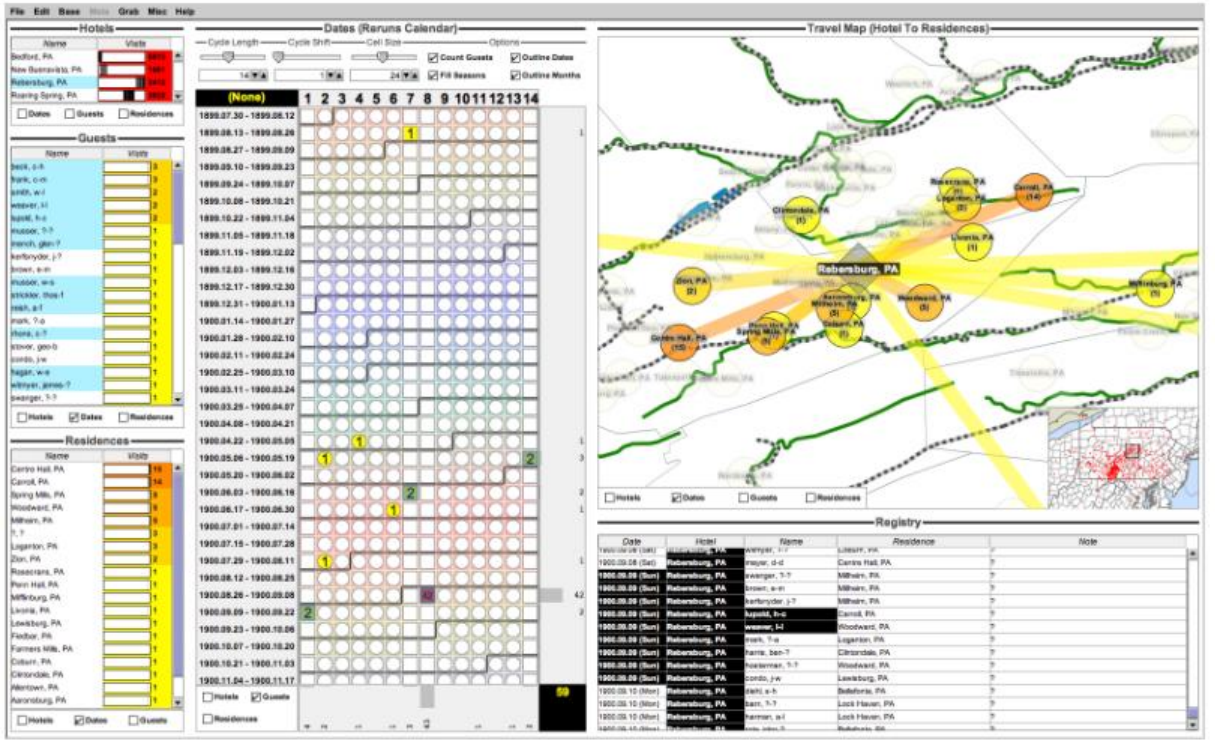
Buckets, http://buckets.peterbeshai.com/

Linked Highlighting with React, D3.js and Reflux

slide by Tamara Munzner

Facet > Juxtapose: coordinated multiple views

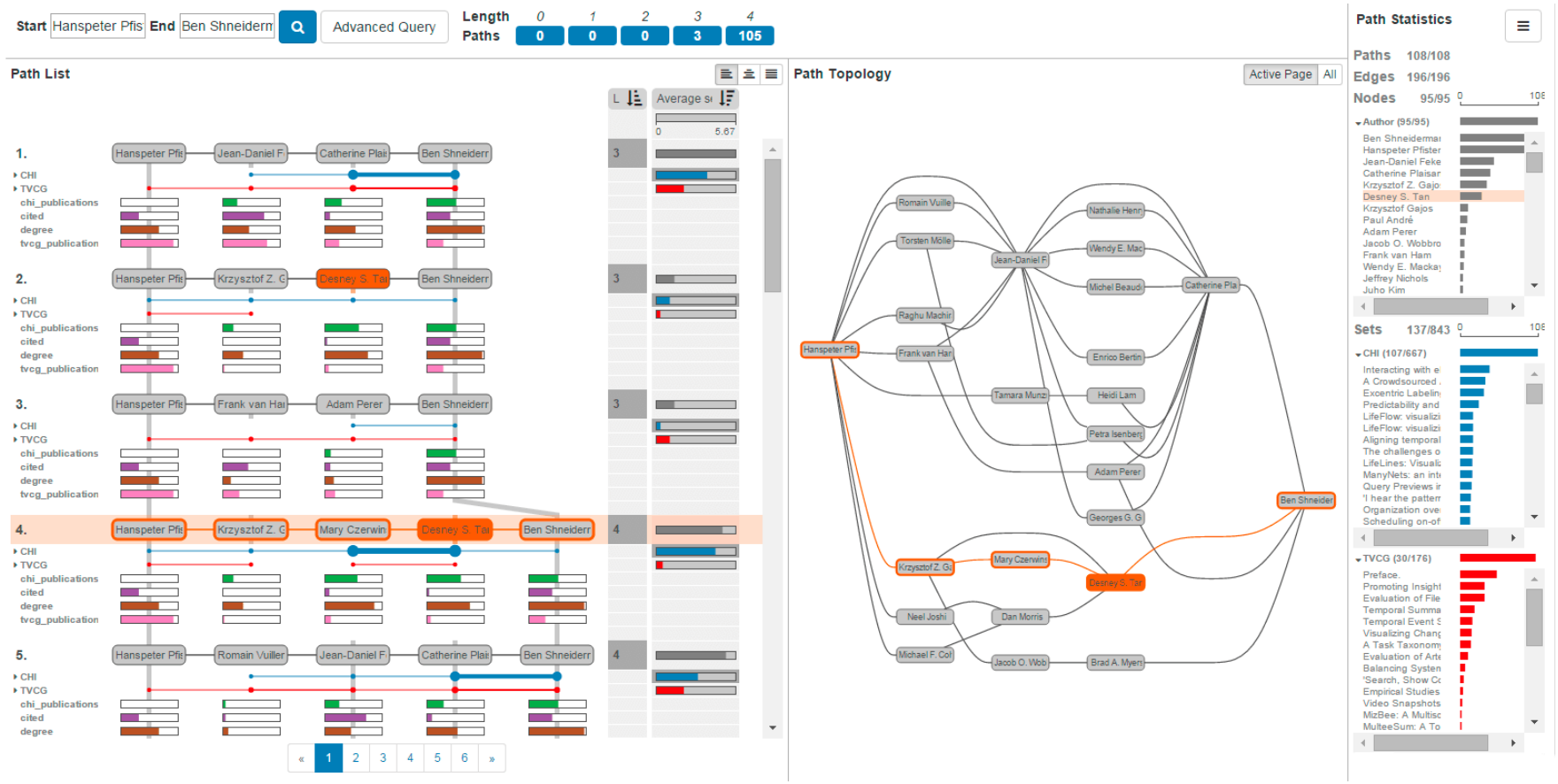
- Visual Analysis of Historical Hotel Visitation Patterns



Improvise
http://www.cs.ou.edu/~weaver/improvise/examples/hotels/

slide by Tamara Munzner

Facet > Juxtapose: Complex linked multiform views

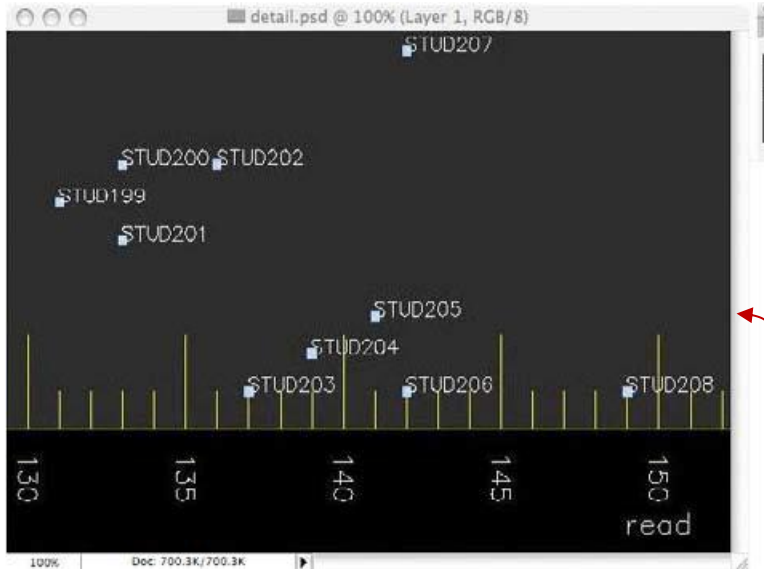


Pathfinder

slide by Tamara Munzner

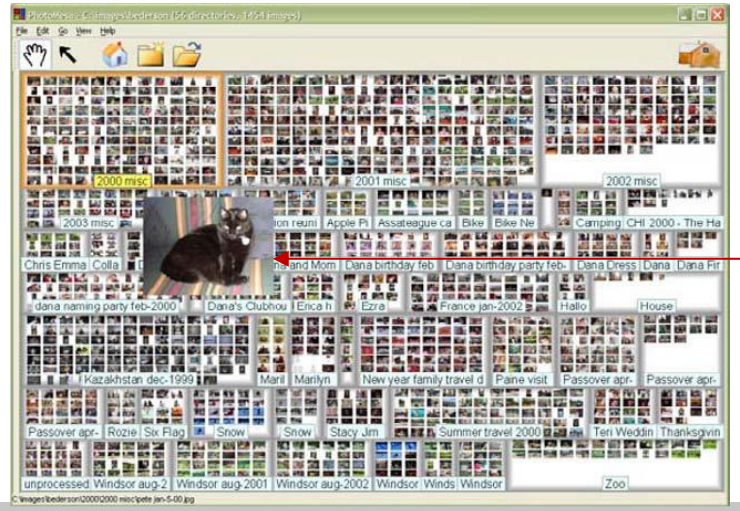
Facet > Overview-detail views

- Examples of overview – detail (non infoviz)



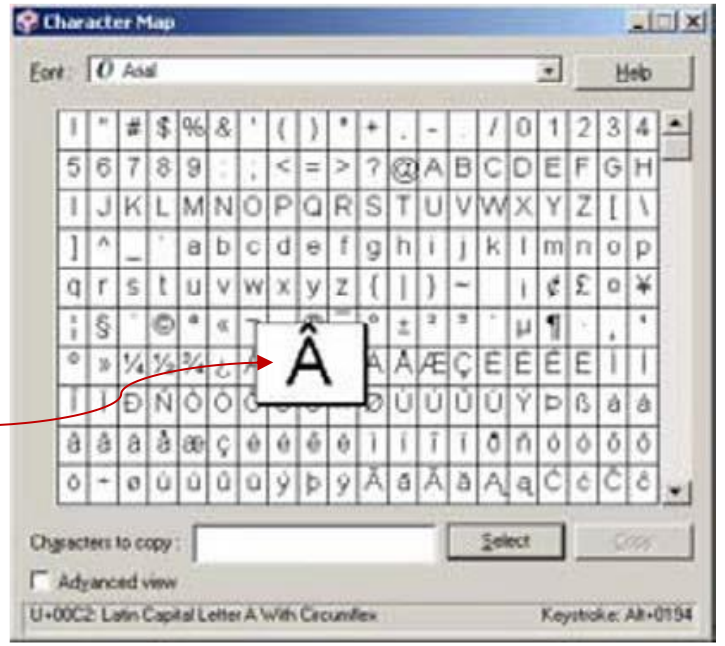
overview

detail



detail

overview



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Facet > Overview-detail views

- a subset of data shared
- navigation shared (bidirectional linking

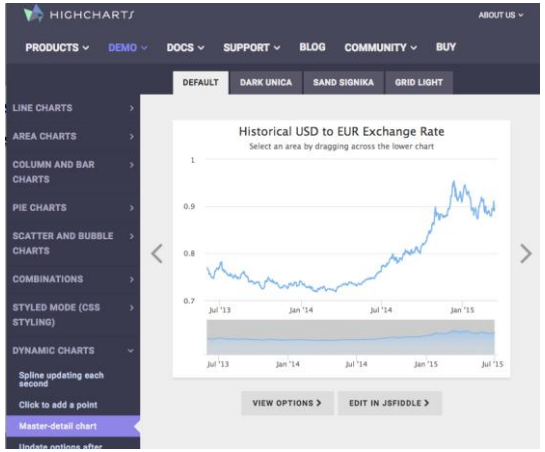
- differences
  - viewpoint
  - (size)

