Data Visualization (CSCI 490/680)
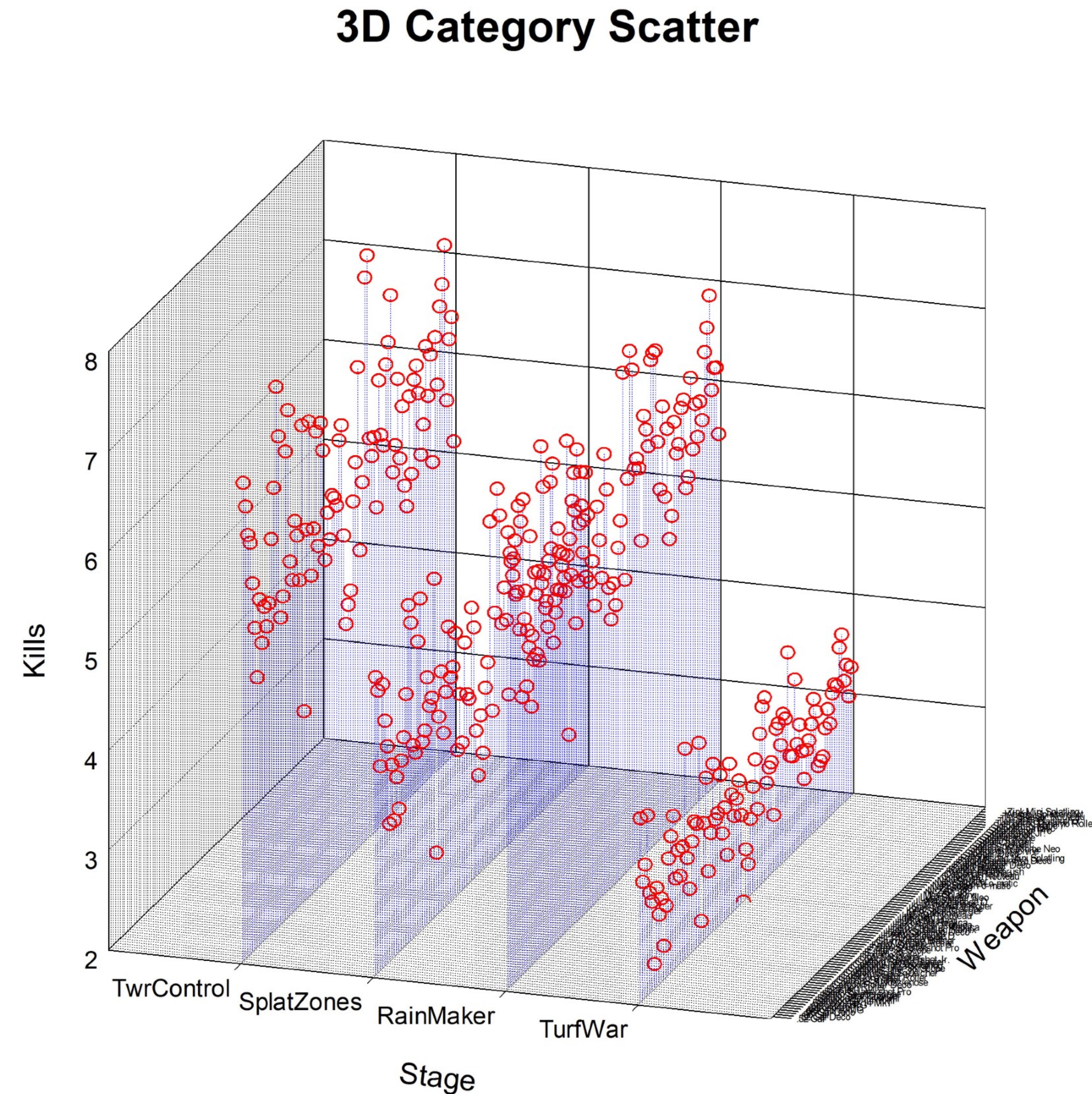
Interaction & Multiple Views
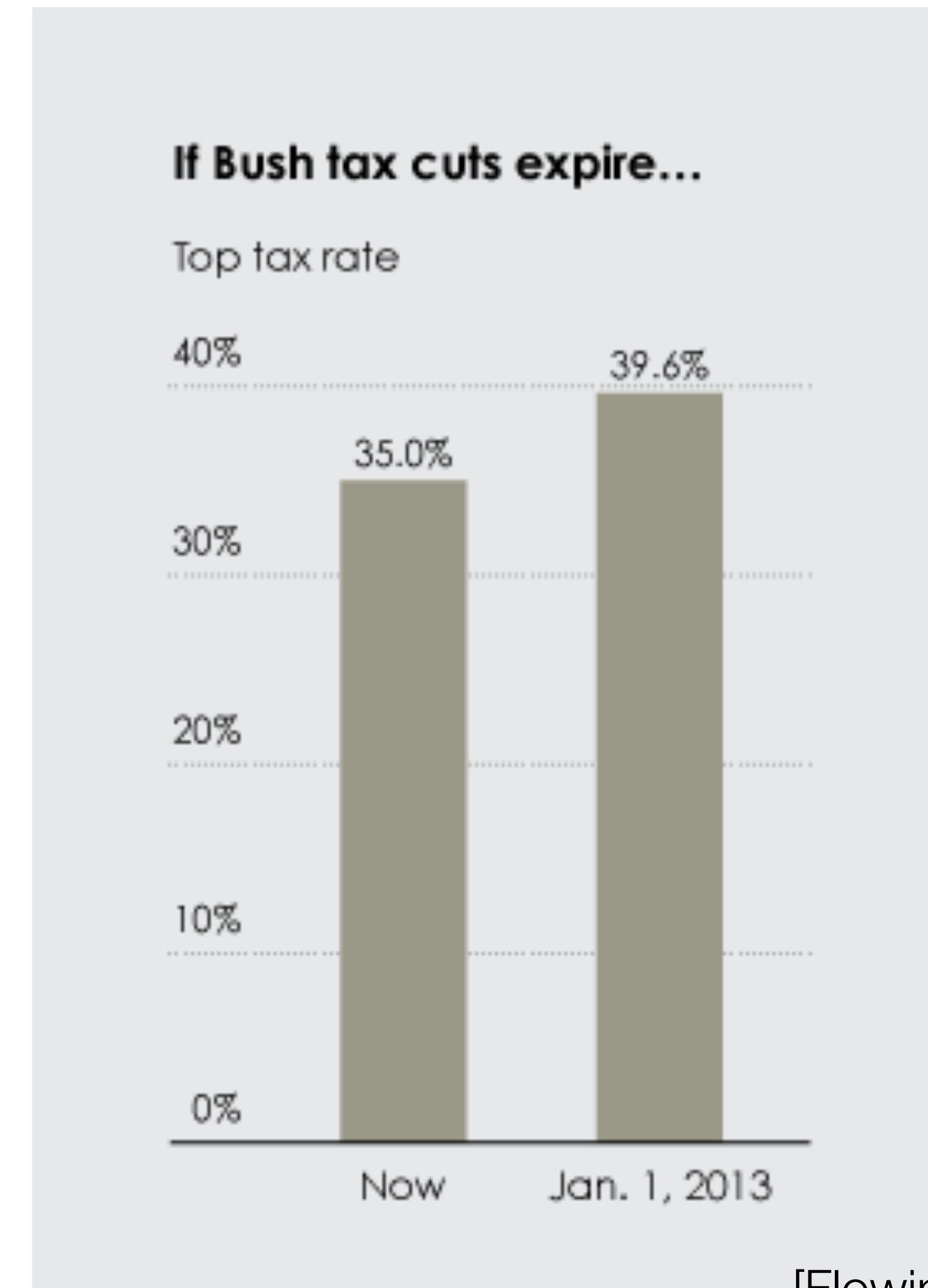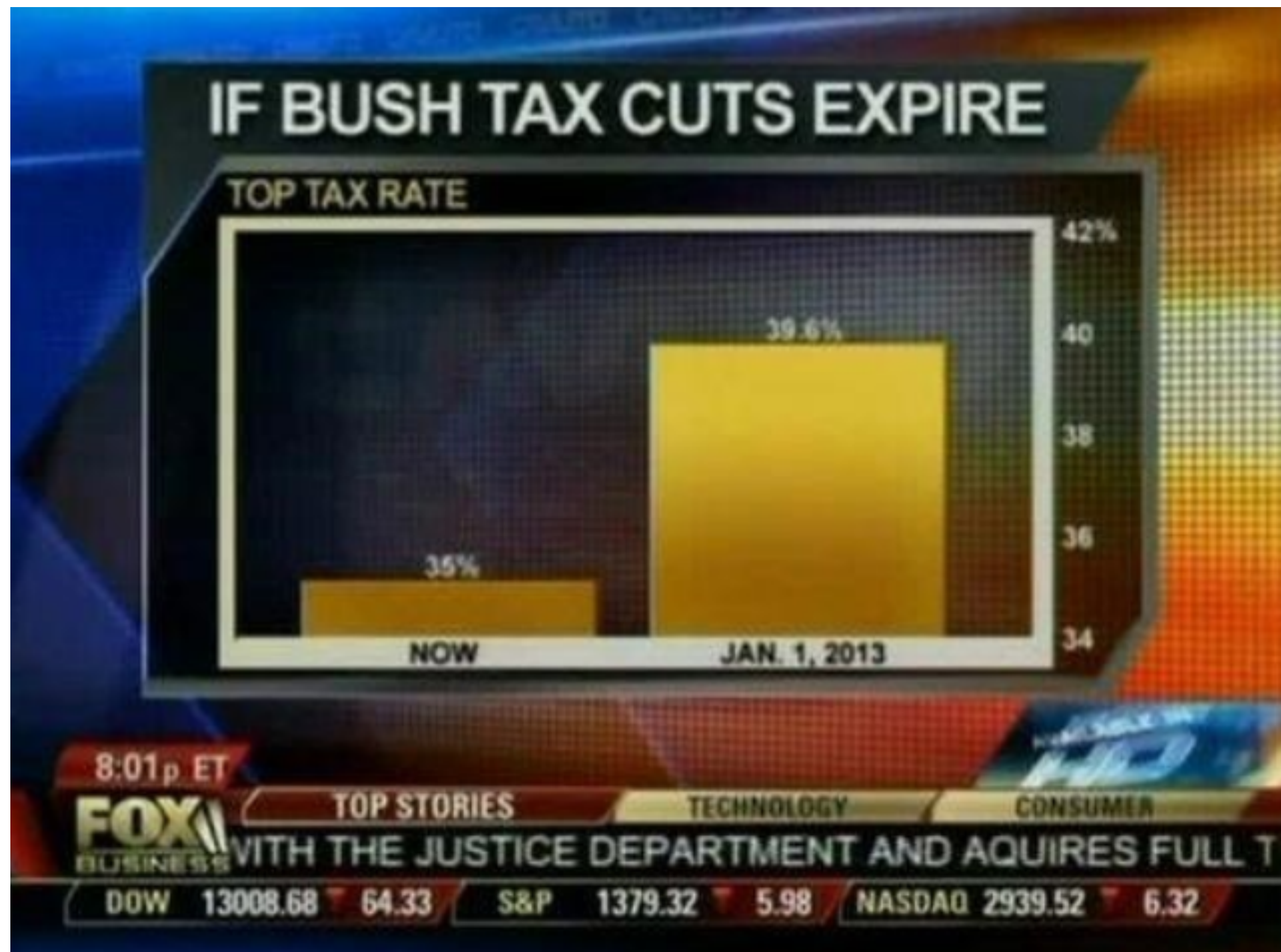
Dr. David Koop

What is wrong with here and how can it be fixed?
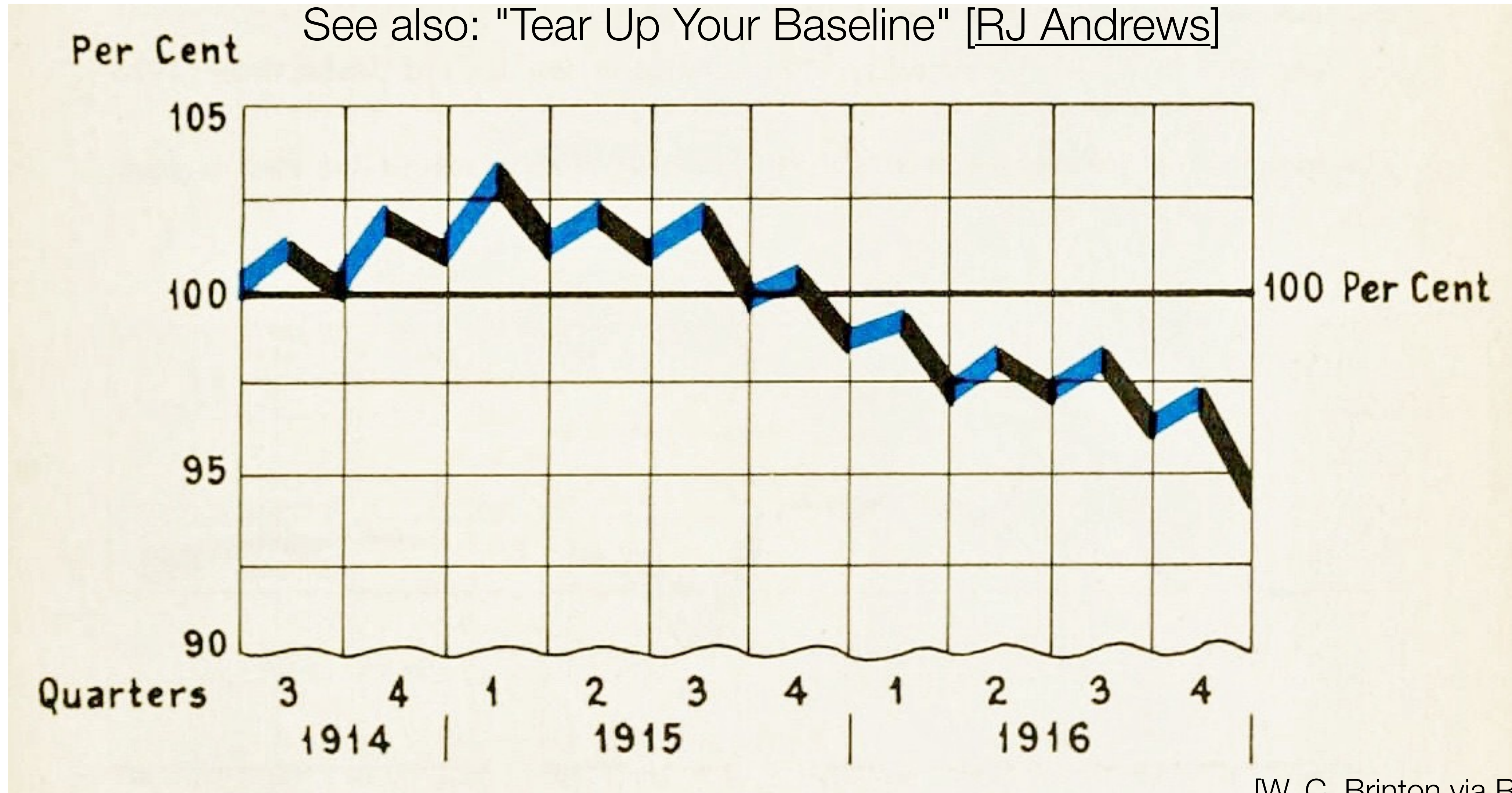
3D Category Scatter