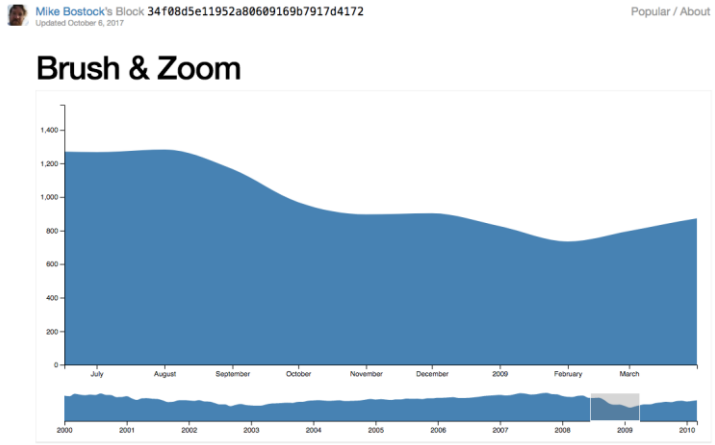
- special case: birds-eye map

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

Facet > Overview-detail navigation

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

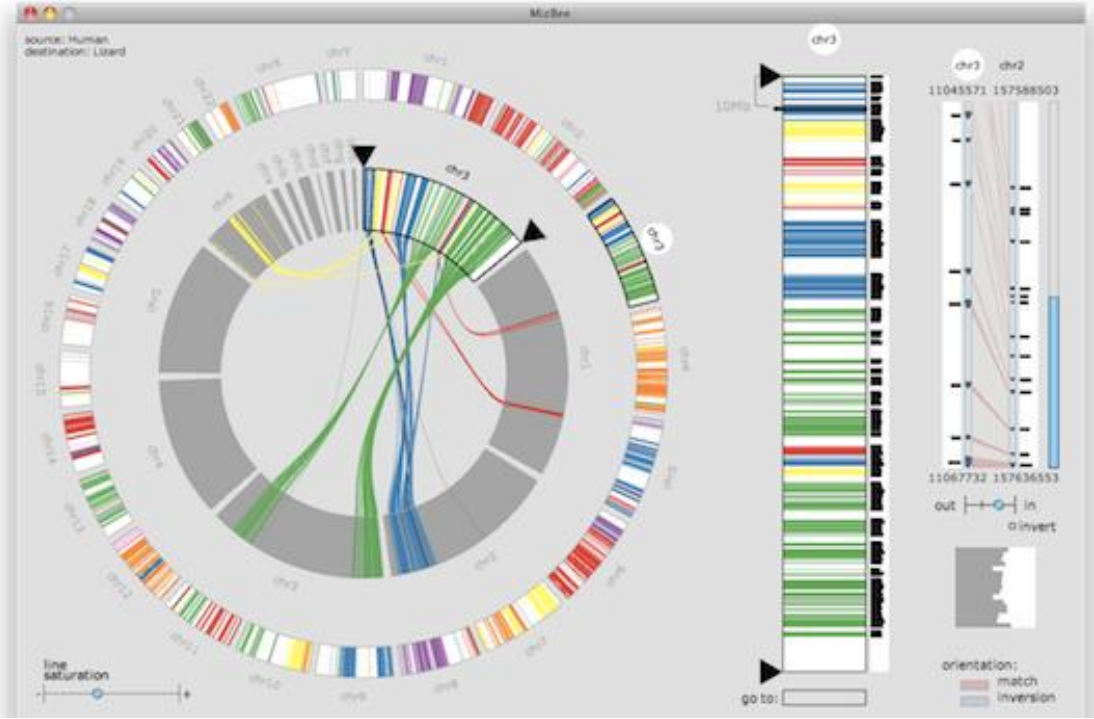




slide by Tamara Munzner

Facet > Overview-detail

- multiscale: three viewing levels side-by-side
  - linked views
  - dynamic filtering
  - tooling: processing (modern version: p5js.org)



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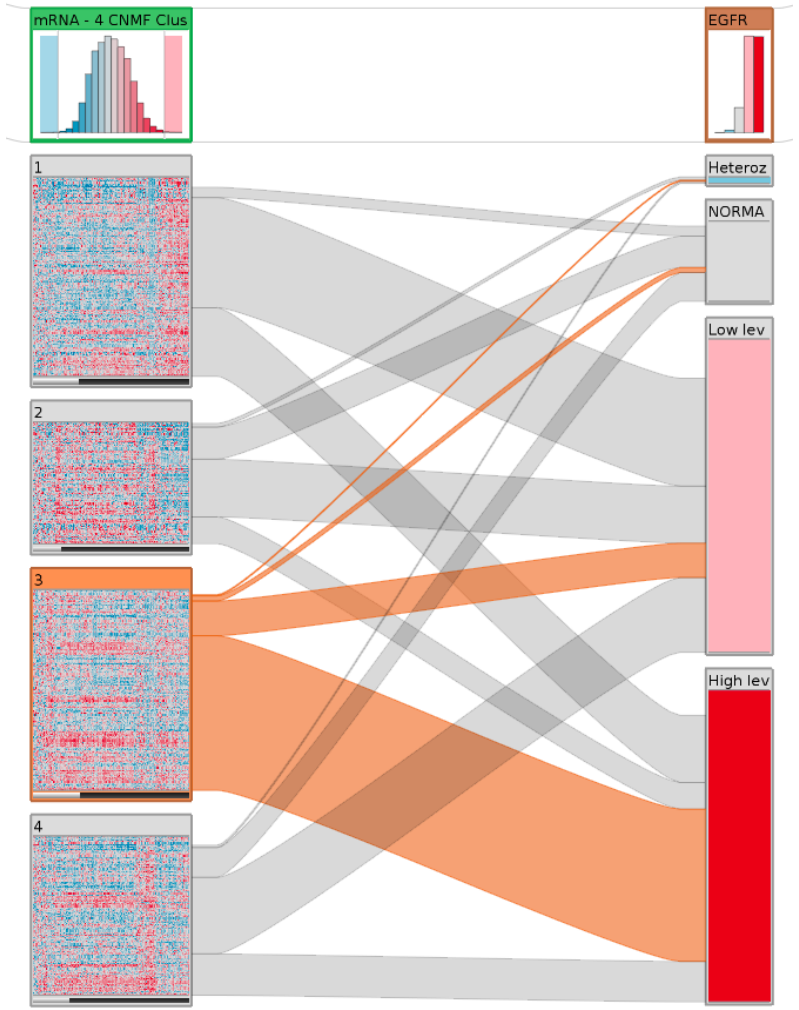
Facet > Overview-detail



https://www.youtube.com/watch?v=UcKDbGqHsdE

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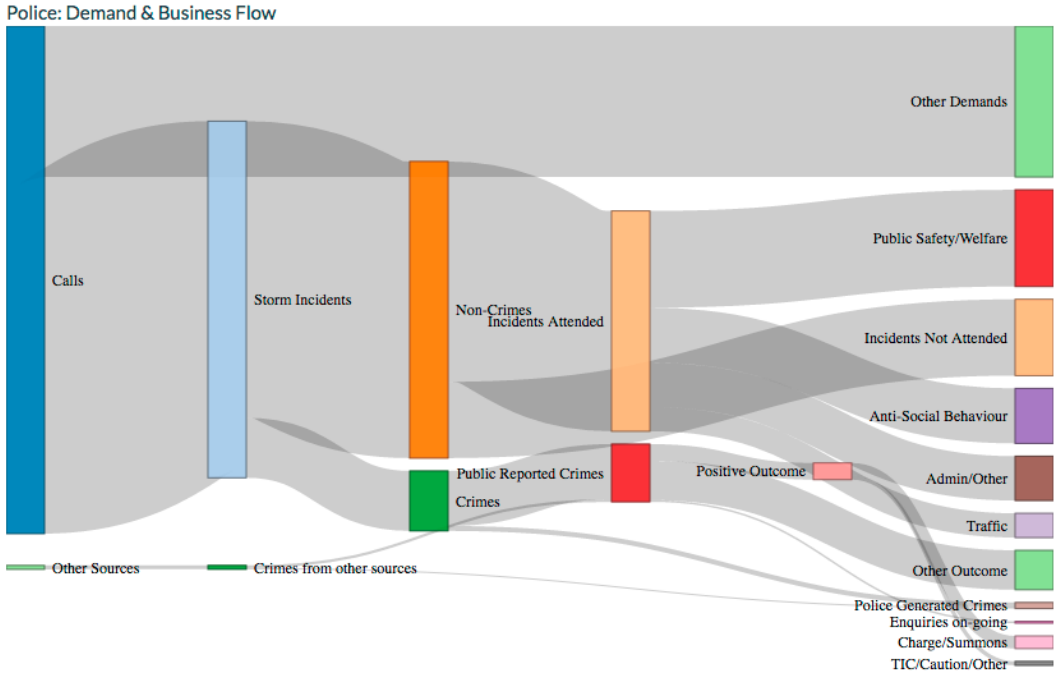
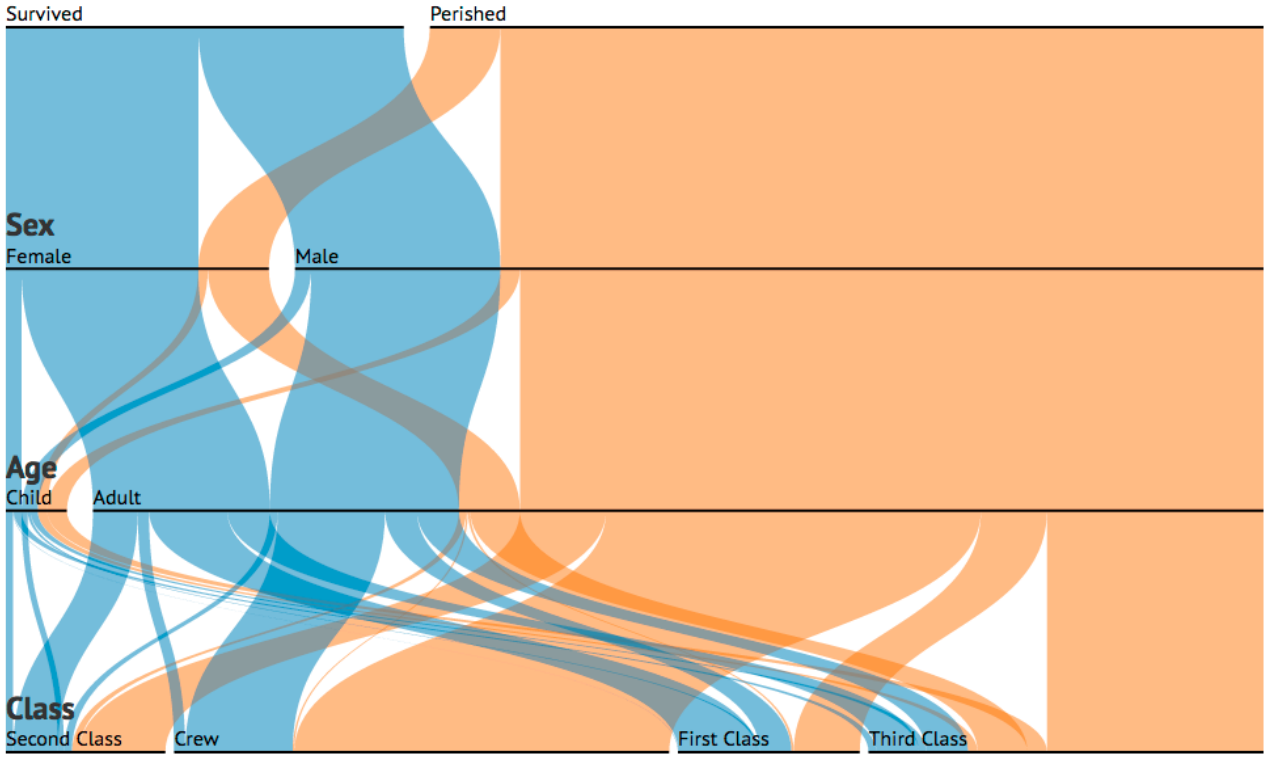
Facet > Flows: R/Shiny



https://gallery.shinyapps.io/TSupplyDemand/

slide by Tamara Munzner

Facet > Parallel sets



https://www.jasondavies.com/parallel-sets/

https://eagereyes.org/parallel-sets

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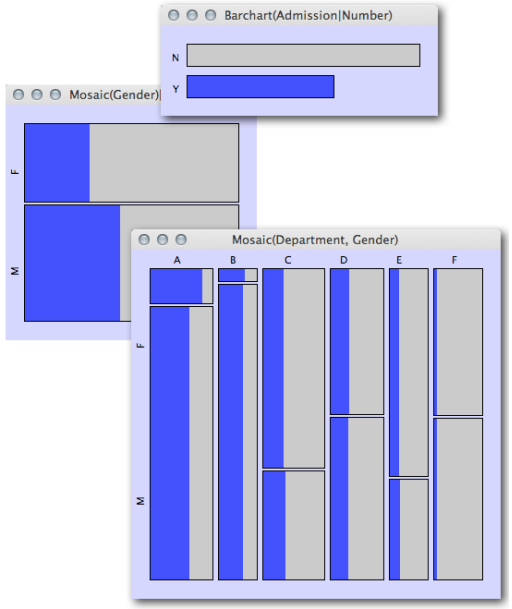
Facet > Mosaic plots