[WTF Visualizations, 2017]

Good: Data magnitude <=> Mark magnitude

[Flowing Data, 2012]

Show when the baseline is not zero
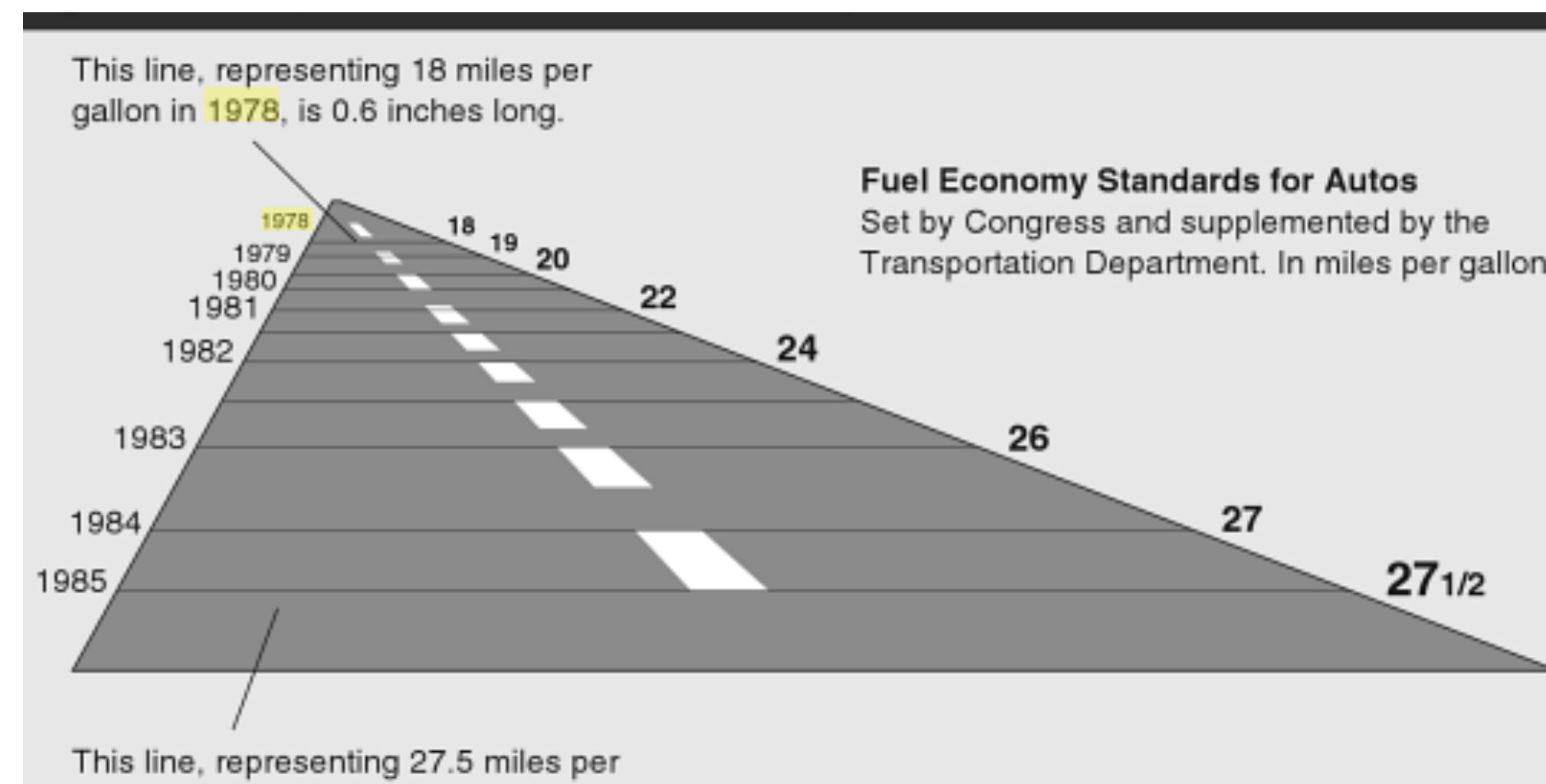
See also: "Tear Up Your Baseline" [RJ Andrews]
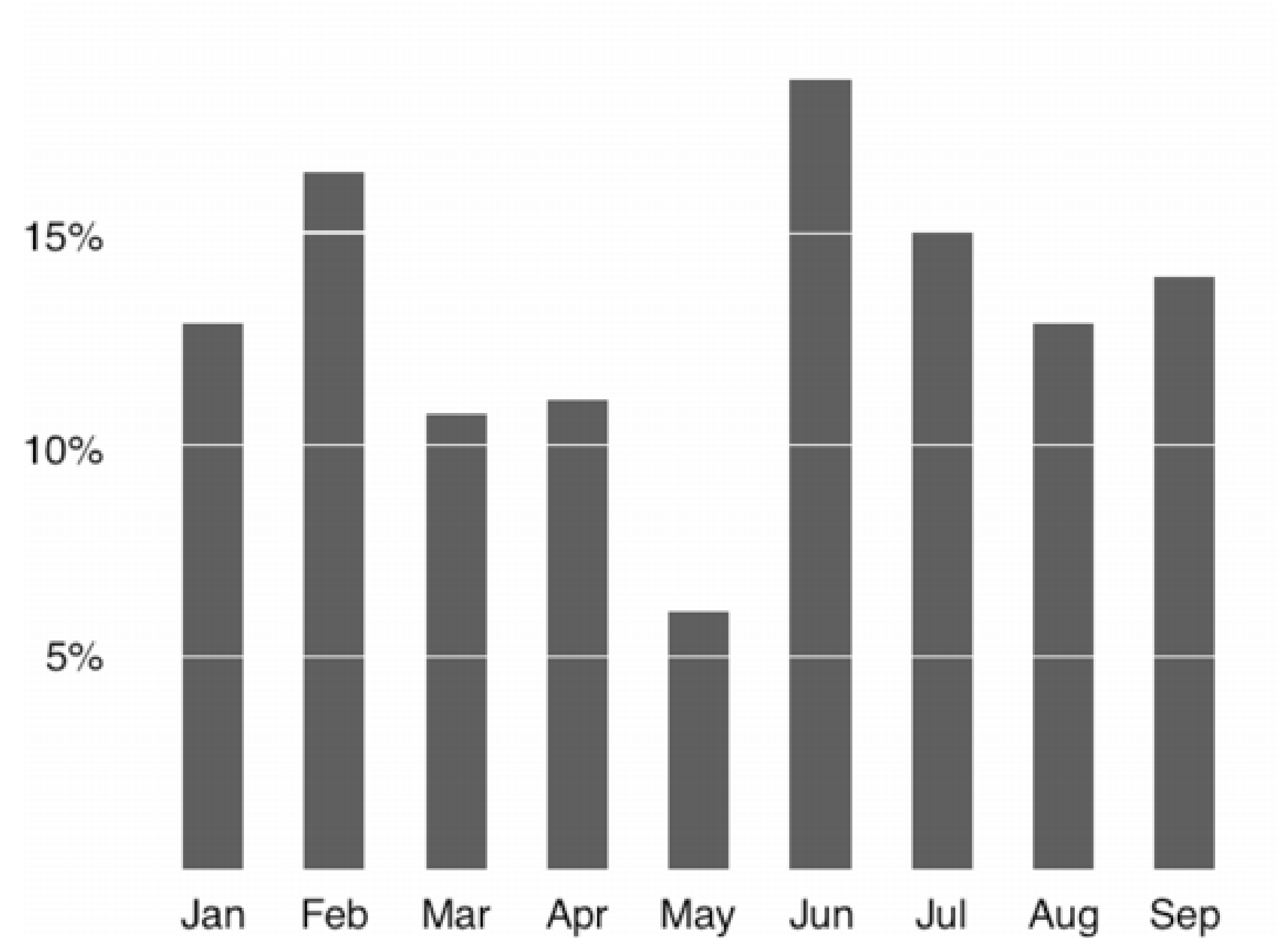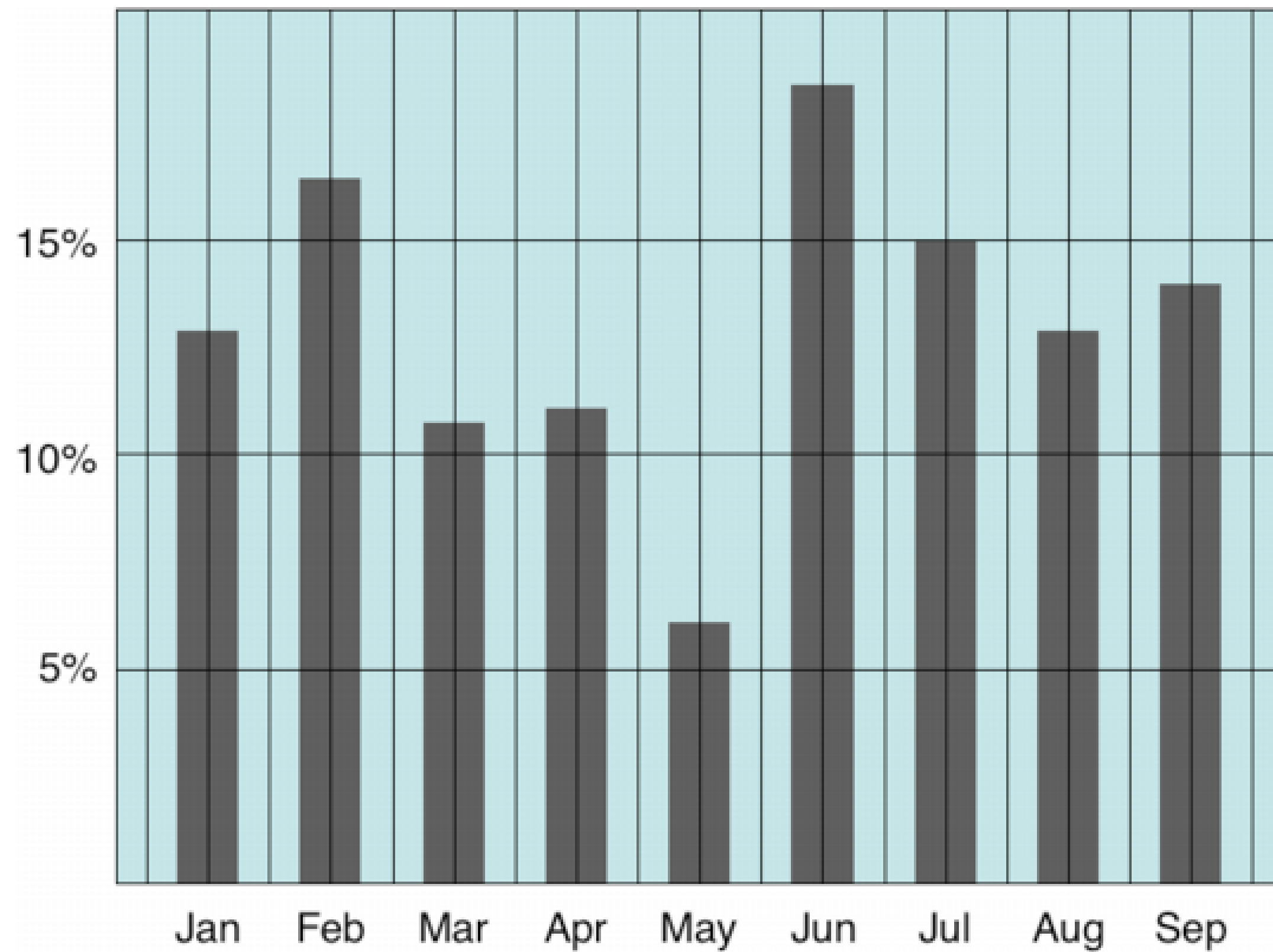

[W. C. Brinton via RJ Andrews]

Tufte's Lie Factor

- Size of effect = (2nd value - 1st value) / (1st value)
- Lie factor = (size of effect in graphic) / (size of effect in data)
- In the graphic:

$$\text{Lie Factor} = \frac{\dfrac{5.3 - 0.6}{0.6}}{\dfrac{27.5 - 18}{18}} = 14.8$$

This line, representing 18 miles per gallon in 1978, is 0.6 inches long.

Fuel Economy Standards for Autos
Set by Congress and supplemented by the Transportation Department. In miles per gallon.

1978   18   19   20
1979
1980   22
1981
1982   24
1983   26
1984   27
1985   27 1/2
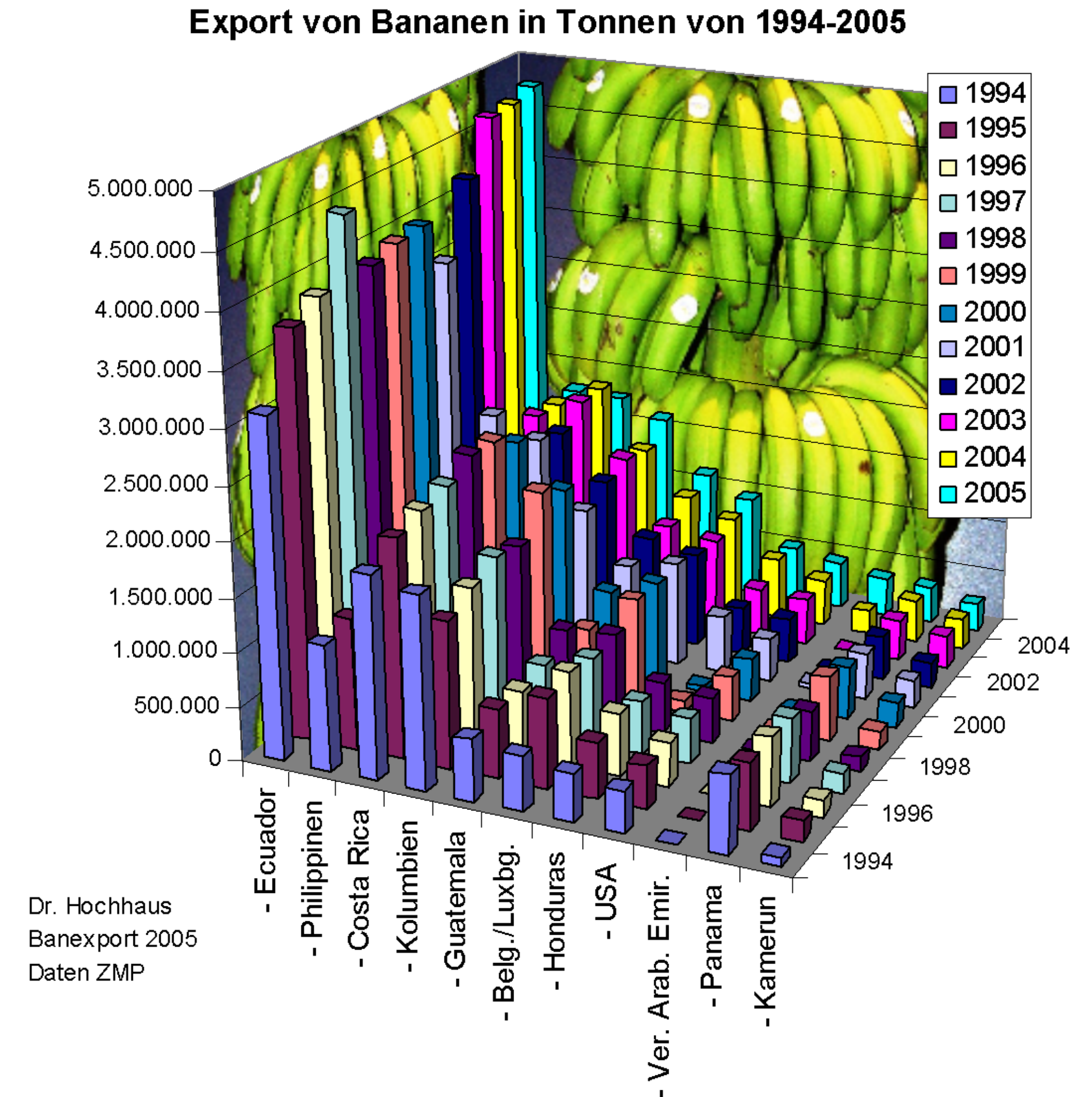
This line, representing 27.5 miles per