http://www.theusrus.de/blog/understanding-mosaic-plots/

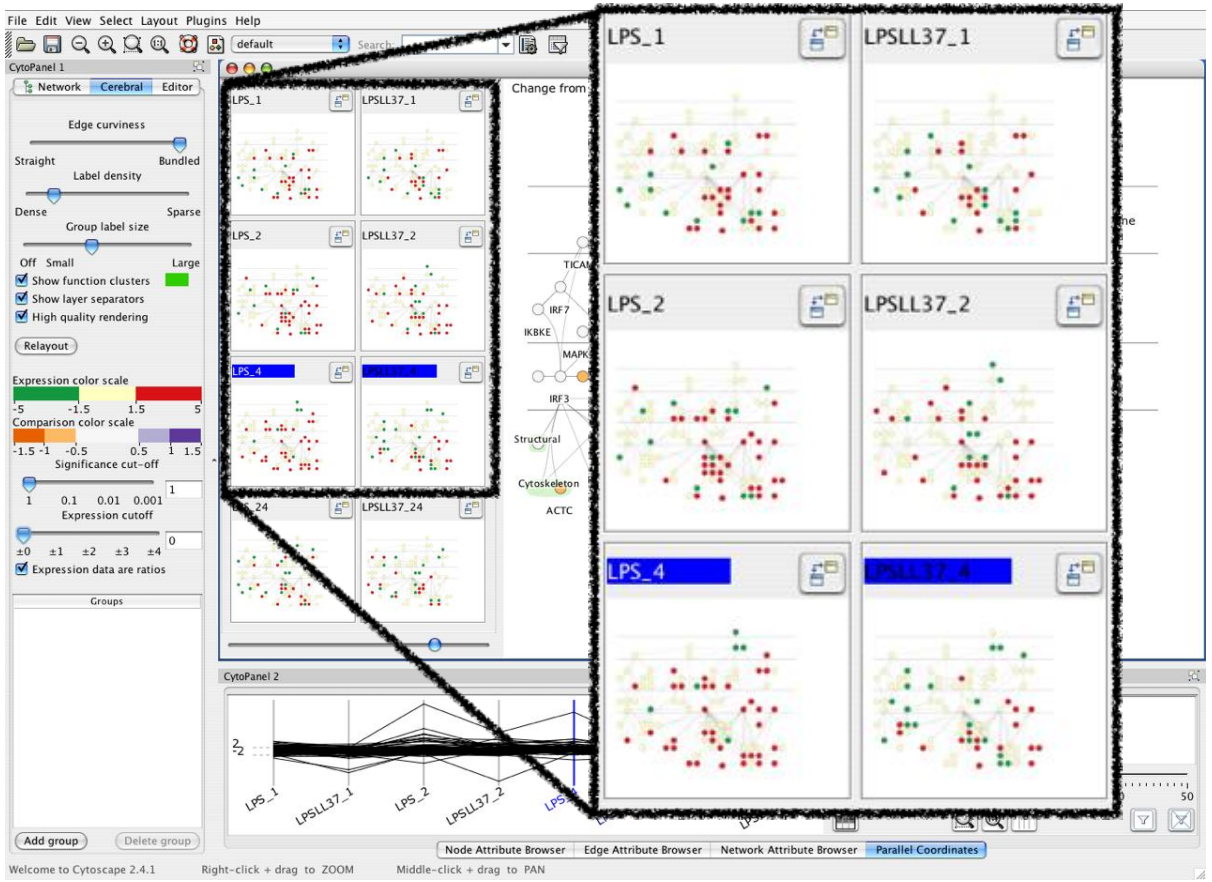
http://www.theusrus.de/Mondrian/

http://www.theusrus.de/blog/making-movies/

slide by Tamara Munzner

Facet > Small multiples

- encoding: same
- no shared data
  - different attributes for node colors
  - (same network layout)
- shared navigation

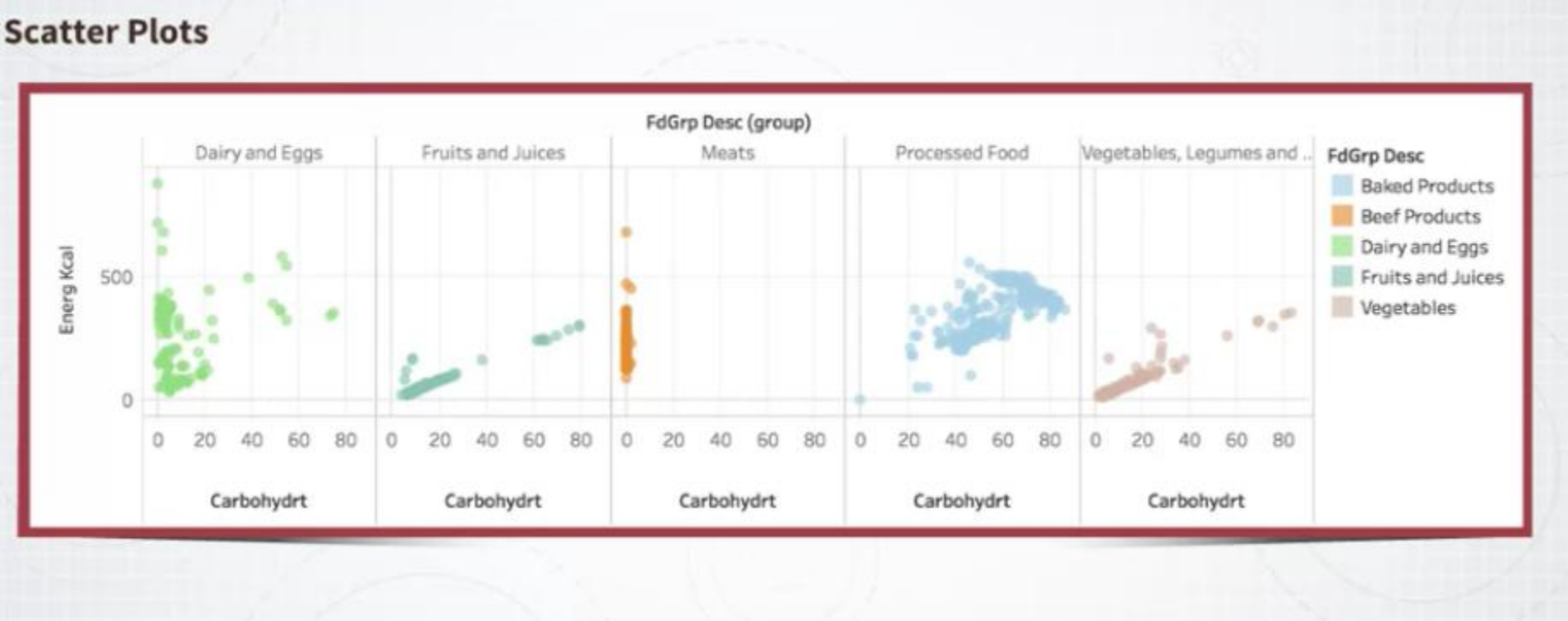


Cerebral: Visualizing Multiple Experimental Conditions on a Graph with Biological Context. Barsky, Munzner, Gardy, and Kincaid. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14:6 (2008), 1253–1260.

slide by Tamara Munzner

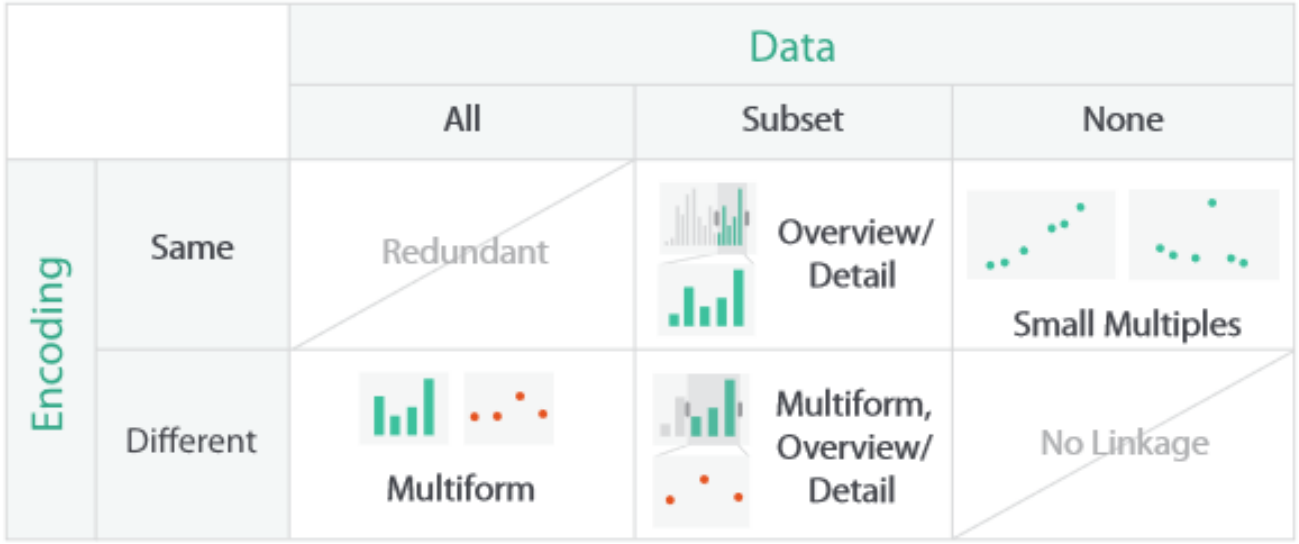
Facet > Small multiples

Facet > Small multiples



Facet > Coordinate views: Design choice interaction

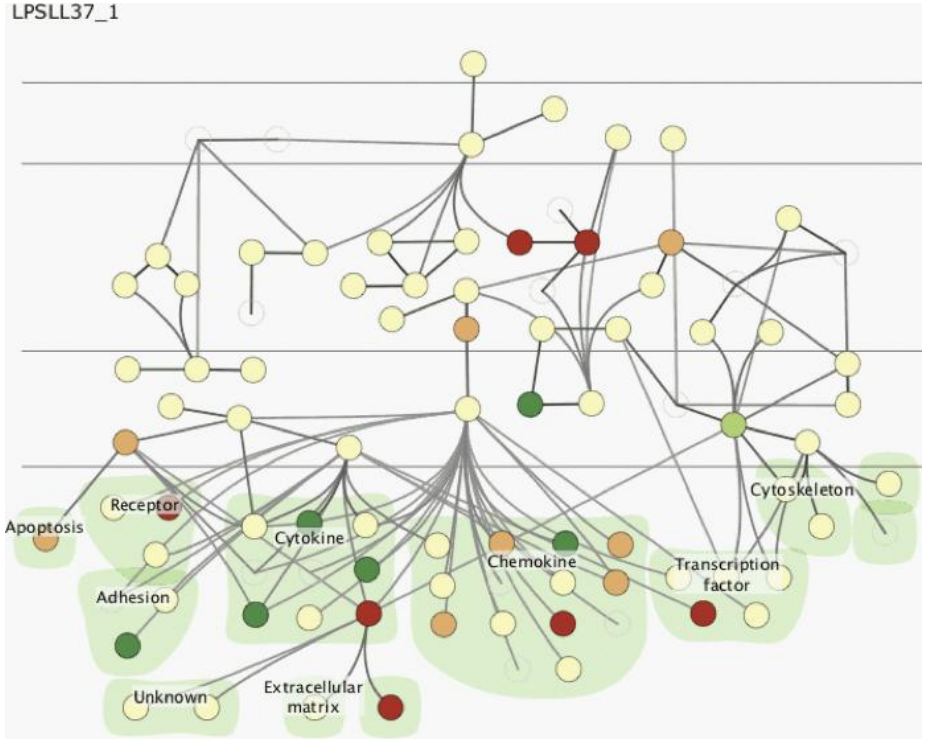
- why juxtapose views?
  - benefits: eyes vs memory
    - lower cognitive load to move eyes between 2 views than remembering previous state with single changing view
  - costs: display area, 2 views side by side each have only half the area of one view



slide by Tamara Munzner

Facet > Why not animation?