Avoid Chartjunk

[T. Brey via A. Lex]

No Unjustified 3D

- Occlusion hides information
- Perspective distortion dangers
- Tilted text isn't legible

- Can **help** with shape perception

Export von Bananen in Tonnen von 1994-2005

Dr. Hochhaus
Banexport 2005
Daten ZMP

Validation at each level

⚠	**Threat**	Wrong problem
☑	**Validate**	Observe and interview target users
⚠	**Threat**	Wrong task/data abstraction
⚠	**Threat**	Ineffective encoding/interaction idiom
☑	**Validate**	Justify encoding/interaction design
⚠	**Threat**	Slow algorithm
☑	**Validate**	Analyze computational complexity

Implement system

|		
☑	**Validate**	Measure system time/memory
☑	**Validate**	Qualitative/quantitative result image analysis
		Test on any users, informal usability study
☑	**Validate**	Lab study, measure human time/errors for task
☑	**Validate**	Test on target users, collect anecdotal evidence of utility
☑	**Validate**	Field study, document human usage of deployed system
☑	**Validate**	Observe adoption rates

[Munzner, 2014]

Five Design Sheet Method
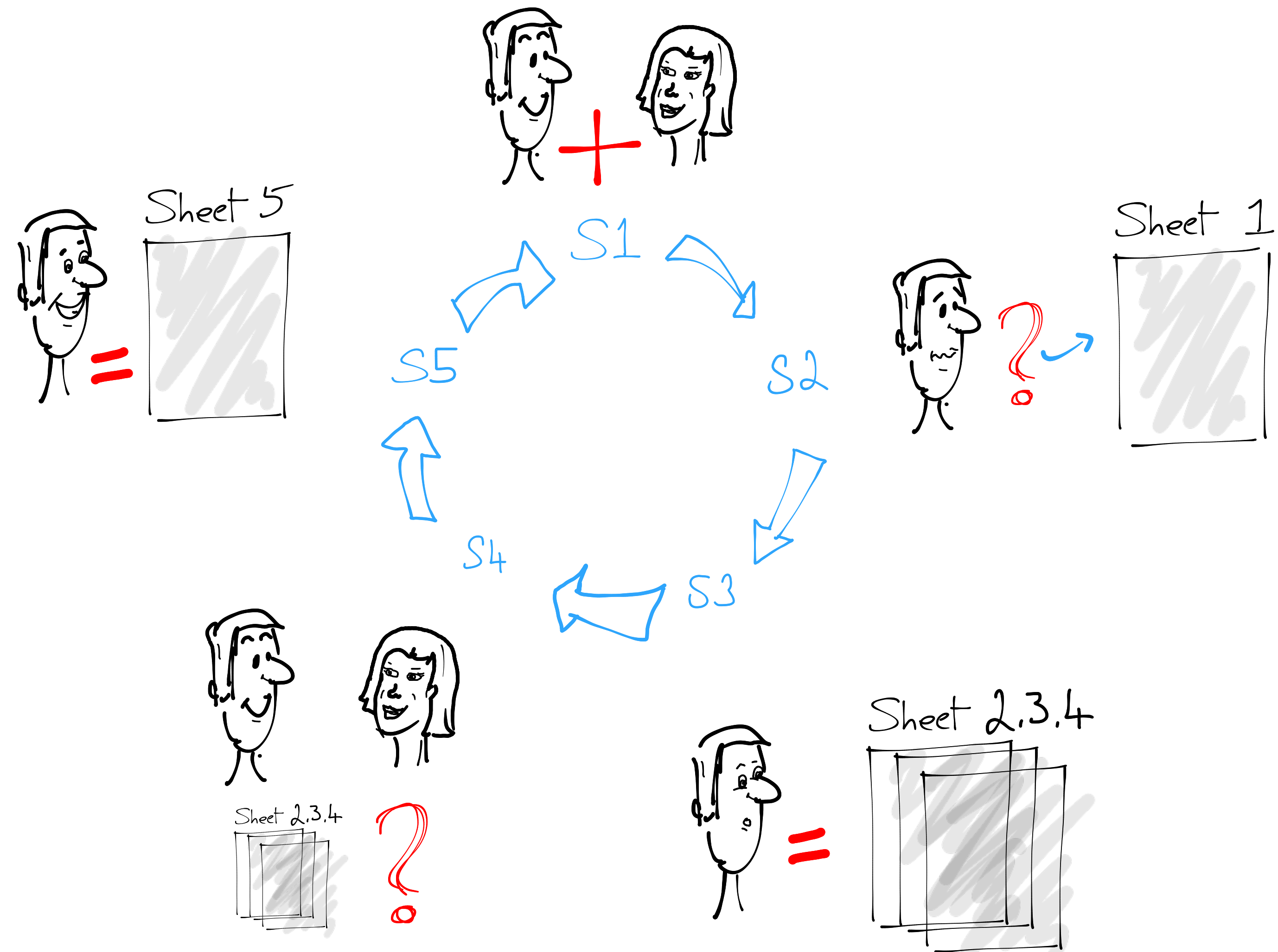

[J. Roberts et al., 2016]

Sheets 2-4
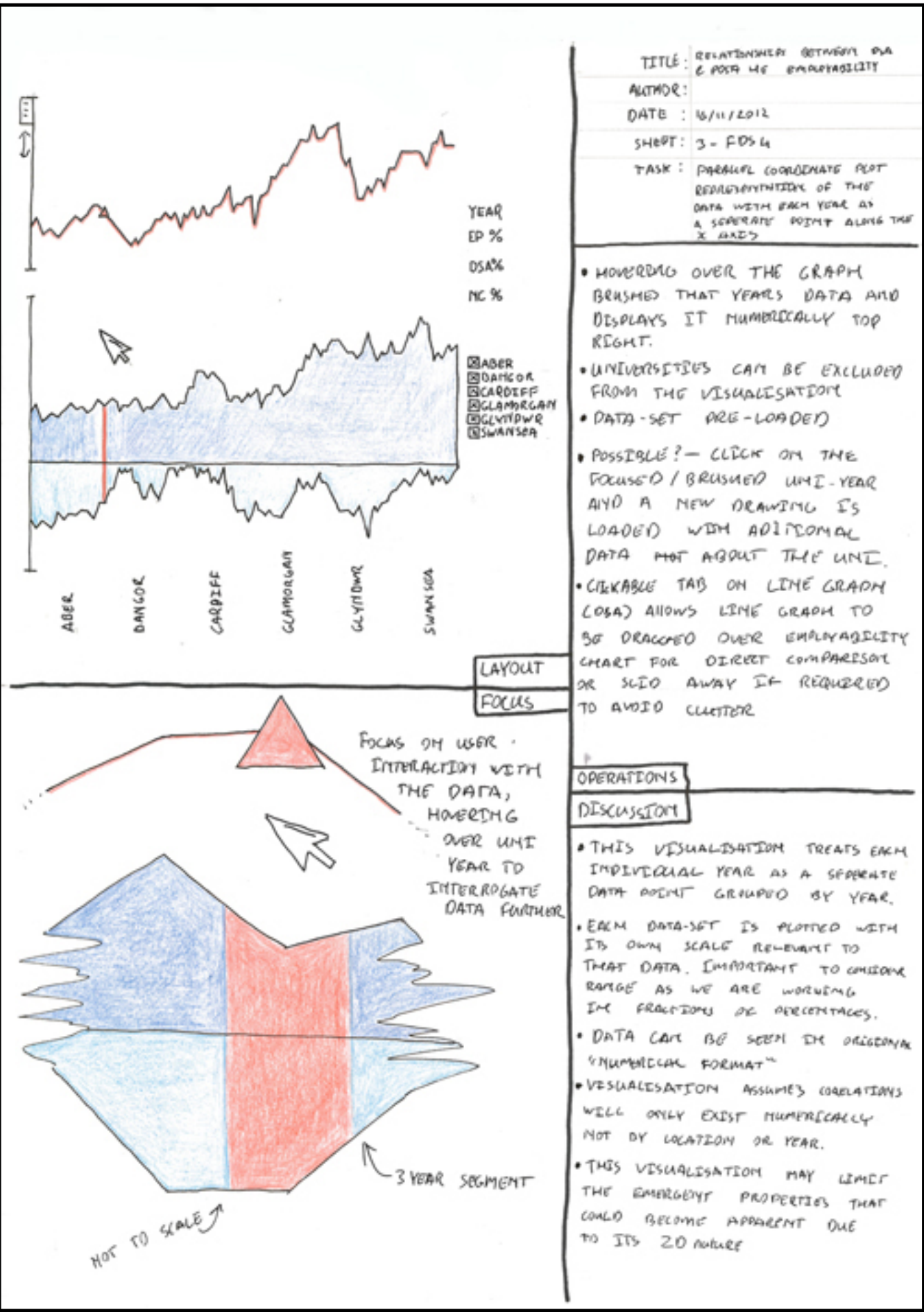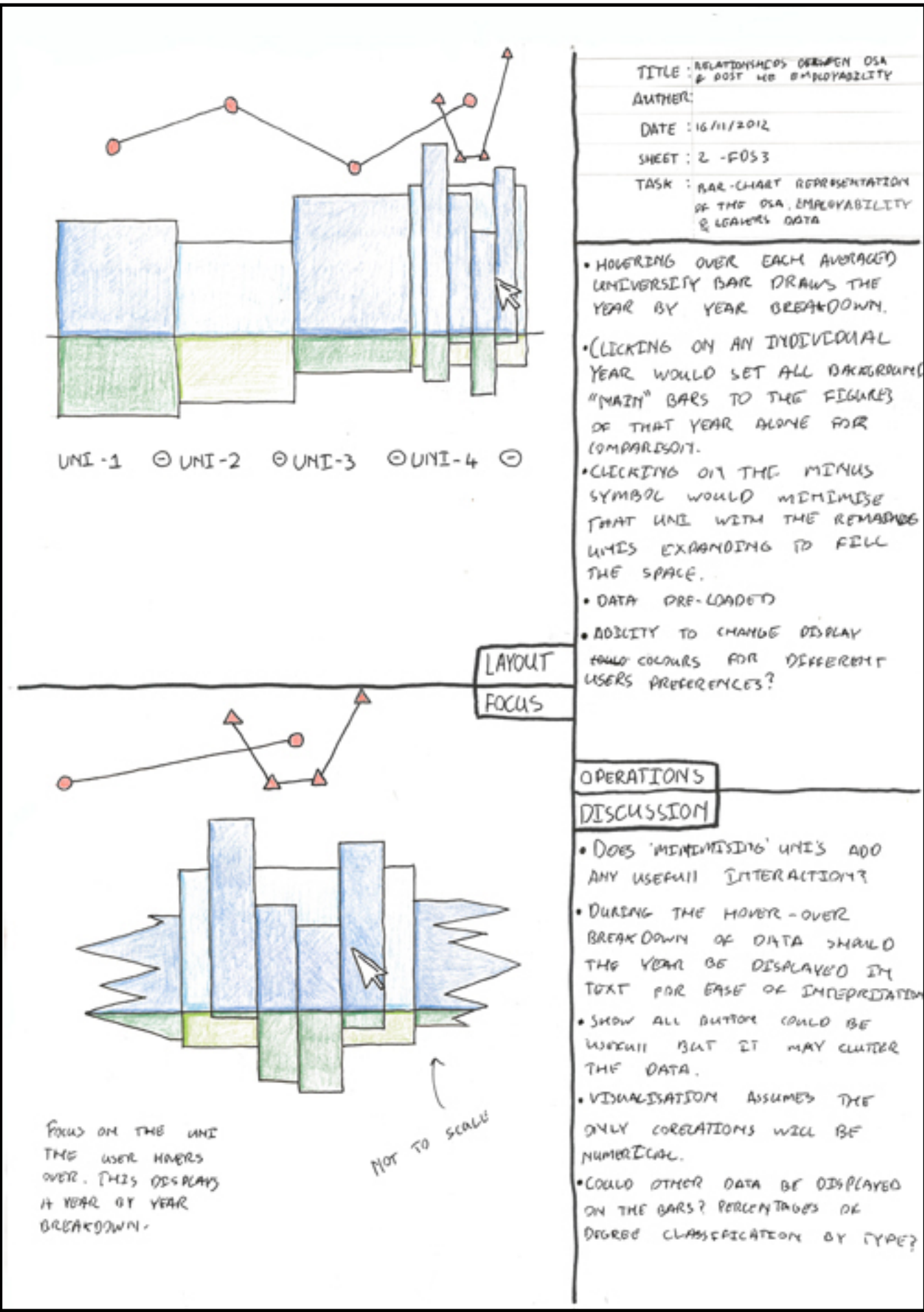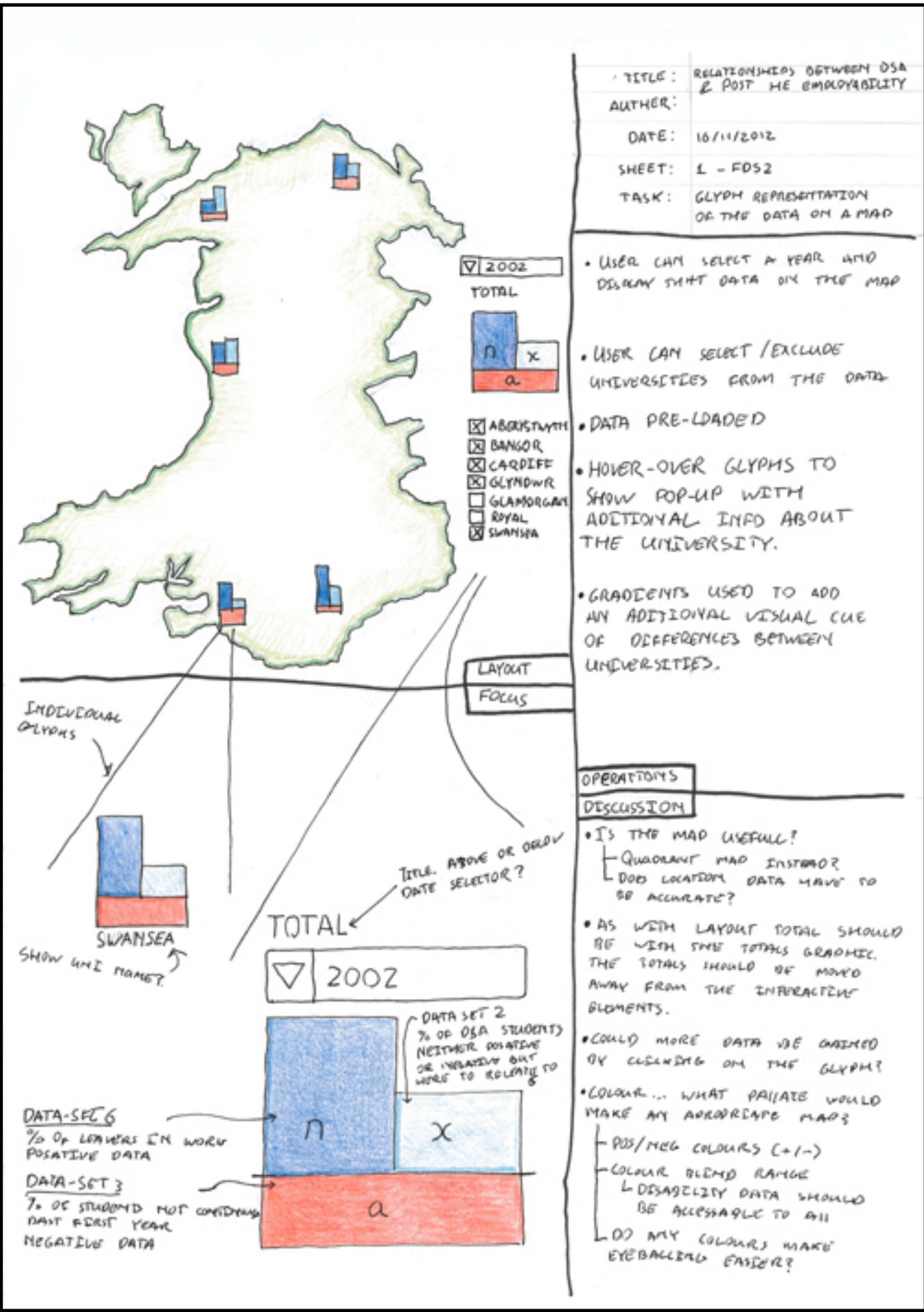
[J. Roberts et al., 2016]

Project Design

- Work on turning your visualization ideas into designs
- Turn in:
  - Three Designs Sketches
  - Progress on Implementation
- Options:
  - Try vastly different options
  - Refine an initial idea
- Due Monday, Nov. 11

Assignment 4

- Create Choropleth Maps
  - Deal with projections and GeoJSON Data
  - Select appropriate colormaps
- [CS 680 Only] Part 3 is using other libraries, you only need to do **one** option
- Example image at the right is **not** a solution to Part 3, needs proper colormapping!
- Due tomorrow
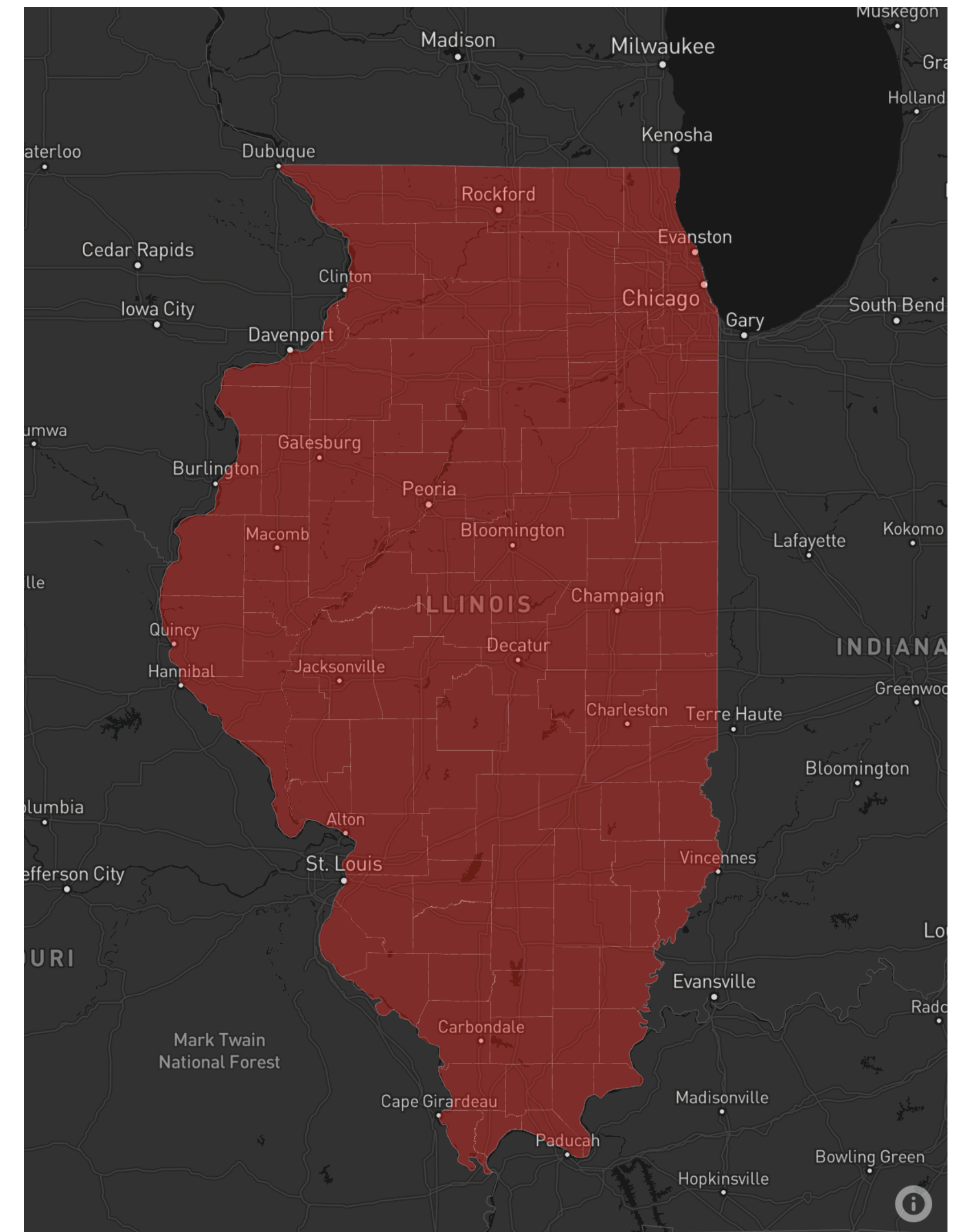
Guidelines for Interaction Design

Responsiveness Required

- Delays are perceived by users

- Visual feedback

  - Show the user they did something (highlighting, etc)

  - Interaction should happen quick!

- Latency: mouse click versus mouse hover

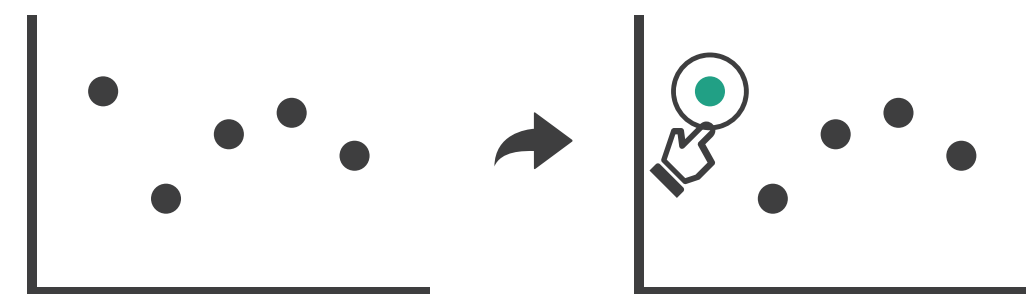- Popup versus detail displays

Interaction

- The view changes over time
- Changes can affect almost any aspect of the visualization
  - encoding
  - arrangement
  - ordering
  - viewpoint
  - attributes being shown
  - aggregation level

Interaction Overview
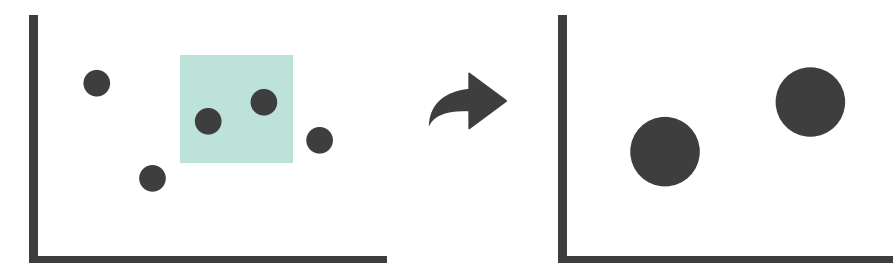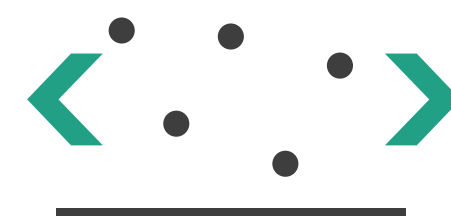
➔ **Change over Time**

➔ **Select**

➔ **Navigate**

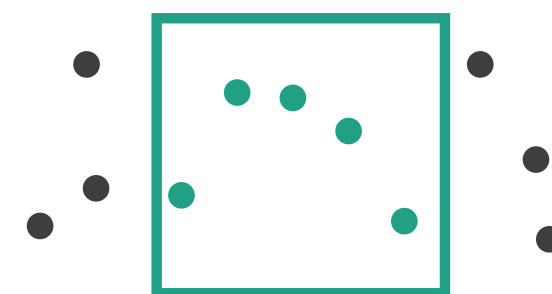➔ Item Reduction

➔ *Zoom*
  Geometric or *Semantic*
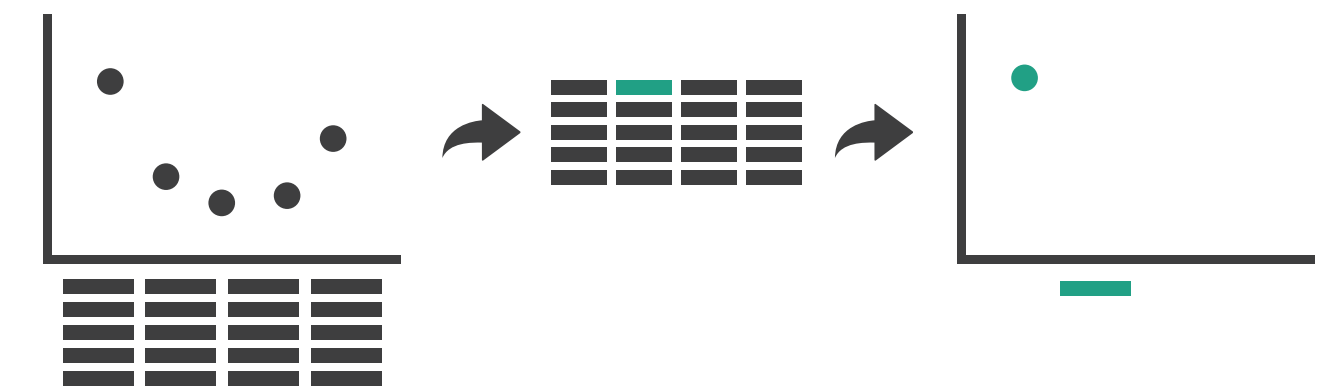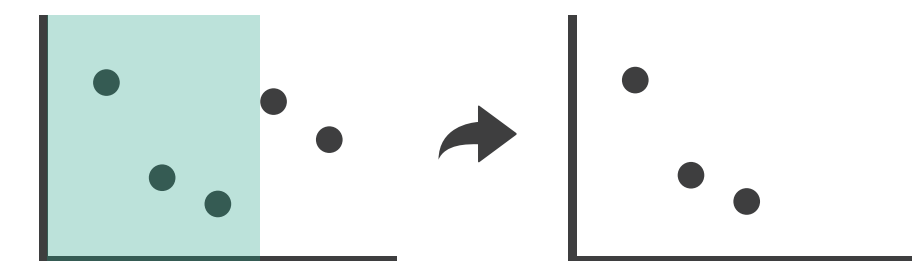
➔ *Pan/Translate*
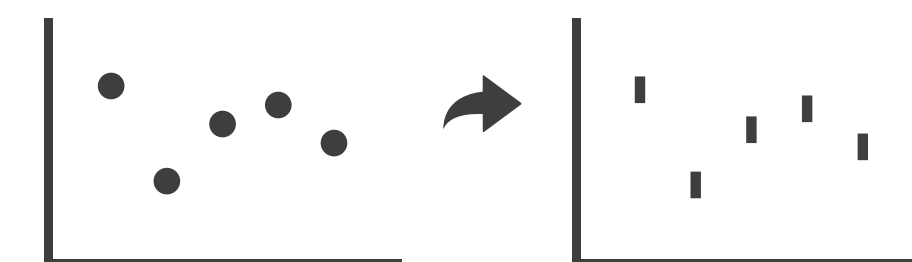
➔ *Constrained*