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

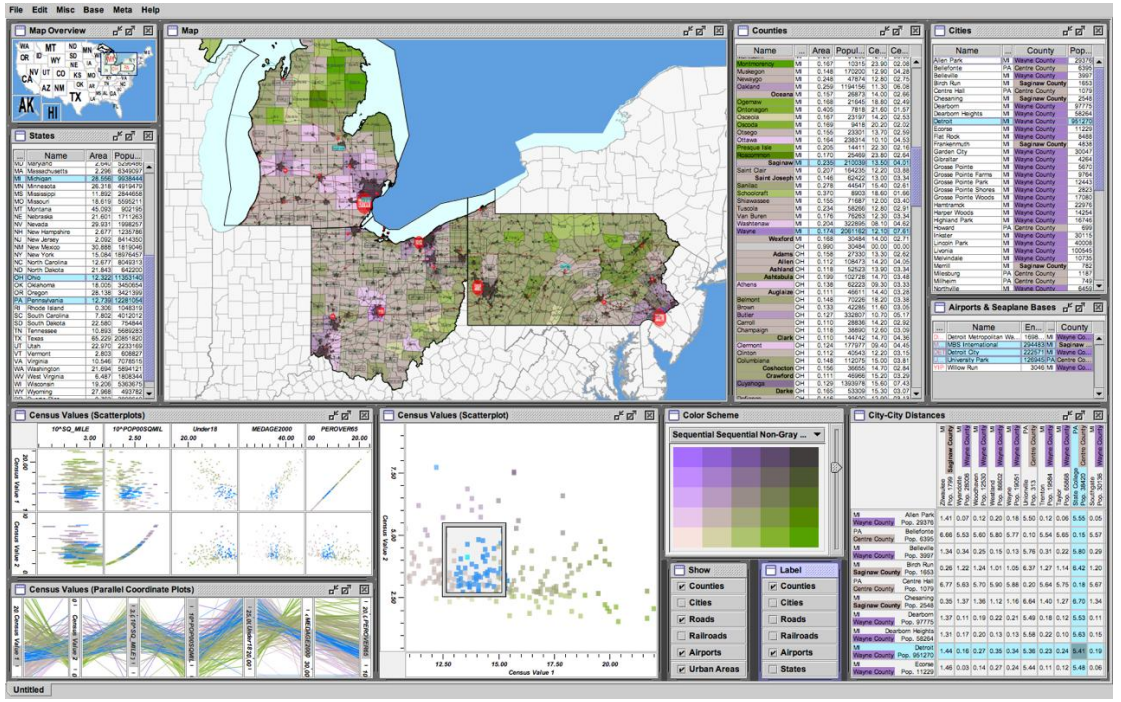


slide by Tamara Munzner

Facet > Improvise

- pushing limits on view count, interaction complexity

- how many is ok?
  - open research question
- reorderable lists
  - easy lookup
  - useful when linked to other encodings



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

slide by Tamara Munzner

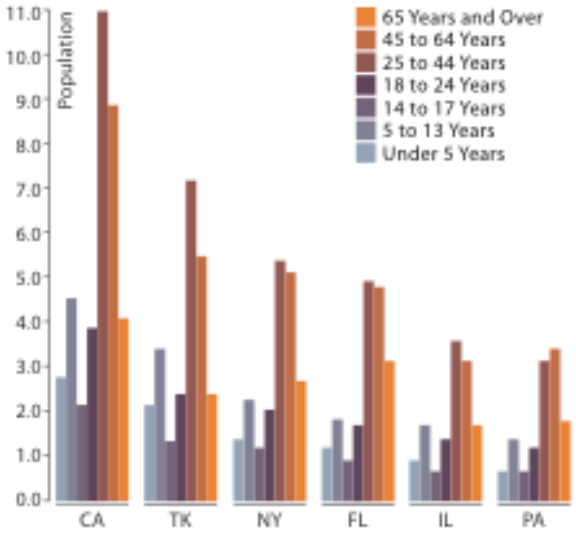
Facet > Partition into views

- 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
- no strict dividing line
  - view: big/detailed
    - contiguous region in which visually encoded data is shown on the display
  - glyph: small/iconic
    - object with internal structure that arises from multiple marks

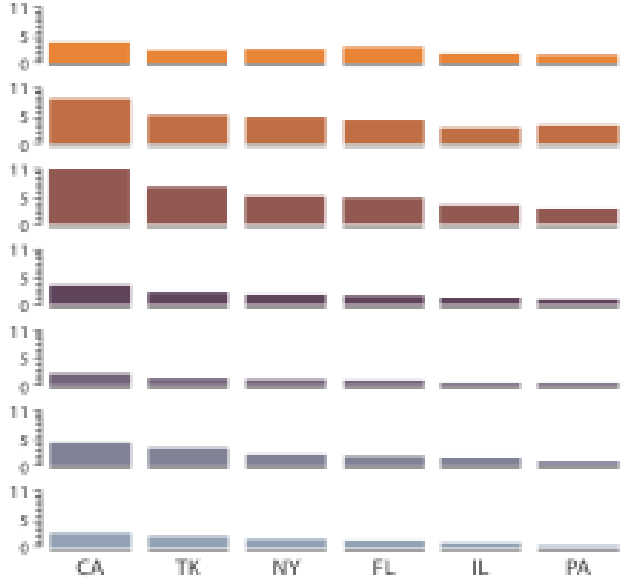
slide by Tamara Munzner

Facet > Partitioning: List alignment

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



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



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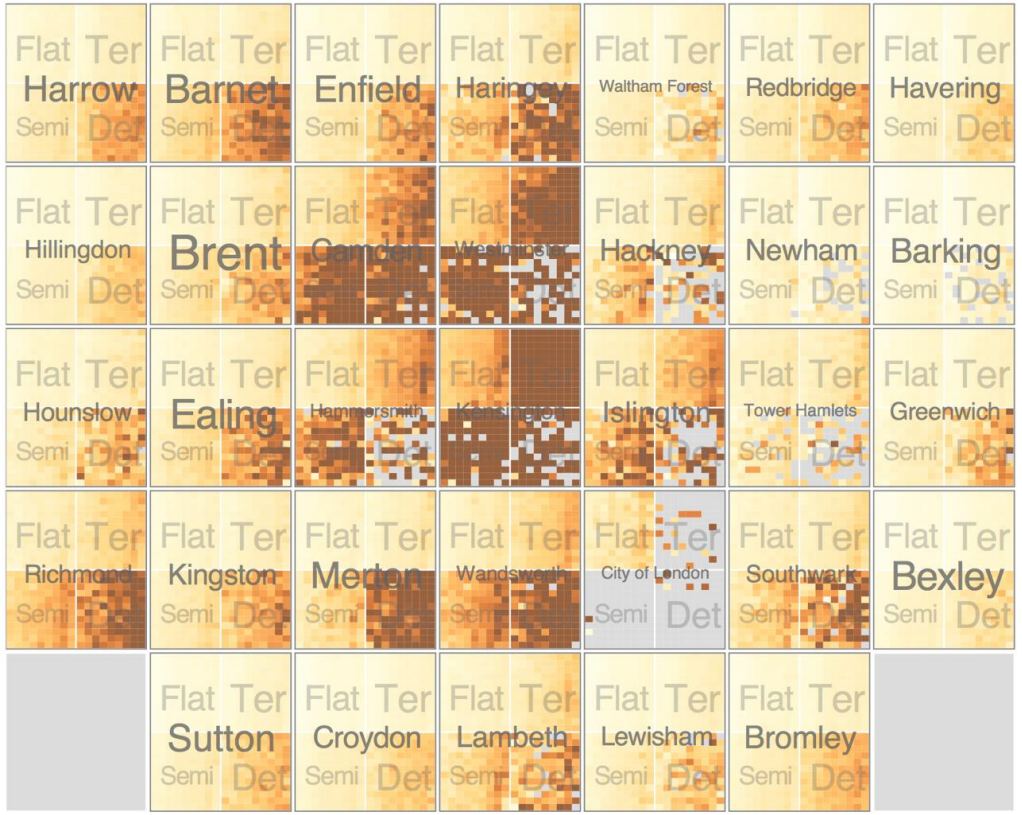
Facet > Partitioning: Recursive subdivision

- split by
  - neighborhood
  - type
  - 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.

slide by Tamara Munzner

Facet > Partitioning: Recursive subdivision

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

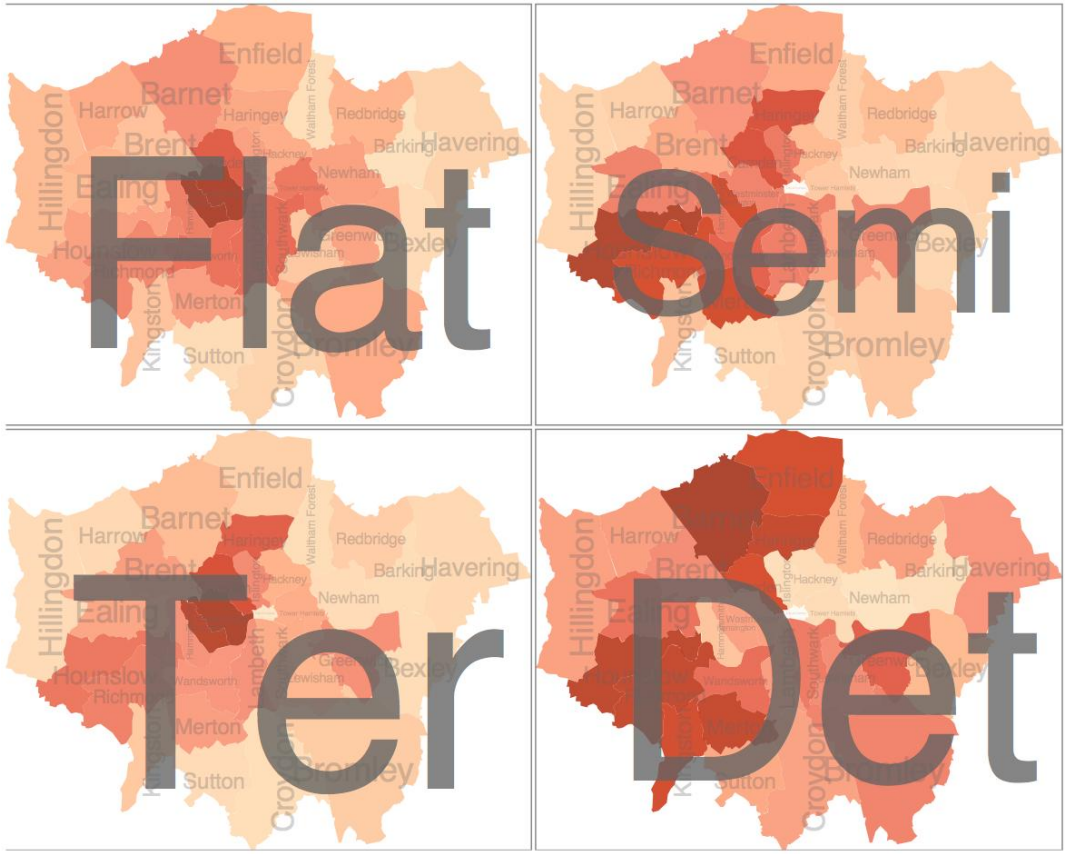
HIVE

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.

slide by Tamara Munzner

Facet > Partitioning: Recursive subdivision

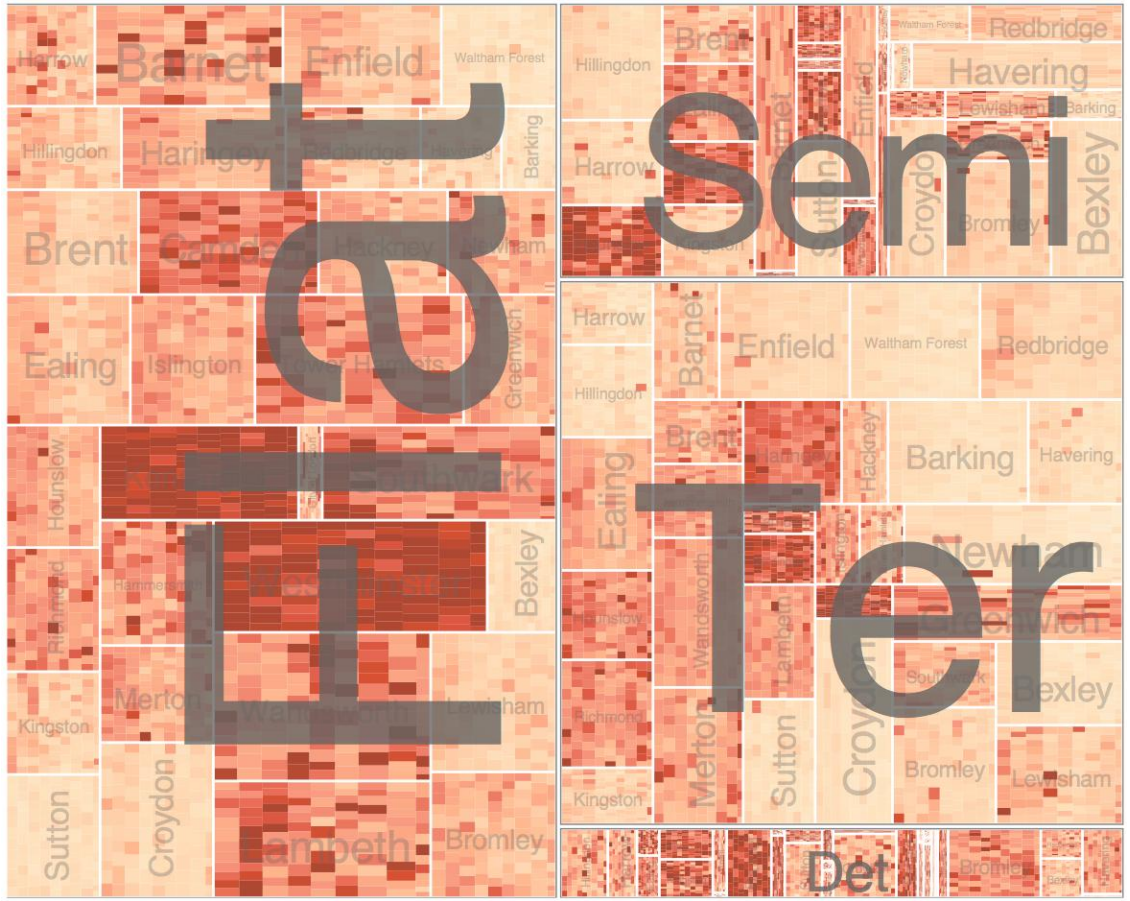
- different encoding for second-level regions
  - choropleth maps