➔ Attribute Reduction

➔ *Slice*

➔ *Cut*

➔ *Project*

[Munzner (ill. Maguire), 2014]
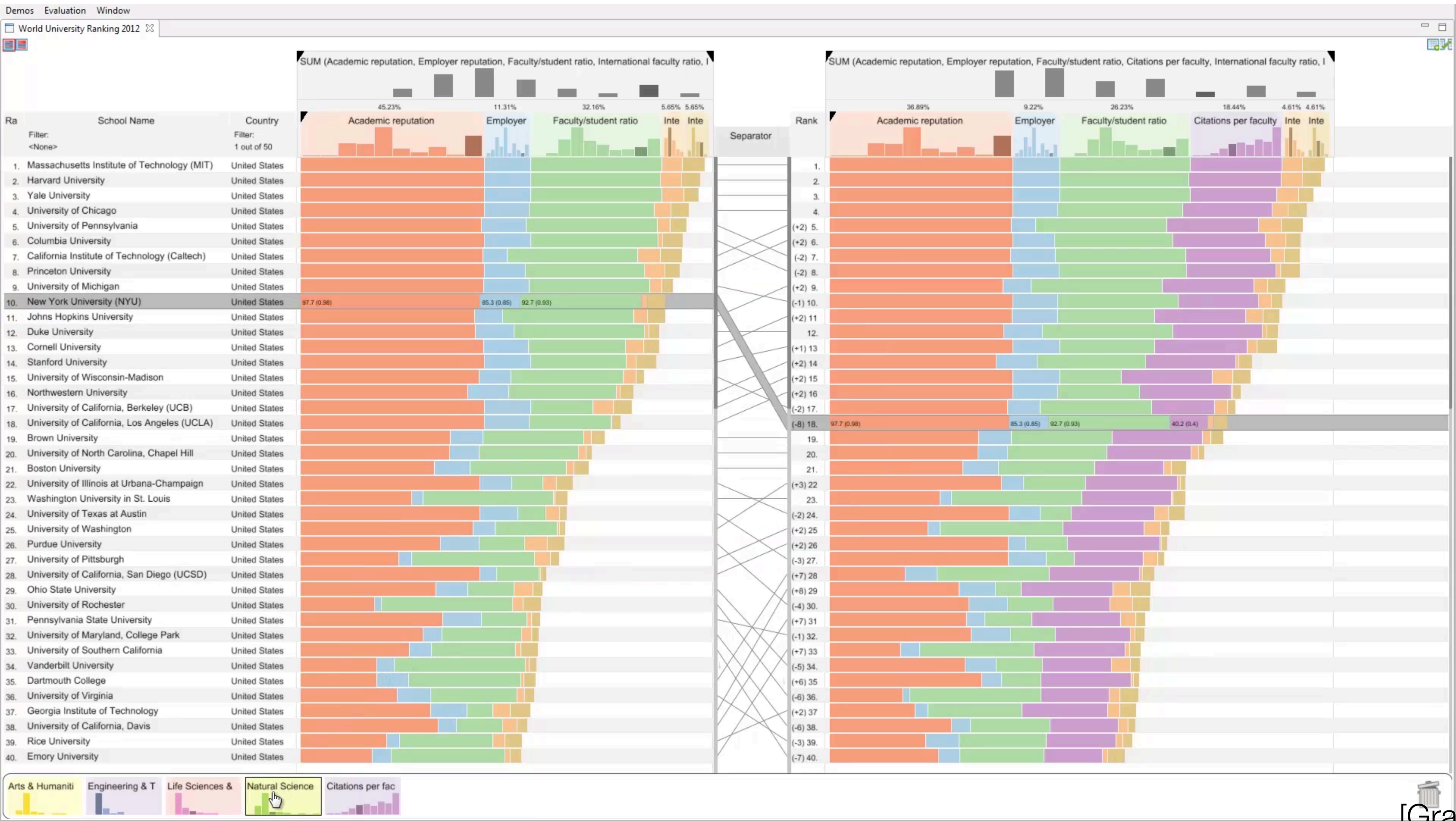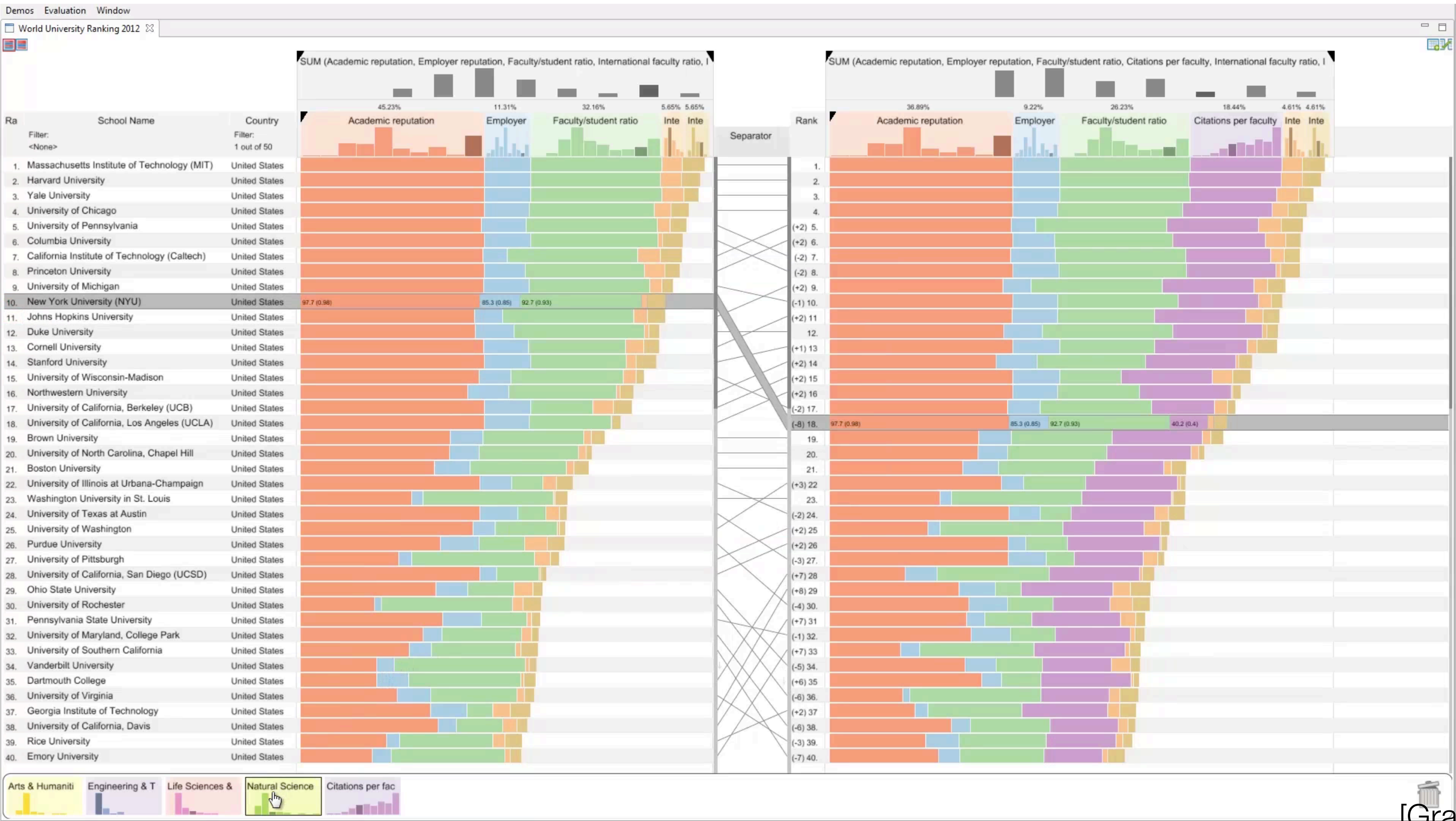
Sorting

- Allow user to find patterns by reordering the data

- Do this with tabular data all the time

- Note that categorical attributes don't really need sorting

  - We can compare these attributes no matter what order

  - Instead, sort categorical attribute based on an ordered attribute

Example: LineUp

[Gratzl et al., 2013]

Example: LineUp

[Gratzl et al., 2013]

Slope Graphs

- Connection marks

- Link the same item appearing in different rows

- Show changes for different attributes (parallel coordinates idea) but with one highlighted item

- Also called bump charts

Animation: Jump Cut vs. Animated Transitions

Q♣	A♣	Q♠
K♦	Q♣	K♣
A♥	J♣	A♦
A♦	Q♠	J♦
Q♠	J♦	Q♣
Q♥	Q♦	J♥
A♣	J♥	A♠
K♠	J♠	J♣
K♥	K♦	J♠
A♠	K♣	A♥
J♥	Q♥	K♠
Q♦	K♥	Q♥
K♣	A♠	A♣
J♦	K♠	Q♦
J♣	A♥	K♥
J♠	A♦	K♦

Animation: Jump Cut vs. Animated Transitions

Q♣	A♣	Q♠
K♦	Q♣	K♣
A♥	J♣	A♦
A♦	Q♠	J♦
Q♠	J♦	Q♣
Q♥	Q♦	J♥
A♣	J♥	A♠
K♠	J♠	J♣
K♥	K♦	J♠
A♠	K♣	A♥
J♥	Q♥	K♠
Q♦	K♥	Q♥
K♣	A♠	A♣
J♦	K♠	Q♦
J♣	A♥	K♥
J♠	A♦	K♦

Animation: Jump Cut vs. Animated Transitions

Q♣	A♣	Q♠
K♦	Q♣	K♣
A♥	J♣	A♦
A♦	Q♠	J♦
Q♠	J♦	Q♣
Q♥	Q♦	J♥
A♣	J♥	A♠
K♠	J♠	J♣
K♥	K♦	J♠
A♠	K♣	A♥
J♥	Q♥	K♠
Q♦	K♥	Q♥
K♣	A♠	A♣
J♦	K♠	Q♦
J♣	A♥	K♥
J♠	A♦	K♦

Animation: Jump Cut vs. Animated Transitions

Q♣	A♣	Q♠
K♦	Q♣	K♣
A♥	J♣	A♦
A♦	Q♠	J♦
Q♠	J♦	Q♣
Q♥	Q♦	J♥
A♣	J♥	A♠
K♠	J♠	J♣
K♥	K♦	J♠
A♠	K♣	A♥
J♥	Q♥	K♠
Q♦	K♥	Q♥
K♣	A♠	A♣
J♦	K♠	Q♦
J♣	A♥	K♥
J♠	A♦	K♦