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 > Partitioning: Recursive subdivision

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

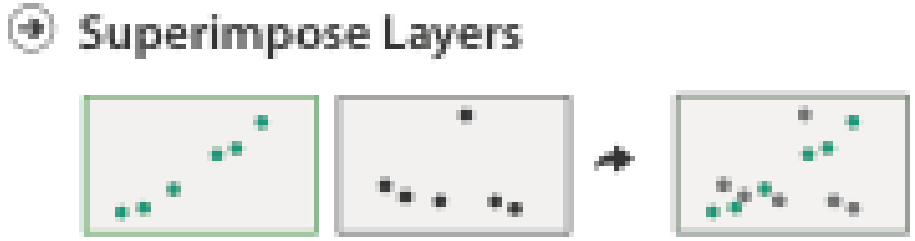


HIVE

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 > 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 achieveable, three with careful design
  - small static set, or dynamic from many possible?

slide by Tamara Munzner

Facet > Static visual layering

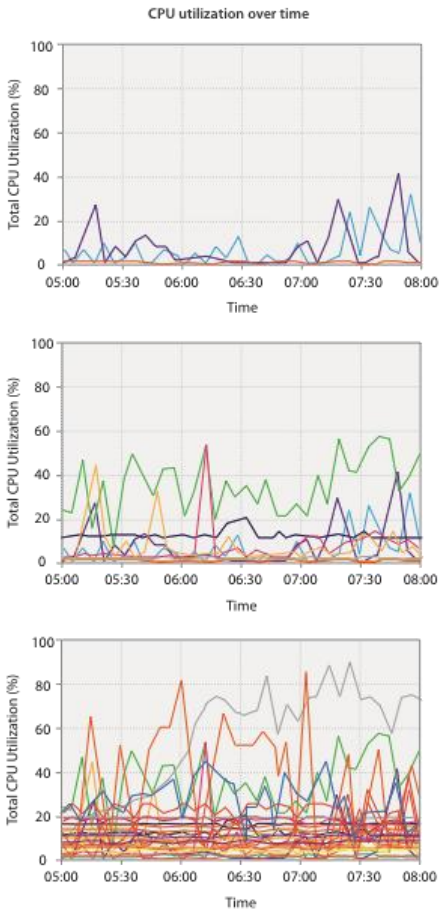
- foreground layer: roads
  - hue, size distinguishing main from minor
  - high luminance contrast from background
- background layer: regions
  - desaturated colors for water, parks, land areas
- user can selectively focus attention
- "get it right in black and white"
  - check luminance contrast with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

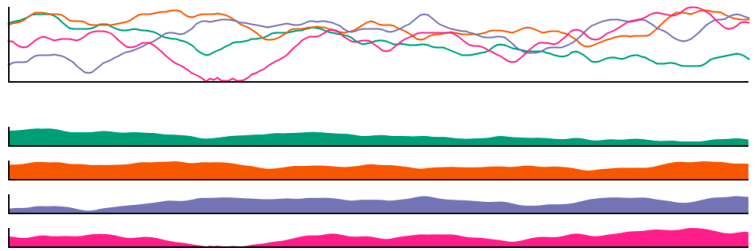
Get it right in black and white, Stone 2010.

slide by Tamara Munzner

Facet > Superimposing limits

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



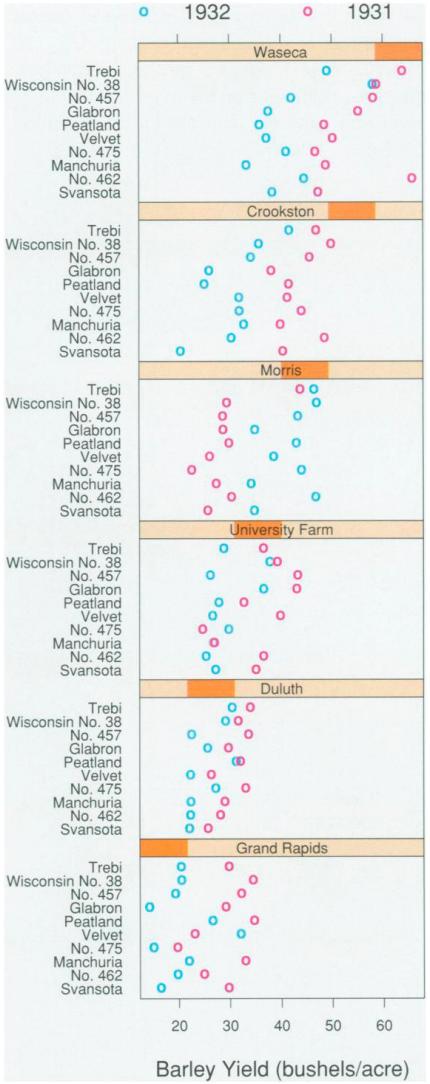


[Graphical Perception of Multiple Time Series. Javed, McDonnel, and Elmqvist. IEEE Transactions on Visualization and Computer Graphics (Proc. IEEE InfoVis 2010) 16:6 (2010), 927–934.]

slide by Tamara Munzner

Facet > Trellis plots

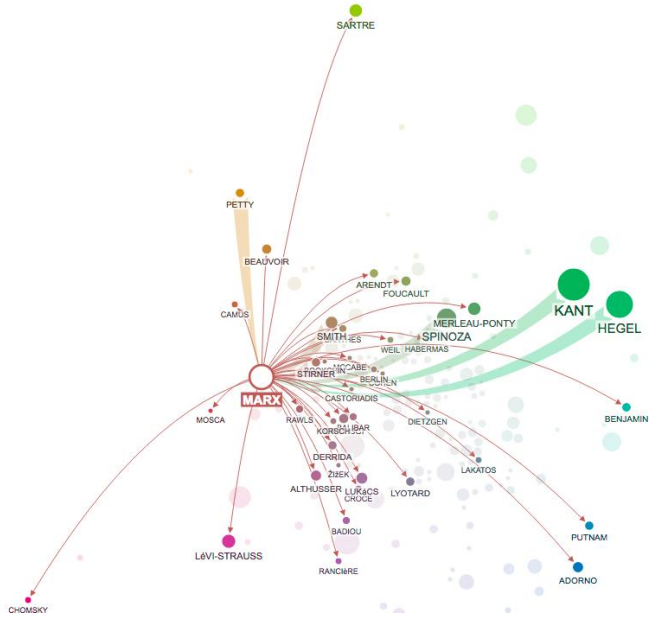
- superimpose within same frame
  - color code by year
- partitioning
  - split by site, rows are wheat varieties
- main-effects ordering
  - derive value of median for group, use to order
  - order rows within view by variety median
  - order views themselves by site median

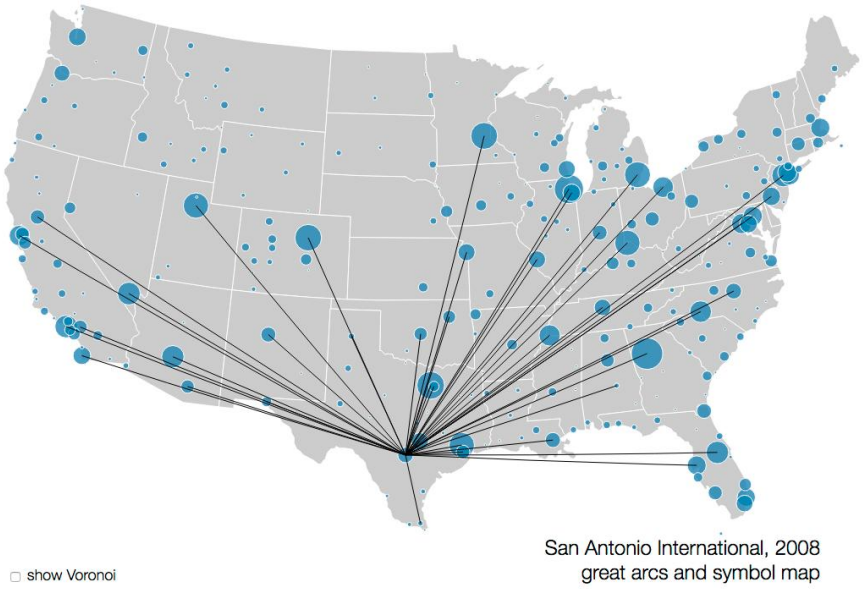


slide by Tamara Munzner

Facet > Dynamic visual layering

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





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

slide by Tamara Munzner

Facet > multiple views example

NASA earth observatory

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

slide by Tamara Munzner

Interaction taxonomy (Munzner)

- How to handle complexity: 1 + 3 strategies

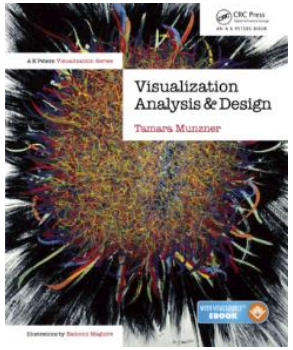
derive new data to show within view

change view over time

facet across multiple views

reduce items/attributes within single view

→ *Derive*



Tamara Munzner

Manipulate

- Change

- Select

- Navigate

Facet

- Juxtapose

- Partition

- Superimpose

Reduce

- Filter

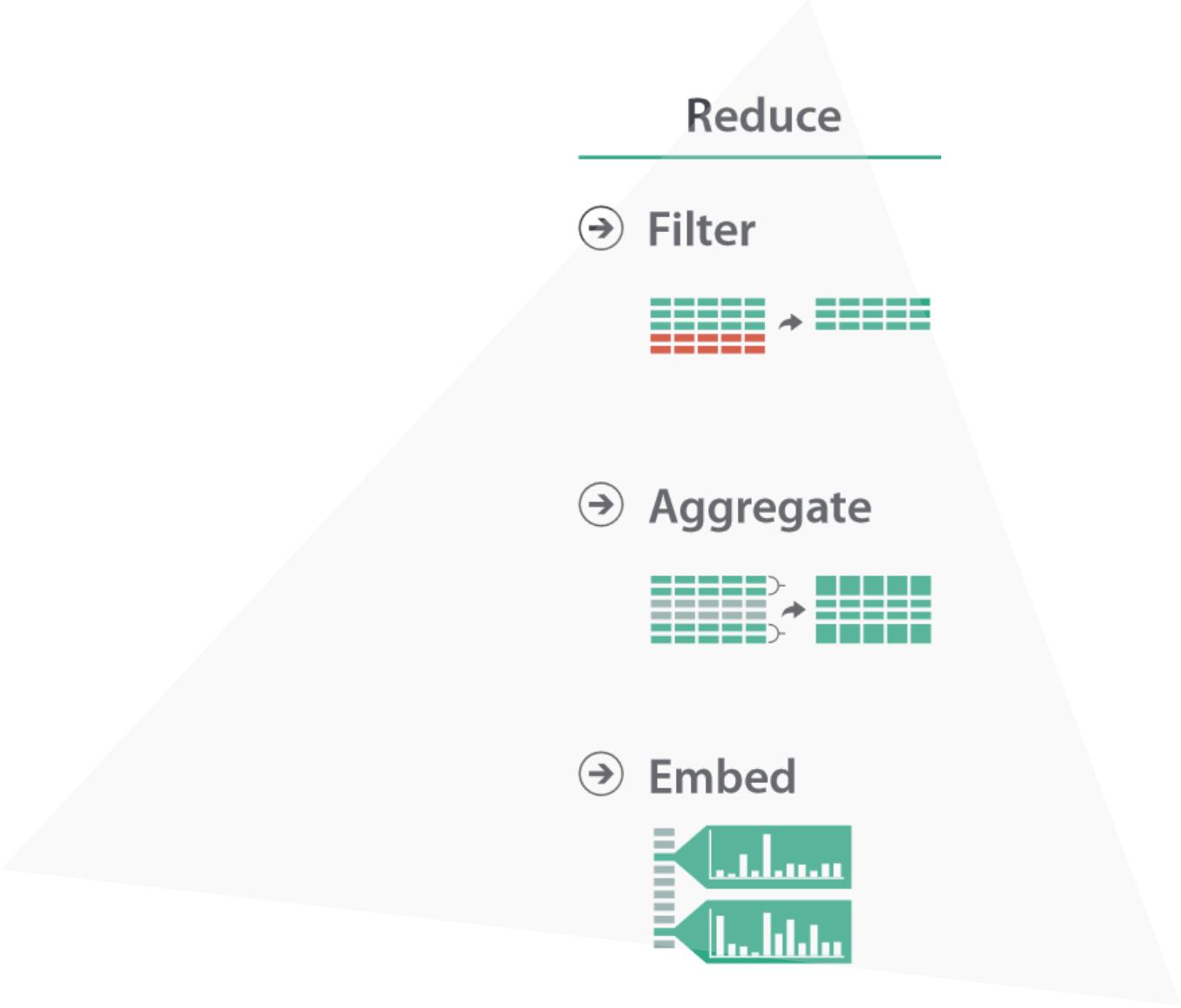
- Aggregate

- Embed

slide by Tamara Munzner

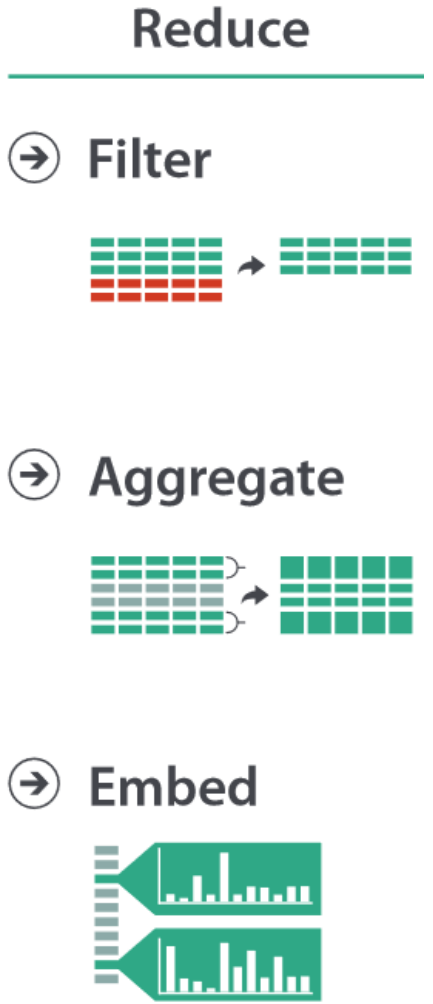
Interaction taxonomy (Munzner)

- Manipulate
  - Change
  - Select
  - Navigate
- Facet
  - Juxtapose
  - Partition
  - Superimpose
- **Reduce**
  - Filter
  - Aggregate
  - Embed



Reduce items and attributes

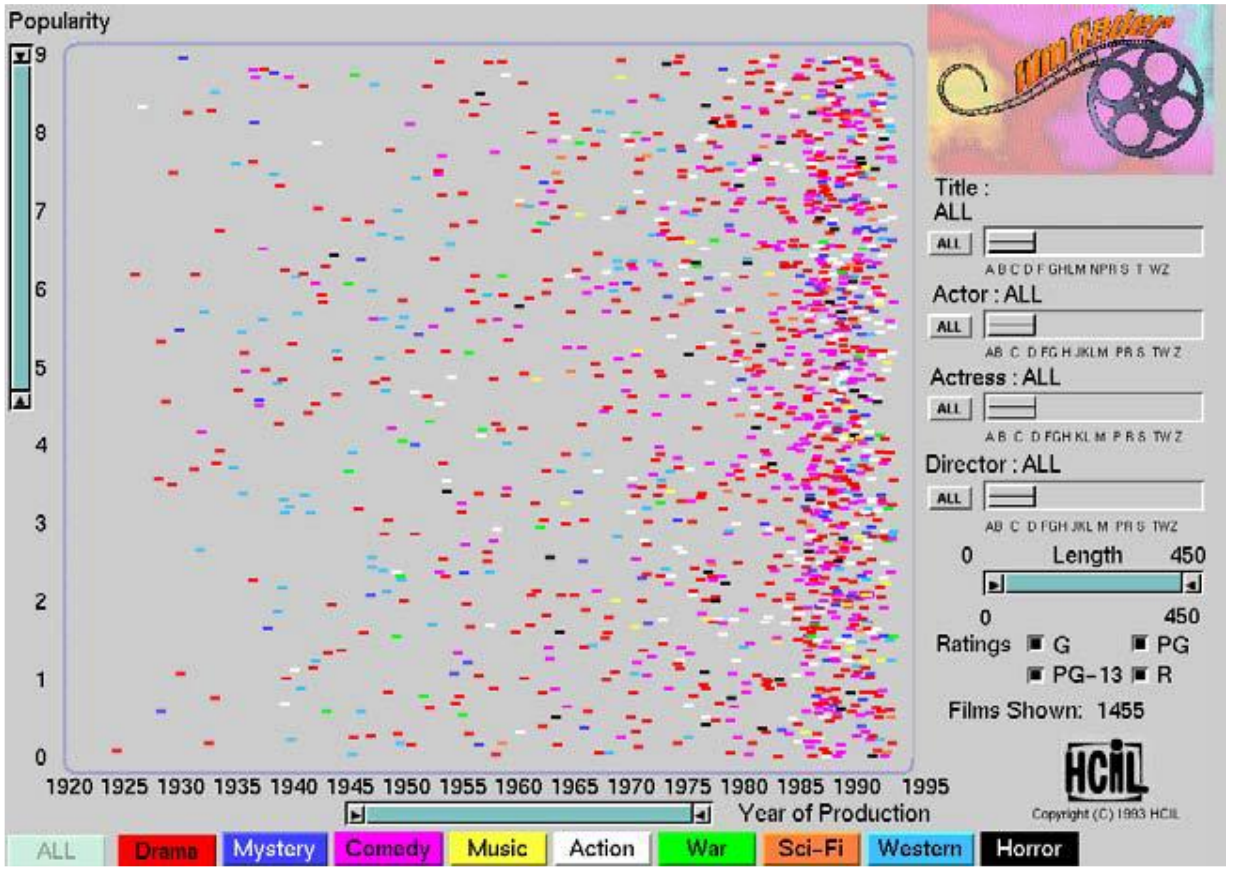
- Filter
  - straightforward and intuitive to understand and compute
  - …but, out of sight = out of mind
- Aggregation
  - inform about whole set
  - …but difficult to avoid losing signal
- not mutually exclusive
  - combine filter, aggregate
  - combine reduce, change, facet



slide by Tamara Munzner

Reduce > Filter

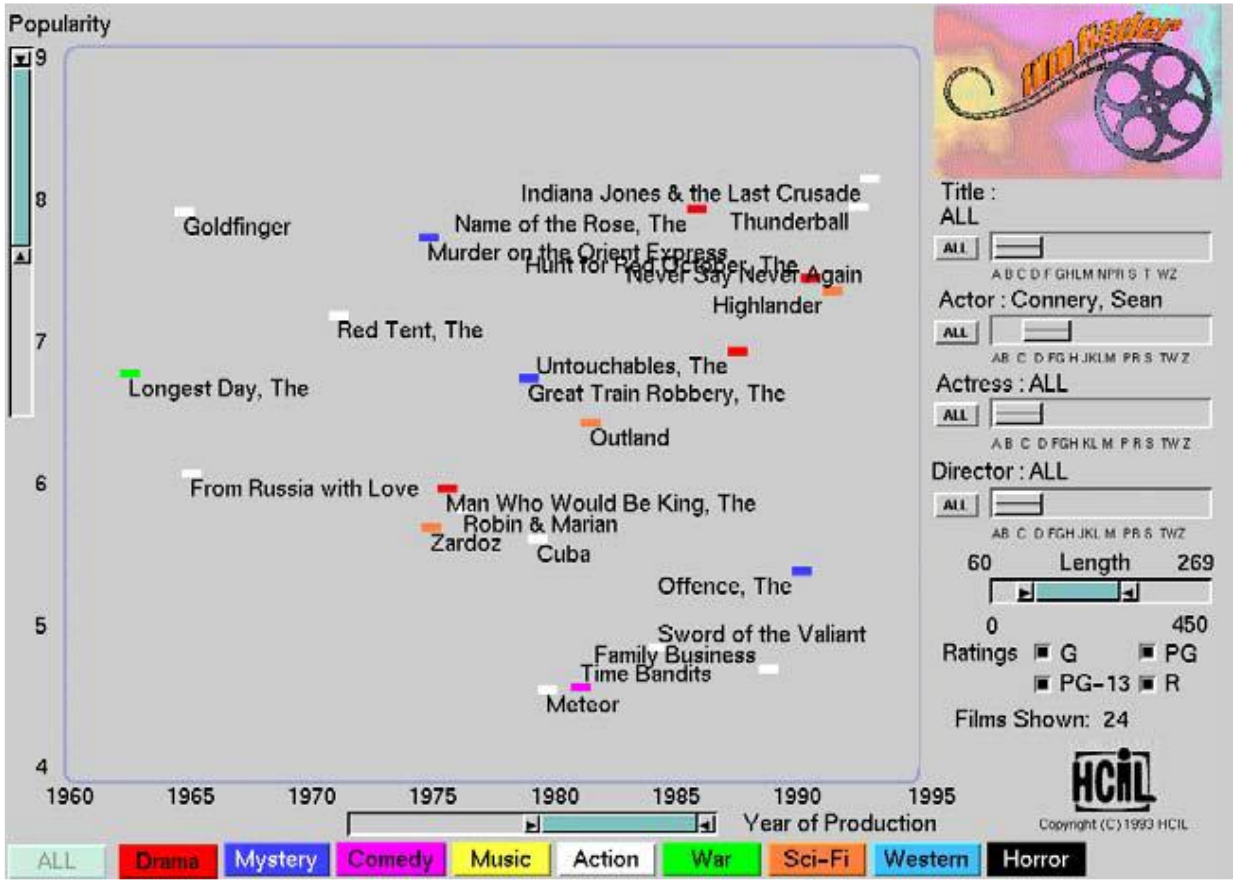
- FilmFinder (overview, filtering, and detail)



University of Maryland, 1994

Reduce > Filter

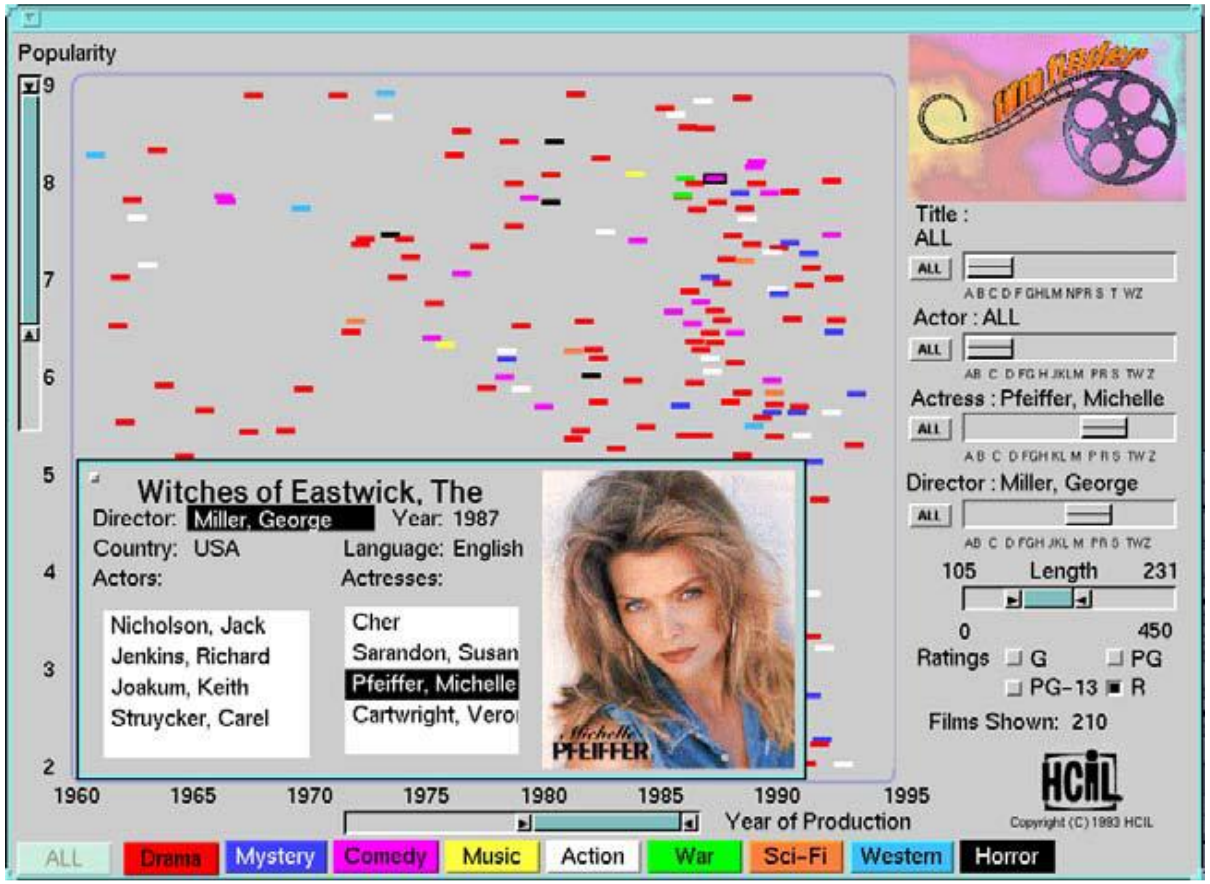
- FilmFinder (overview, filtering, and detail)