Side-by-side views

Q♣	A♦
K♦	Q♥
A♥	Q♠
A♦	A♣
Q♠	Q♦
Q♥	J♦
A♣	K♦
K♠	Q♣
K♥	K♥
A♠	A♠
J♥	J♠
Q♦	A♥
K♣	J♣
J♦	K♠
J♣	K♣
J♠	J♥

Side-by-side views

Q♣	A♦
K♦	Q♥
A♥	Q♠
A♦	A♣
Q♠	Q♦
Q♥	J♦
A♣	K♦
K♠	Q♣
K♥	K♥
A♠	A♠
J♥	J♠
Q♦	A♥
K♣	J♣
J♦	K♠
J♣	K♣
J♠	J♥

Animated Transitions
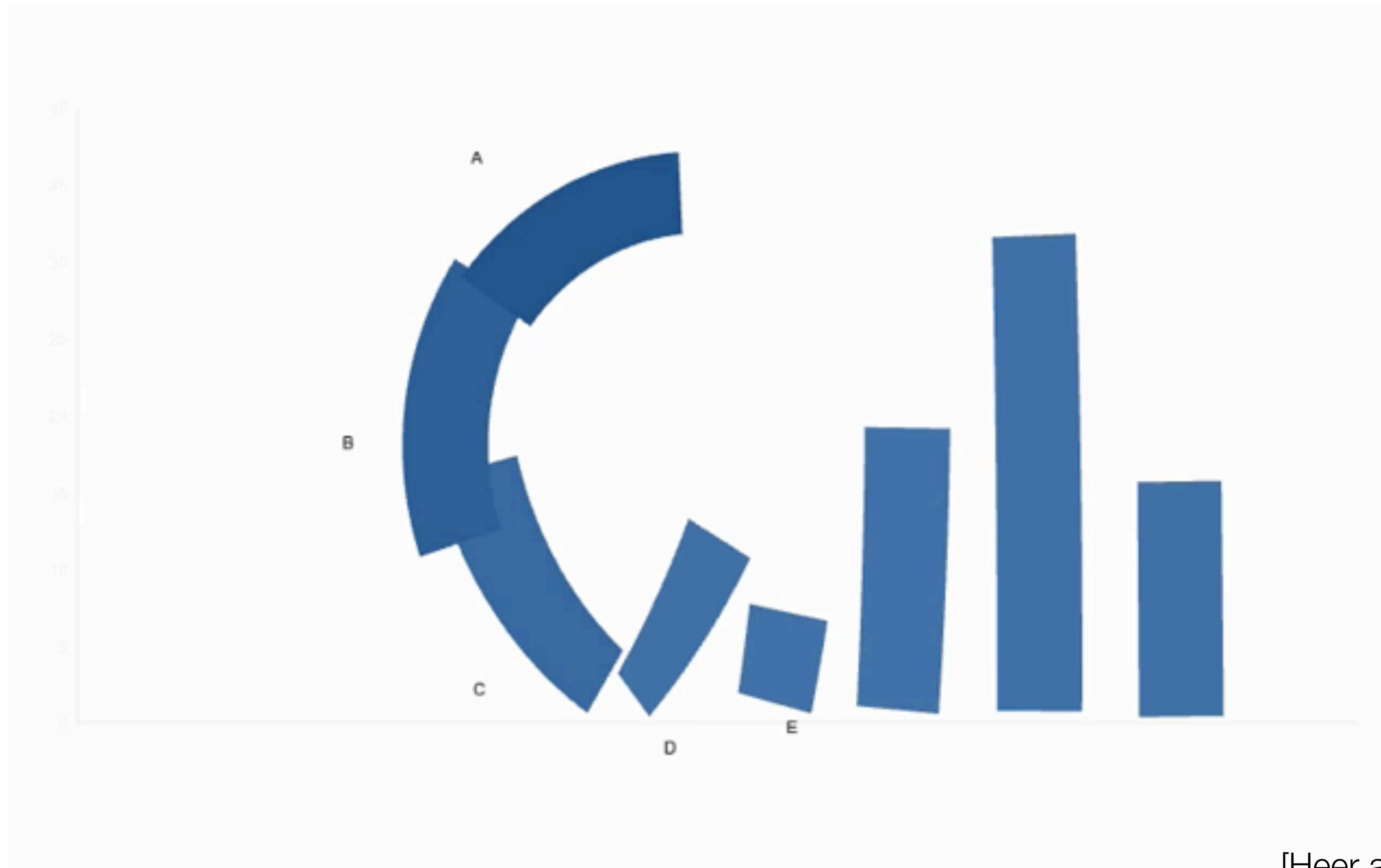

[M. Bostock]
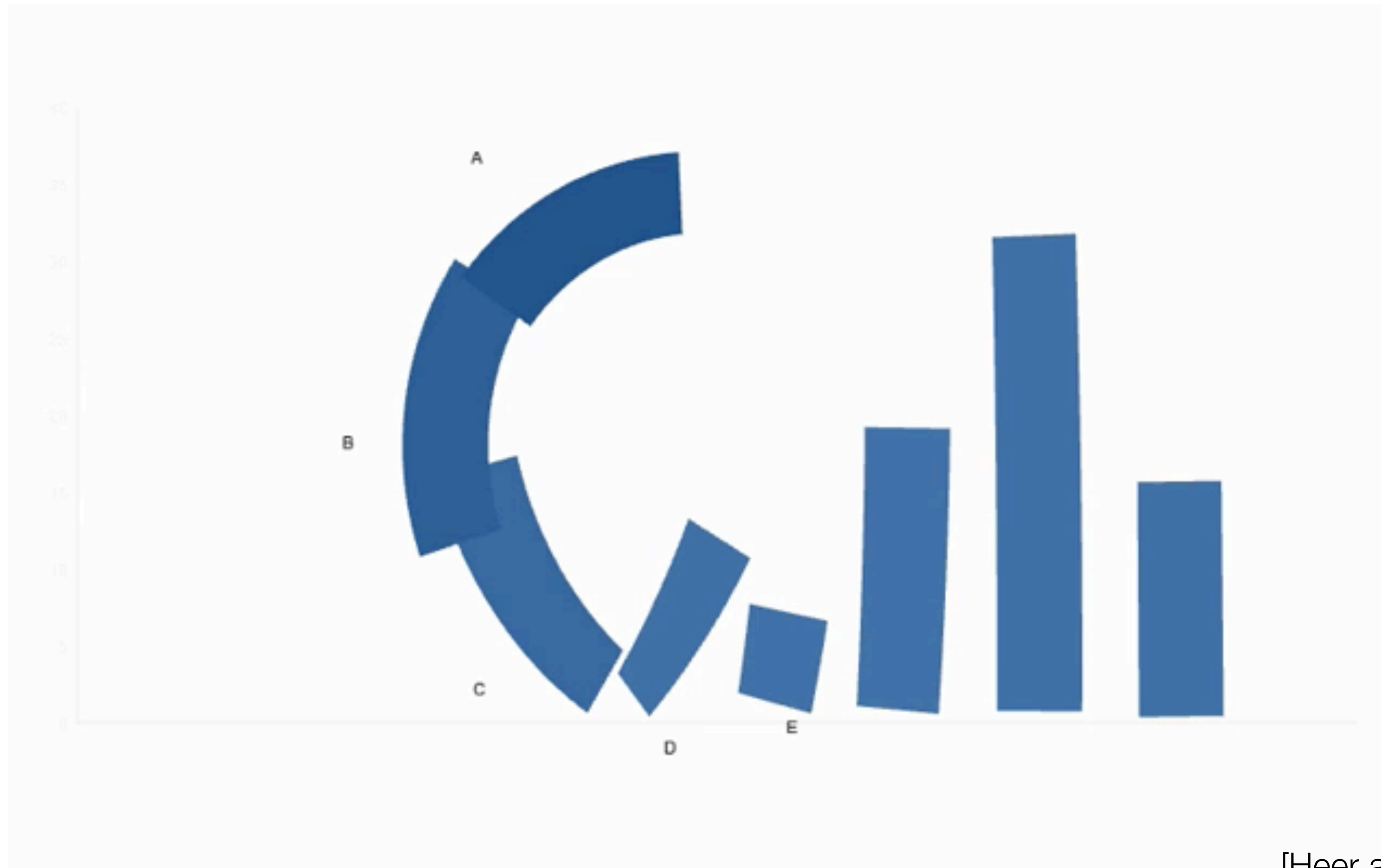
Animated Transitions

[M. Bostock]

Animated Transitions

- "Jump cuts" are hard to follow

- Animations help users maintain sense of context between two states

- Empirical study showed that they work (Heer & Robertson, 2007)

Studying Animated Transitions

[Heer and Robertson, 2007]

Studying Animated Transitions
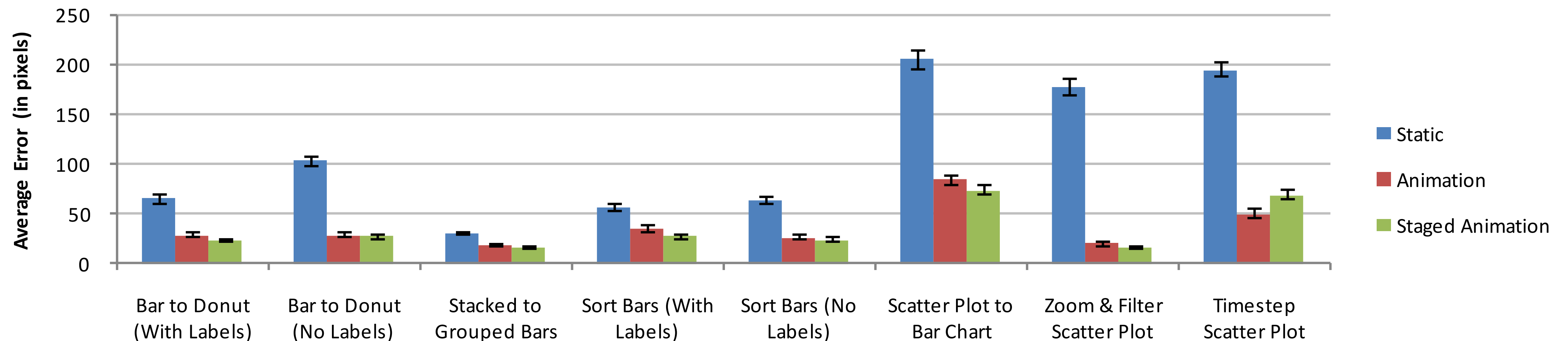

[Heer and Robertson, 2007]

Design Considerations

- Based on Tversky et al.'s Congruence and Apprehension Principles

- Congruence:
  - Use consistent semantic-syntactic mappings
  - Respect semantic correspondence
  - Avoid ambiguity

- Apprehension
  - Group similar transitions
  - Minimize occlusion
  - Maximize predictability
  - Use simple transitions
  - Use staging for complex transitions
  - Transitions as long as needed, but no longer
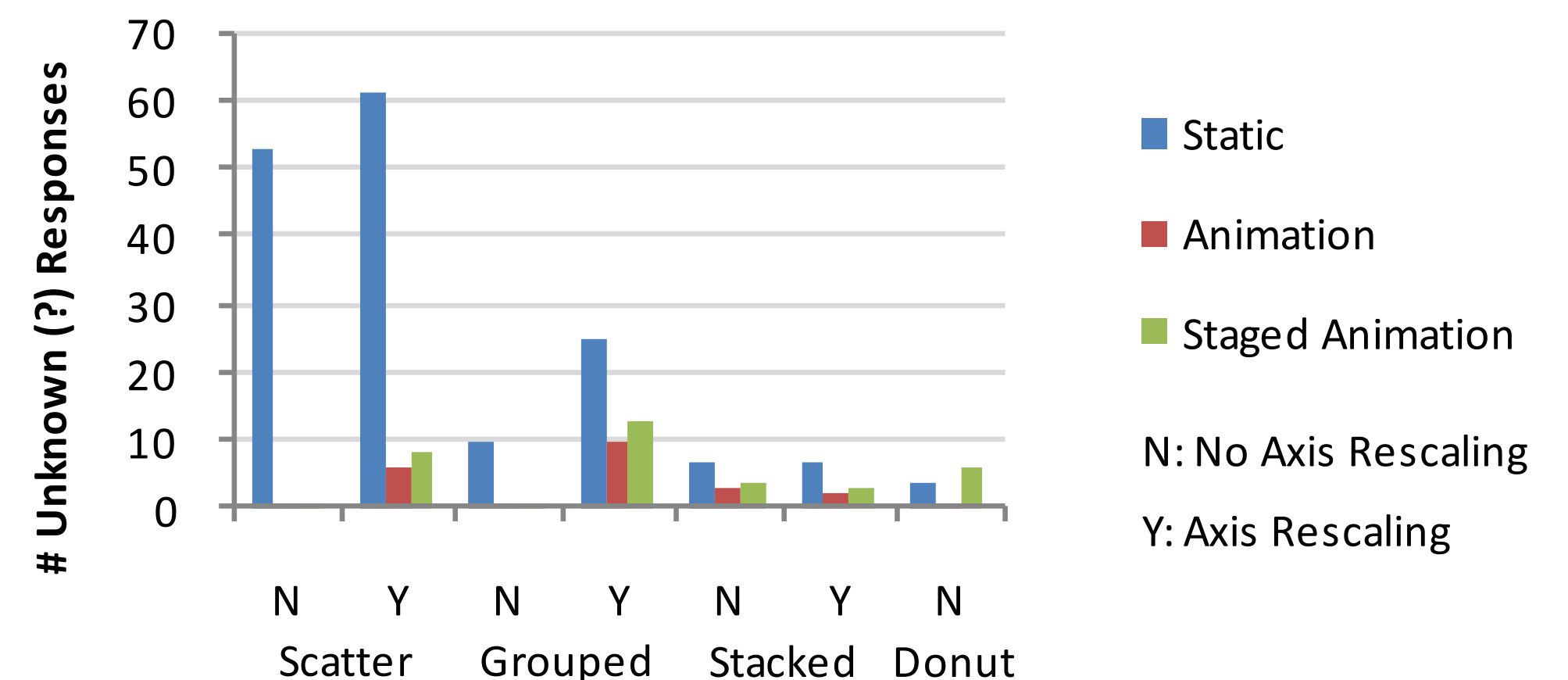
[Heer and Robertson, 2007]

Experiment 1 (Syntactic)

- Object Tracking: Follow objects across a transition and identify the locations of the objects in the final graphic

  - Tests: bar chart to donut chart, stacked to grouped bars, sorting a bar chart, scatter plot to bar chart, timestep in a scatterplot

  - Either a jump cut or an animated transition

  - Users pick highlighted elements after transition (measure #pixels from correct)

[Heer and Robertson, 2007]

Experiment 2 (Semantic)

- Estimating Changing Values: Follow a single target across transition and estimate the percentage change in value

  - Tests: axis rescaling + timestep animations

  - In stacked bars, each stack level updates separately, donut charts are multi-stage

  - Users asked to enter an estimate of change (increments of 20% from -90% to 90% or click "?" for no idea)
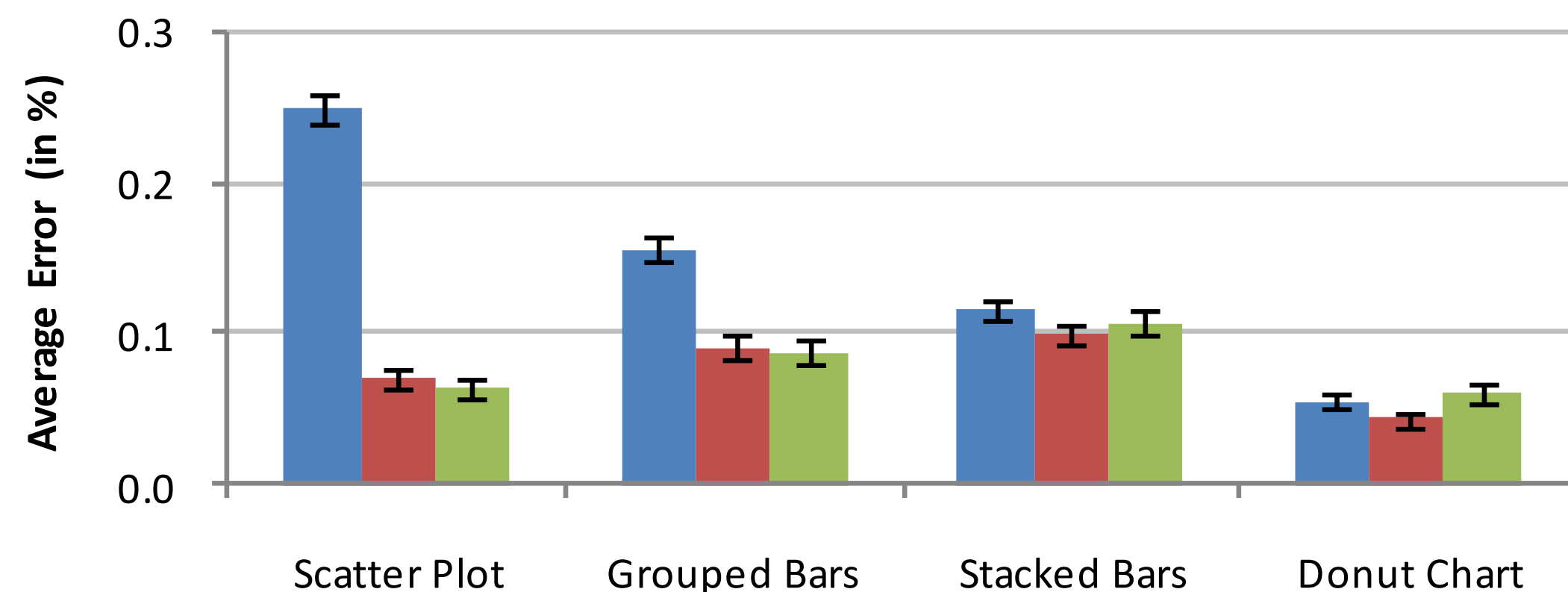
[Heer and Robertson, 2007]

Results/Conclusions

- User Preferences: Staged animation > animation > static transitions
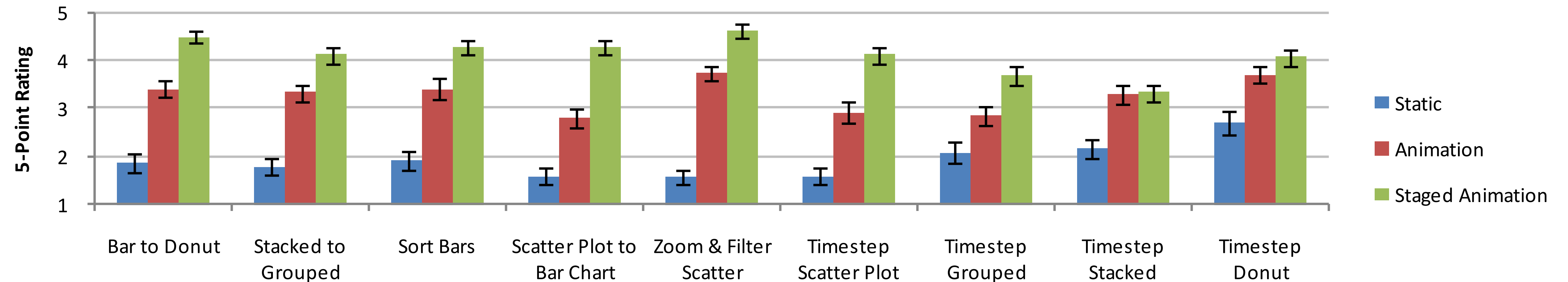
- Animation improves graphical perception
- Staging is better (do axis rescaling before value changes)
- Avoid axis rescaling when possible

[Heer and Robertson, 2007]

Change Blindness

- https://www.youtube.com/watch?v=uO8wpm9HSB0

Change Blindness

- https://www.youtube.com/watch?v=uO8wpm9HSB0

Selection

- Selection is often used to initiate other changes
- User needs to select something to drive the next change
- What can be a selection target?
  - Items, links, attributes, (views)
- How?
  - mouse click, mouse hover, touch
  - keyboard modifiers, right/left mouse click, force
- Selection modes:
  - Single, multiple
  - Contiguous?

Highlighting

- Selection is the user action

- Feedback is important!

- How? Change selected item's visual encoding

  - Change color: want to achieve visual popout

  - Add outline mark: allows original color to be preserved

  - Change size (line width)

 - Add motion: marching ants

Highlighting

- Selection is the user action

- Feedback is important!