University of Maryland, 1994

Reduce > Filter

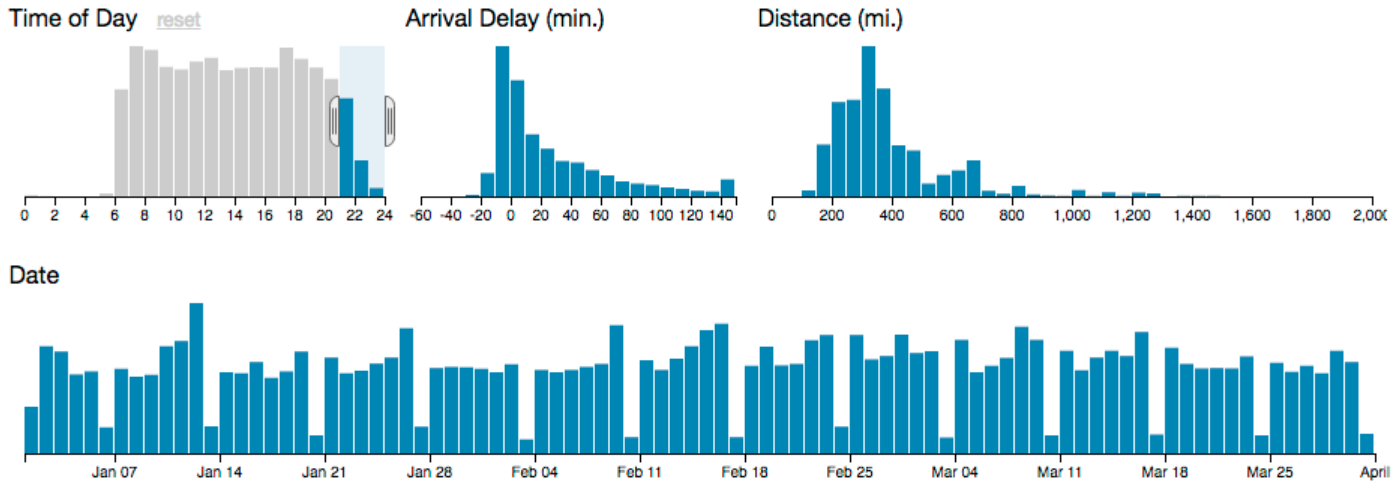
- FilmFinder (overview, filtering, and detail)



University of Maryland, 1994

Reduce > Filter: cross filtering

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



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

slide by Tamara Munzner

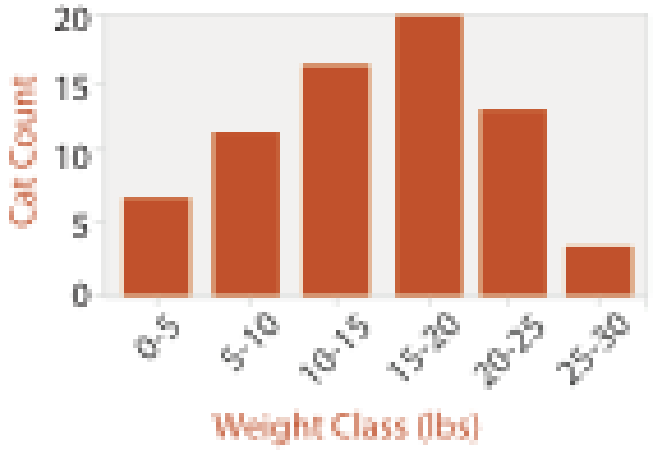
Reduce > Filter: cross filtering

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

slide by Tamara Munzner

Reduce > Aggregate: histogram

- task: find distribution
- data: table
- derived data
  - new table: keys are bins, values are counts

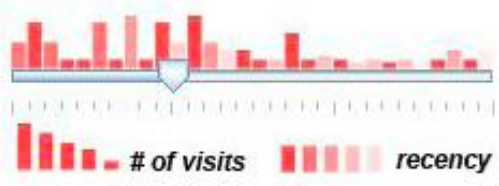


- bin size crucial
  - pattern can change dramatically depending on discretization
  - opportunity for interaction: control bin size on the fly

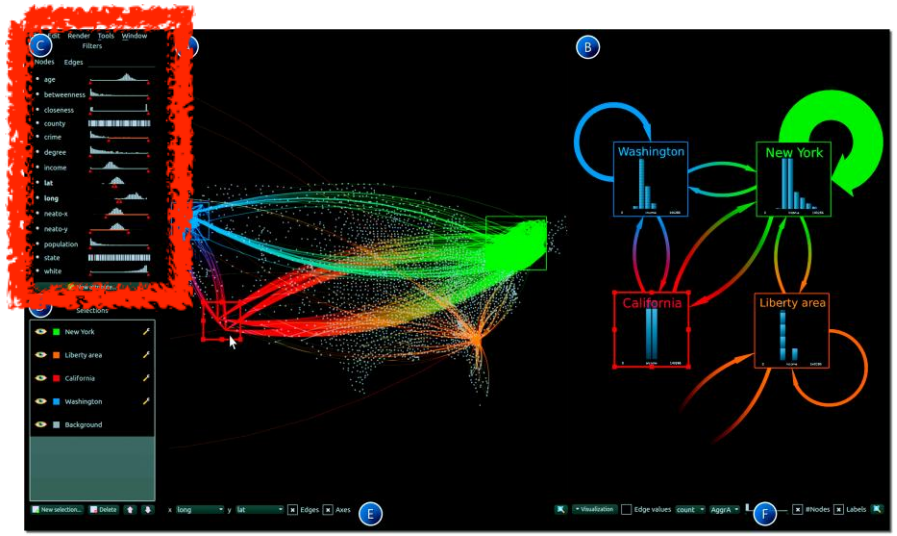
slide by Tamara Munzner

Reduce > Aggregate: scented widgets

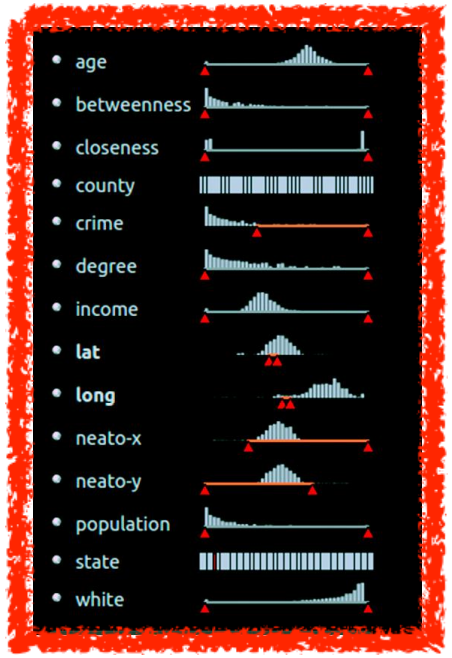
- augmented widgets show information scent
  - cues to show whether value in drilling down further vs looking elsewhere
- concise use of space: histogram on slider



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

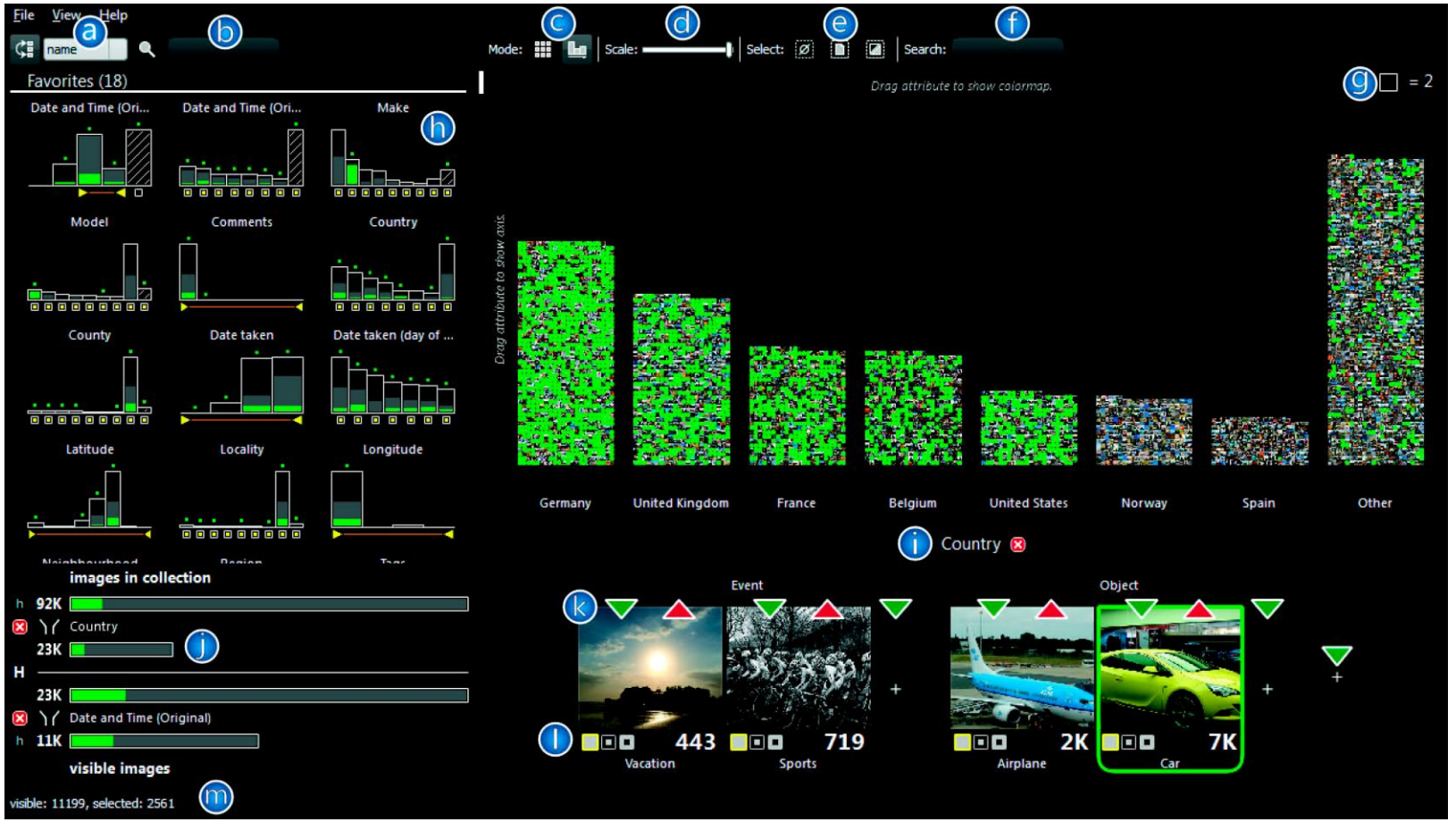


[Multivariate Network Exploration and Presentation: From Detail to Overview via Selections and Aggregations. van den Elzen, van Wijk, IEEE TVCG 20(12): 2014 (Proc. InfoVis 2014).]