- How? Change selected item's visual encoding

  - Change color: want to achieve visual popout

  - Add outline mark: allows original color to be preserved

  - Change size (line width)

  - Add motion: marching ants

Highlighting

Obama has **431** ways to win
84% of paths

5 ties
0.98% of paths

Romney has **76** ways to win
15% of paths

D Florida

R Ohio — If Romney wins Ohio…

R North Carolina — N.C.,

R Virginia — Va.,

R Wisconsin — Wis.,

R Colorado — Colo.,

R Iowa — Iowa,

R Nevada — Nev.,

R New Hampshire — and N.H.,

Romney wins.
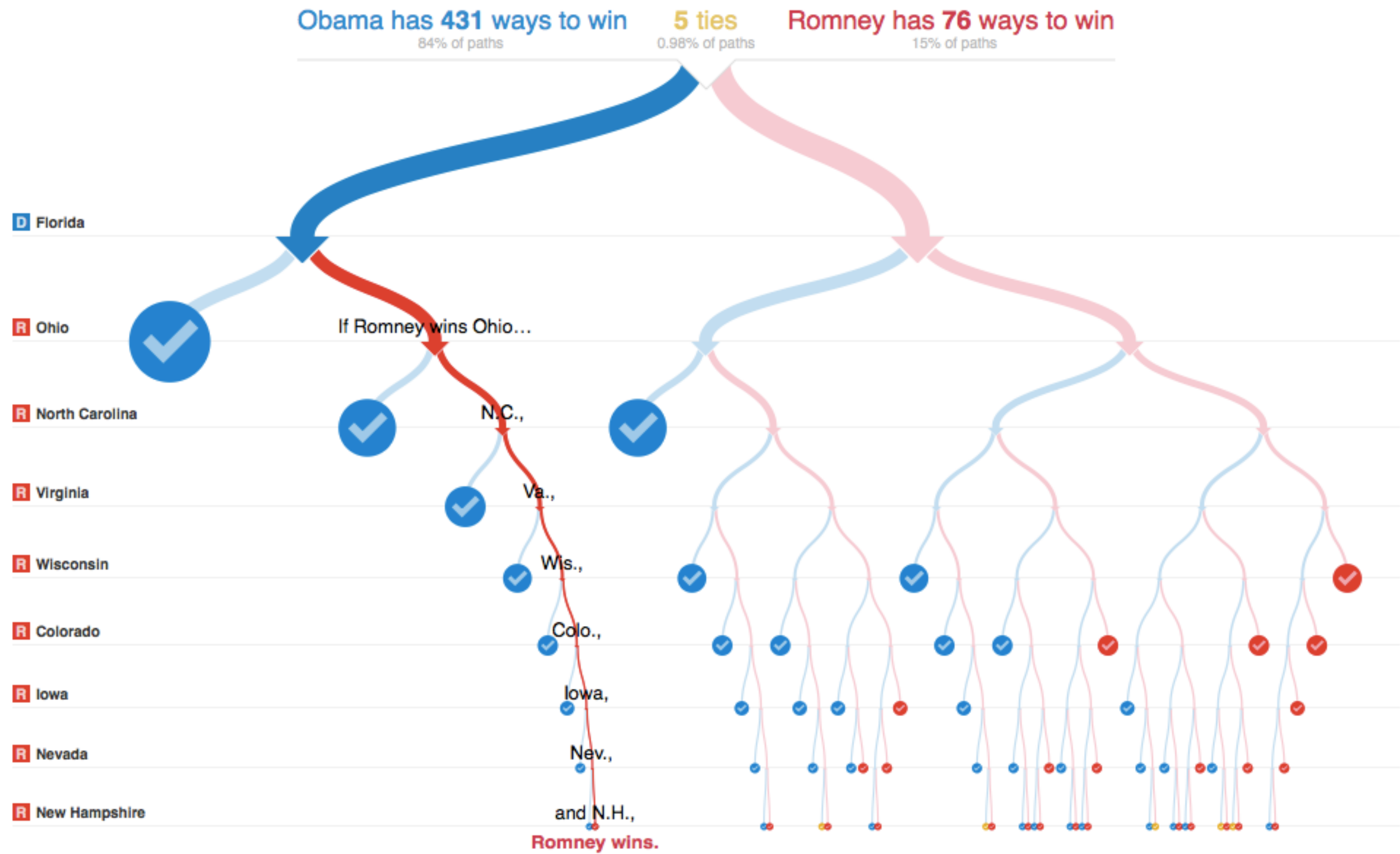
[NYTimes]

Selection Outcomes

- Selection is usually a part of an action sequence
- Can filter, aggregate, reorder selected items

Responsiveness Required

- Delays are perceived by users

- Visual feedback

  - Show the user they did something (highlighting, etc)

  - Interaction should happen quick!

- Latency: mouse click versus mouse hover

- Popup versus detail displays

Interaction Latency

- The Effects of Interactive Latency on Exploratory Visual Analysis, Z. Liu and J. Heer, 2014

- Brush & link, select, pan, zoom
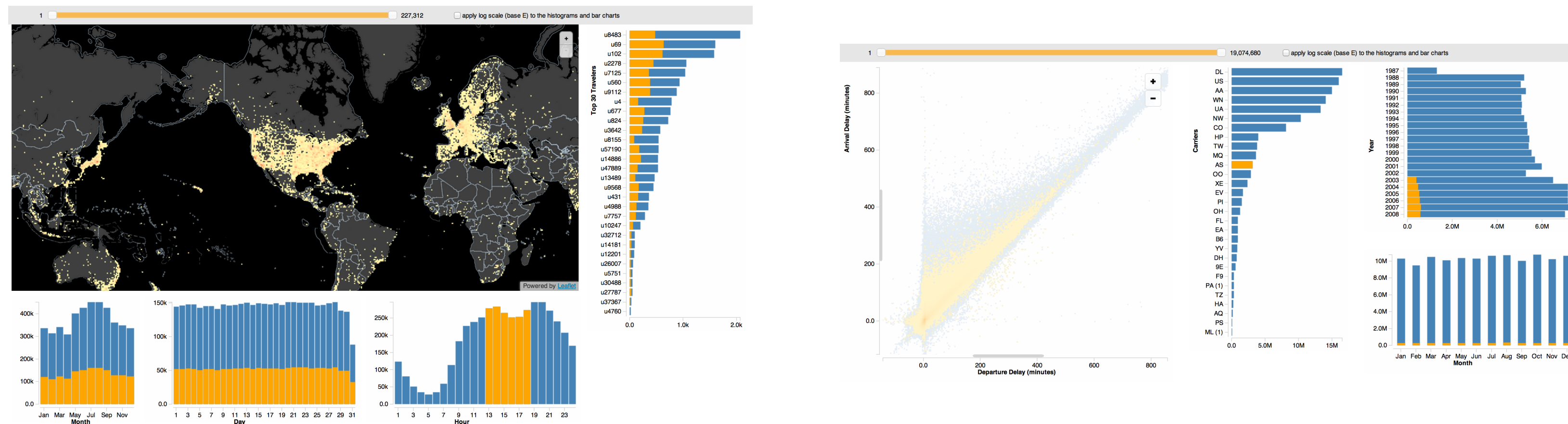
- 500ms added latency causes significant cost

  - decreases user activity and dataset coverage

  - reduces rate of observations, generalizations, and hypotheses

Interaction Overview
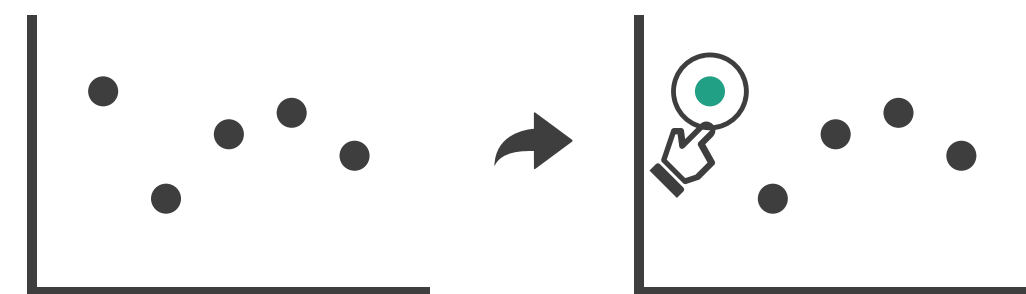
**Change over Time**

Select

Navigate

➔ Item Reduction

➔ *Zoom*
Geometric or *Semantic*

➔ *Pan/Translate*

➔ *Constrained*

➔ Attribute Reduction

➔ *Slice*

➔ *Cut*
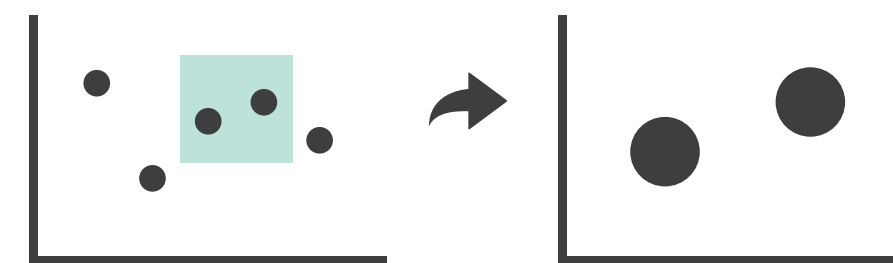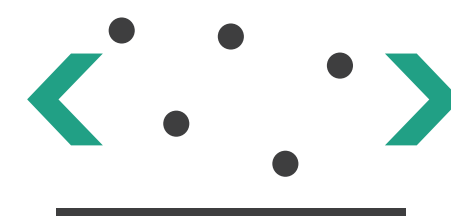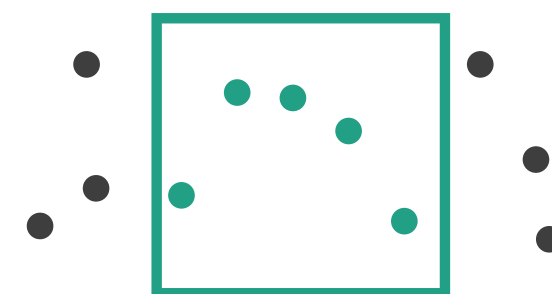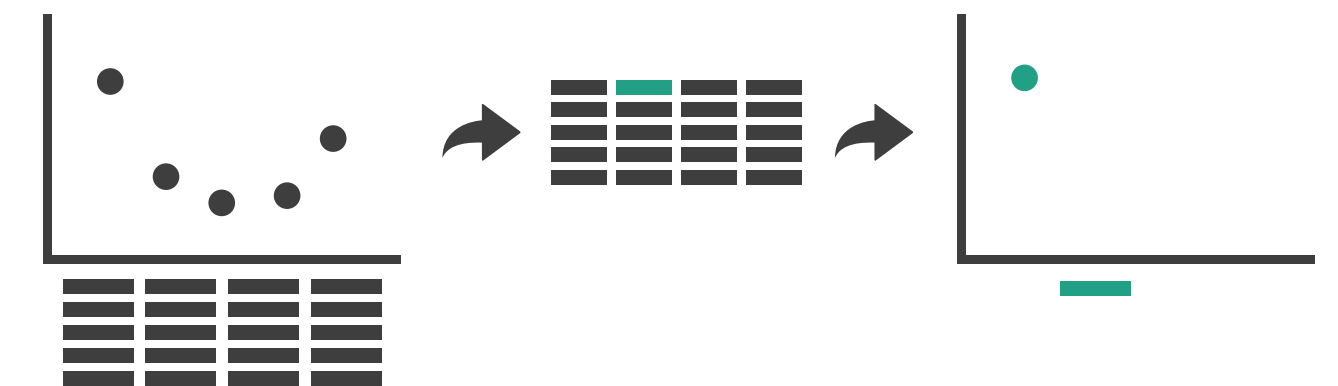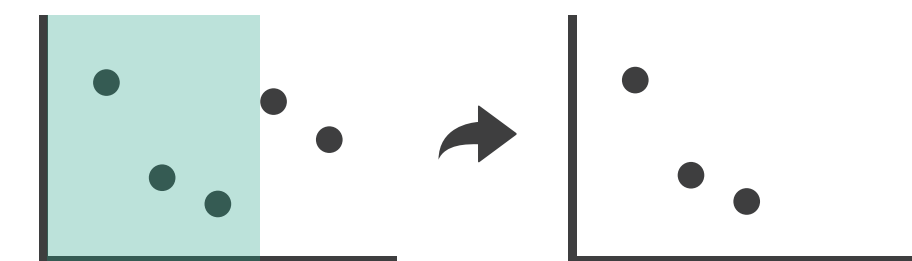
➔ *Project*
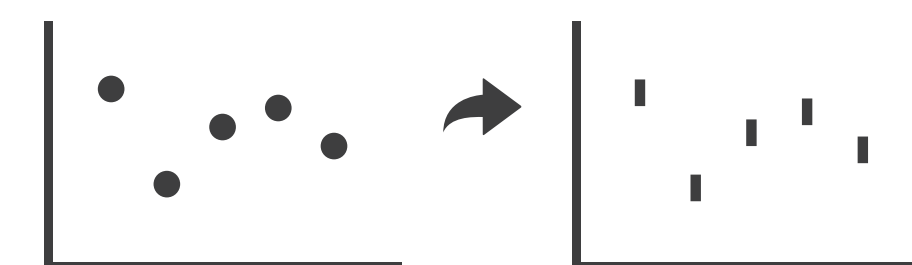
[Munzner (ill. Maguire), 2014]

Navigation

- Fix the layout of all visual elements but provide methods for the viewpoint to change

- Camera analogy: only certain features visible in a frame

  - Zooming

  - Panning (aka scrolling)

  - Translating

  - Rotating (rare in 2D, important in 3D)

Navigation

➜ Item Reduction

   ➜ *Zoom*
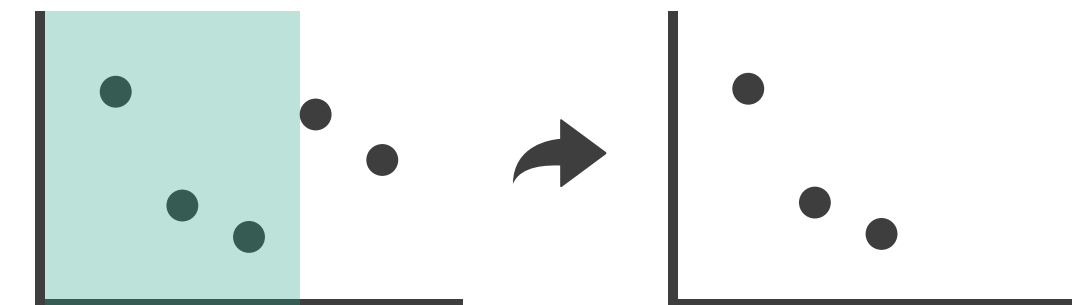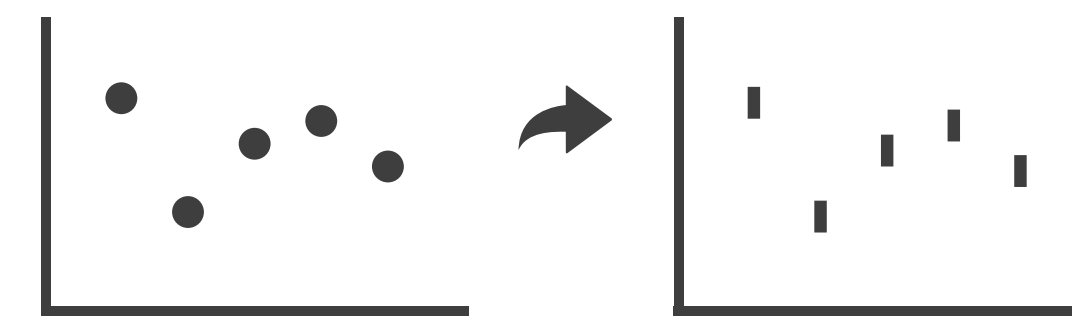   *Geometric* or *Semantic*
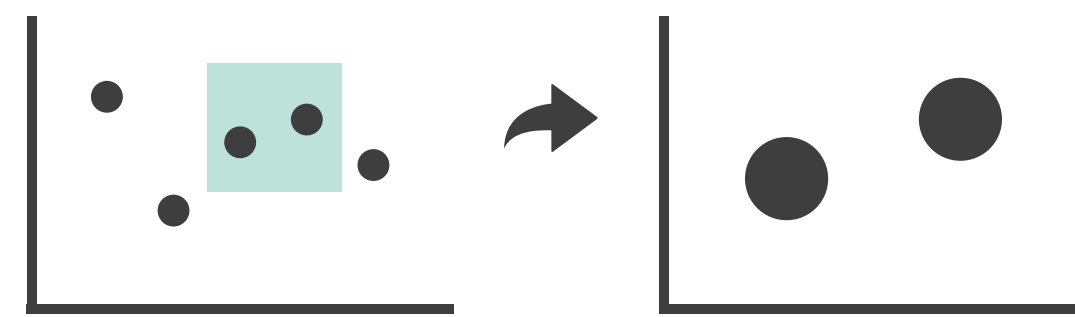
   ➜ *Pan/Translate*