slide by Tamara Munzner

Reduce > Aggregate: Scented histogram bisliders: detailed

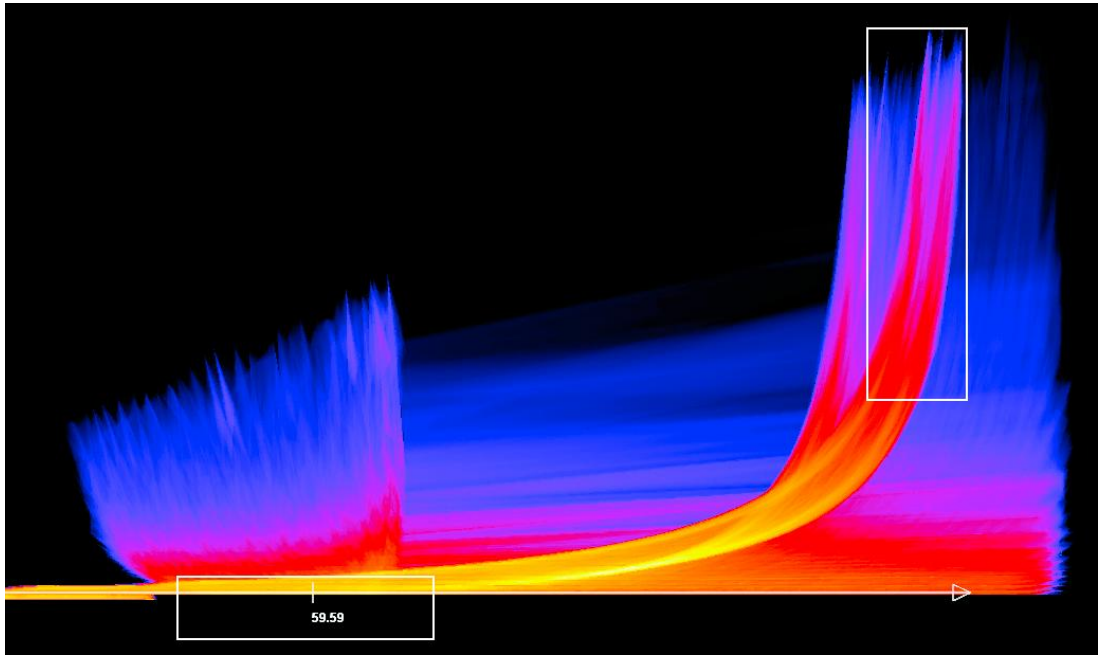


ICLIC: Interactive categorization of large image collections. van der Corput and van Wijk. Proc. PacificVis 2016.

slide by Tamara Munzner

Reduce > Aggregate: Continuous scatterplot

- data: table
- derived data: table
  - key attribs x,y for pixels
  - quant attrib:
    overplot density



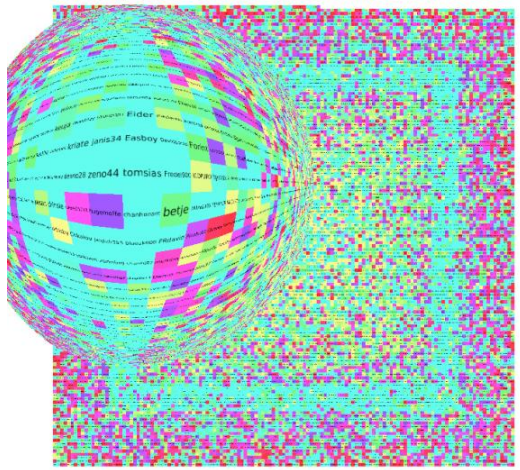
- dense space-filling 2D matrix
- color: sequential categorical hue + ordered luminance colormap

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

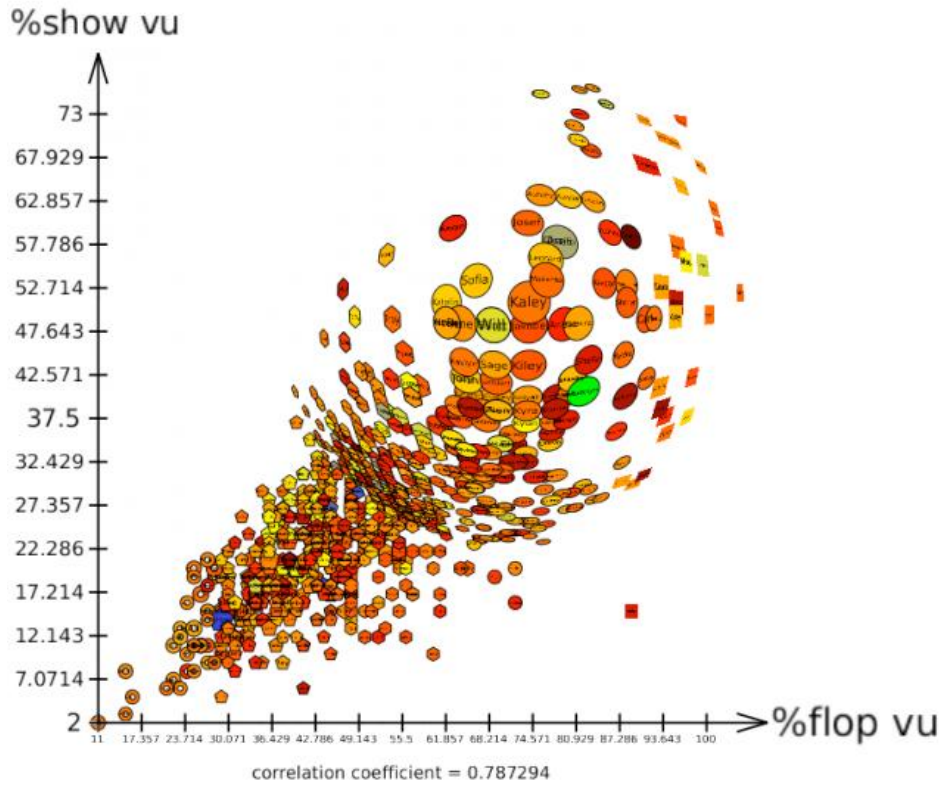
slide by Tamara Munzner

Reduce > Fisheye Lens

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



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



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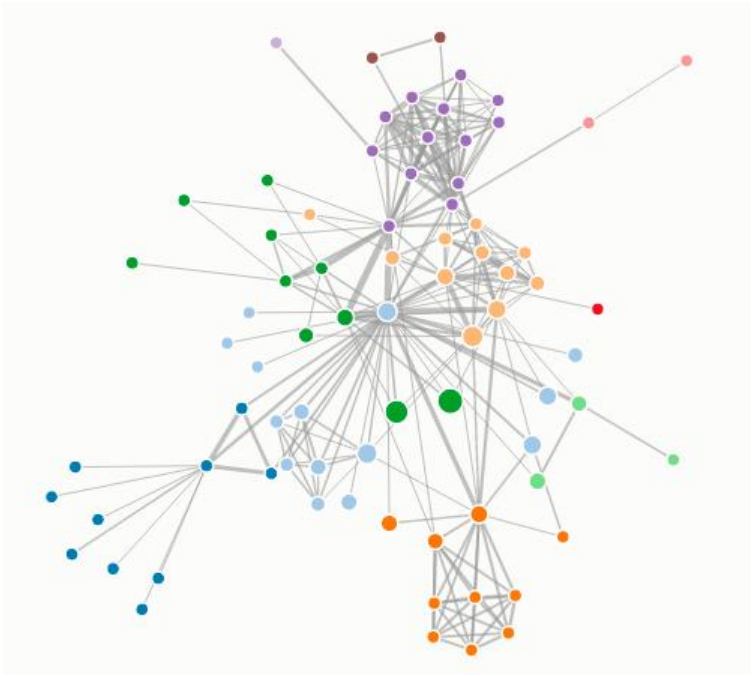
Reduce > Fisheye Lens



D3 Fisheye Lens, https://bost.ocks.org/mike/fisheye/

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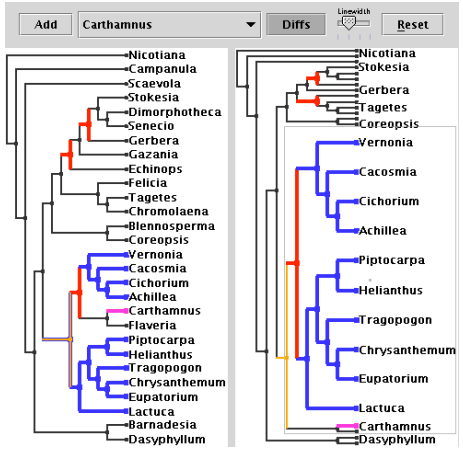
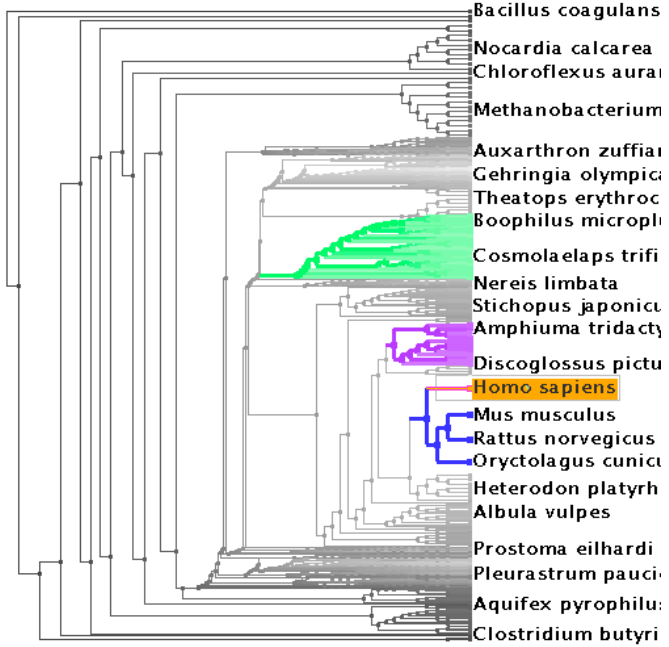
Reduce > Stretch and Squish Navigation

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





[https://youtu.be/GdaPj8a9QEo]

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

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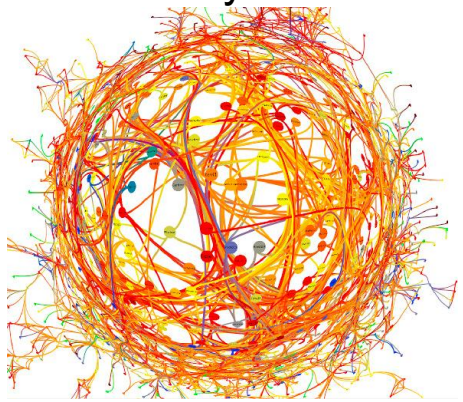
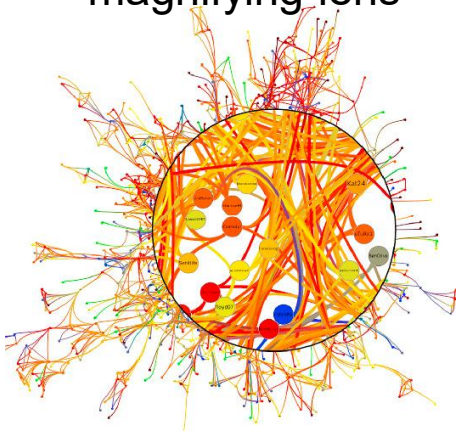
Reduce > Distortion costs and benefits

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

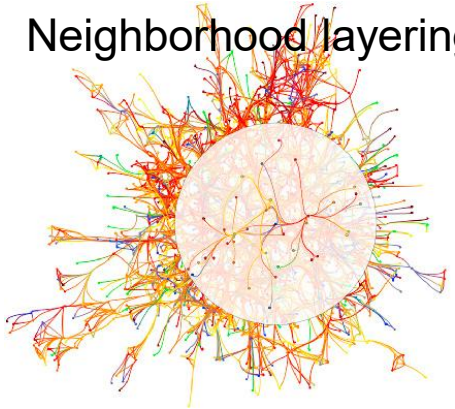
fisheye lens



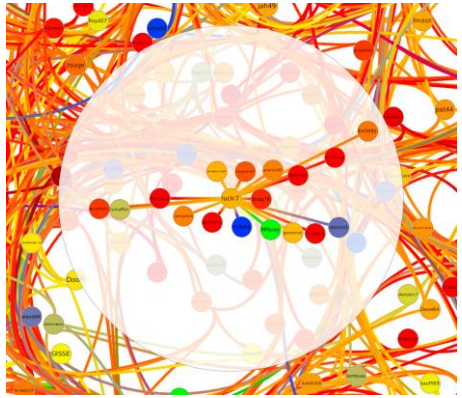
magnifying lens



Neighborhood layering



Bring and Go



Living Flows: Enhanced Exploration of Edge-Bundled Graphs Based on GPU-Intensive Edge Rendering. Lambert, Auber, and Melançon. Proc. Intl. Conf. Information Visualisation (IV), pp. 523–530, 2010.

Further reading

- Yi, J. S., Kang, Y. ah, Stasko, J. T., & Jacko, J. A. (2007). Toward a Deeper Understanding of the Role of Interaction in Information Visualization. *IEEE Transactions on Visualization and Computer Graphics (TVCG)*, *13*(6), 1224–1231. Retrieved from http://www.cc.gatech.edu/~stasko/papers/infovis07-interaction.pdf
- Raskin, J. (2000). *The Humane Interface: New Directions for Designing Interactive Systems*. Addison Wesley.

Thank you!

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http://eclass.uoa.gr/courses/DI411/