   ➜ *Constrained*

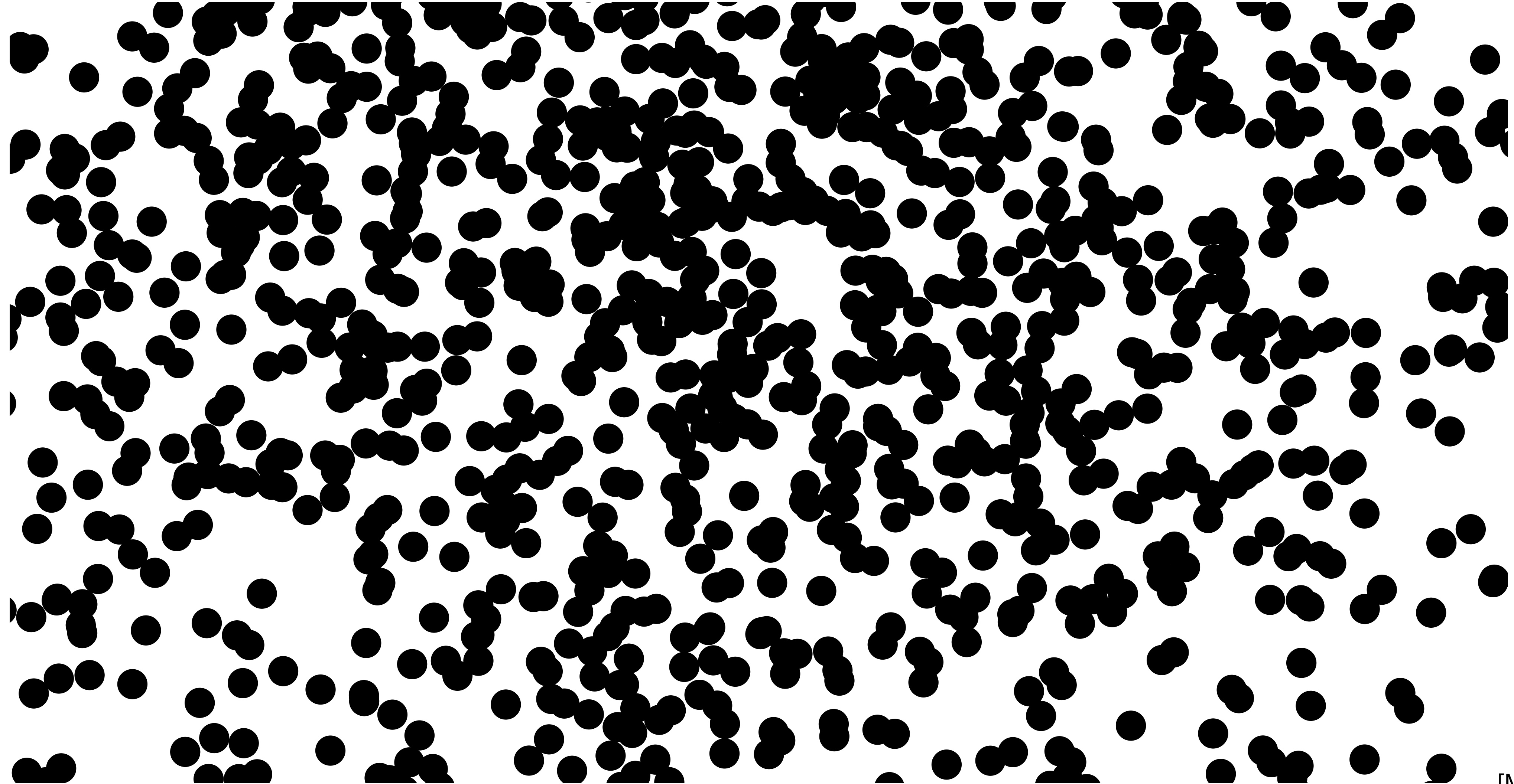➜ Attribute Reduction

   ➜ *Slice*

   ➜ *Cut*
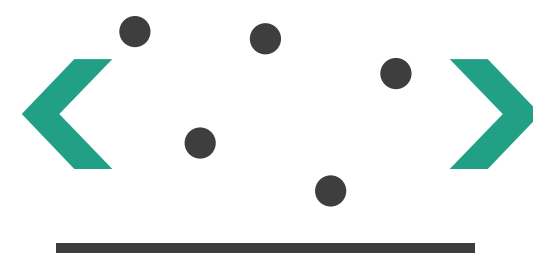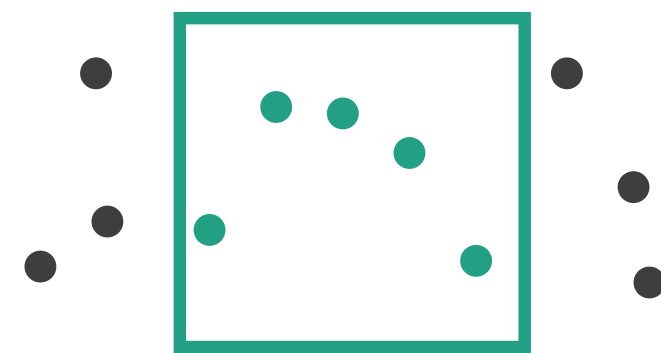
   ➜ *Project*

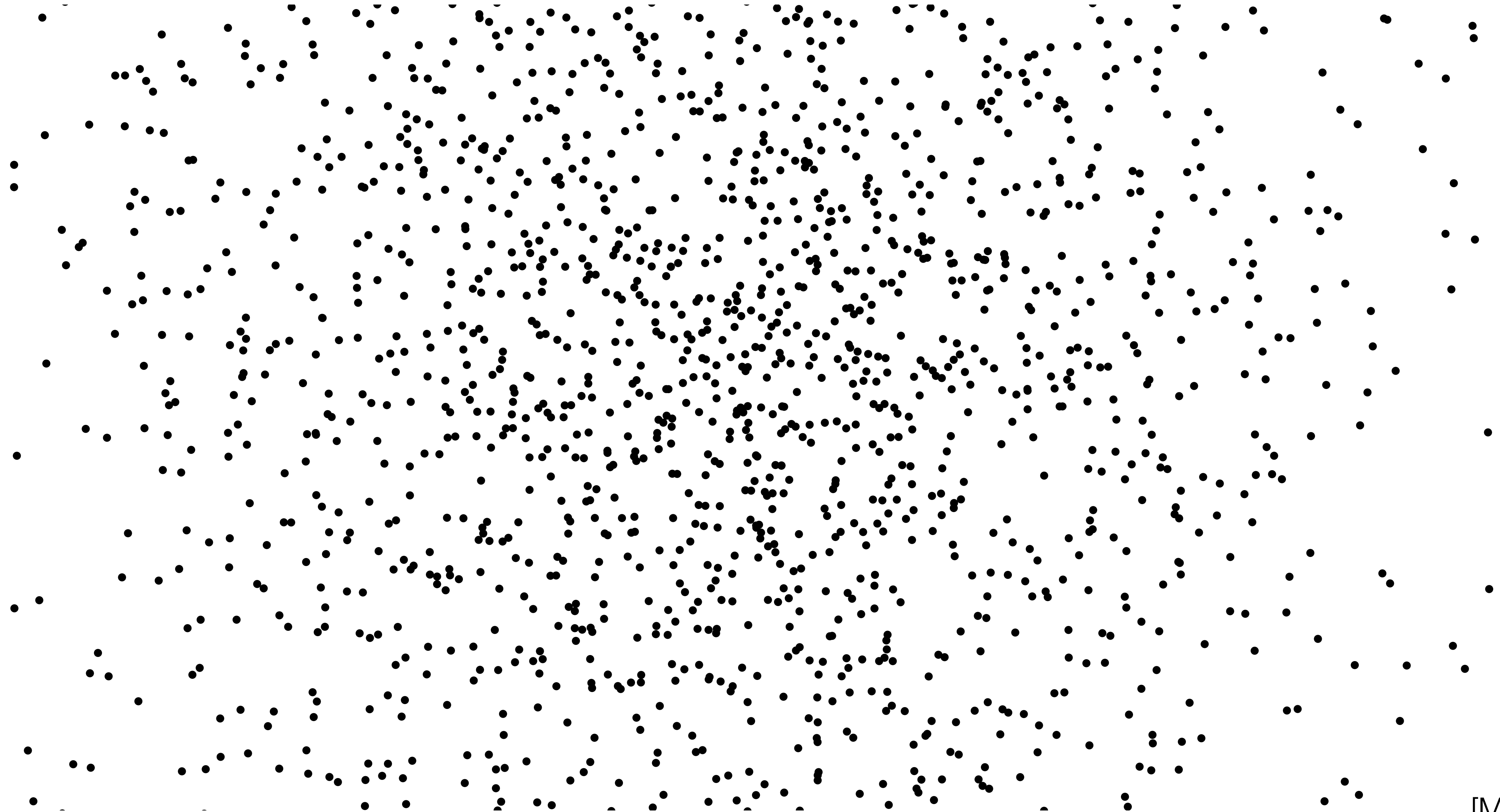[Munzner (ill. Maguire), 2014]

Zooming
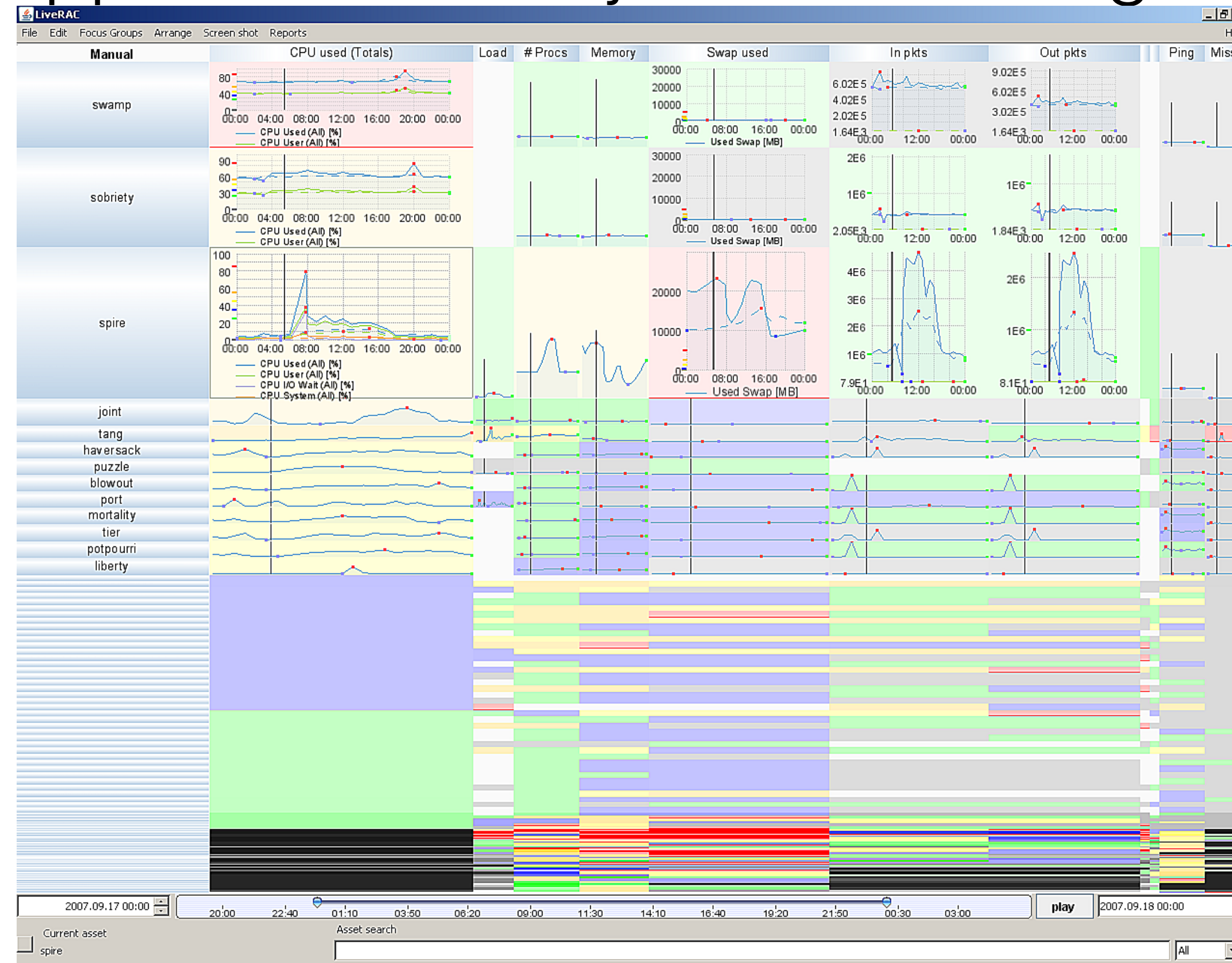

[M. Bostock]

Geometric Zooming

[M. Bostock]

Zooming

Semantic Zooming

Zooming

- Geometric Zooming: just like a camera

- Semantic Zooming: visual appearance of objects can change at different scales

- LiveRAC Example:
(focus + context)



[McLachlan et al., 2008]

Navigation Constraints

- **Unconstrained** navigation: walking around in the world or an immersive 3D environment

  - Fairly standard in computer games to go where you want

  - Constrained by walls, objects (collision detection)

- Constrained navigation:

  - 3D: camera must be right-side up

  - Limit pan/zoom to certain areas

  - Comes up often with **multiple views**: want to show an area in one view that corresponds to a selection in another view
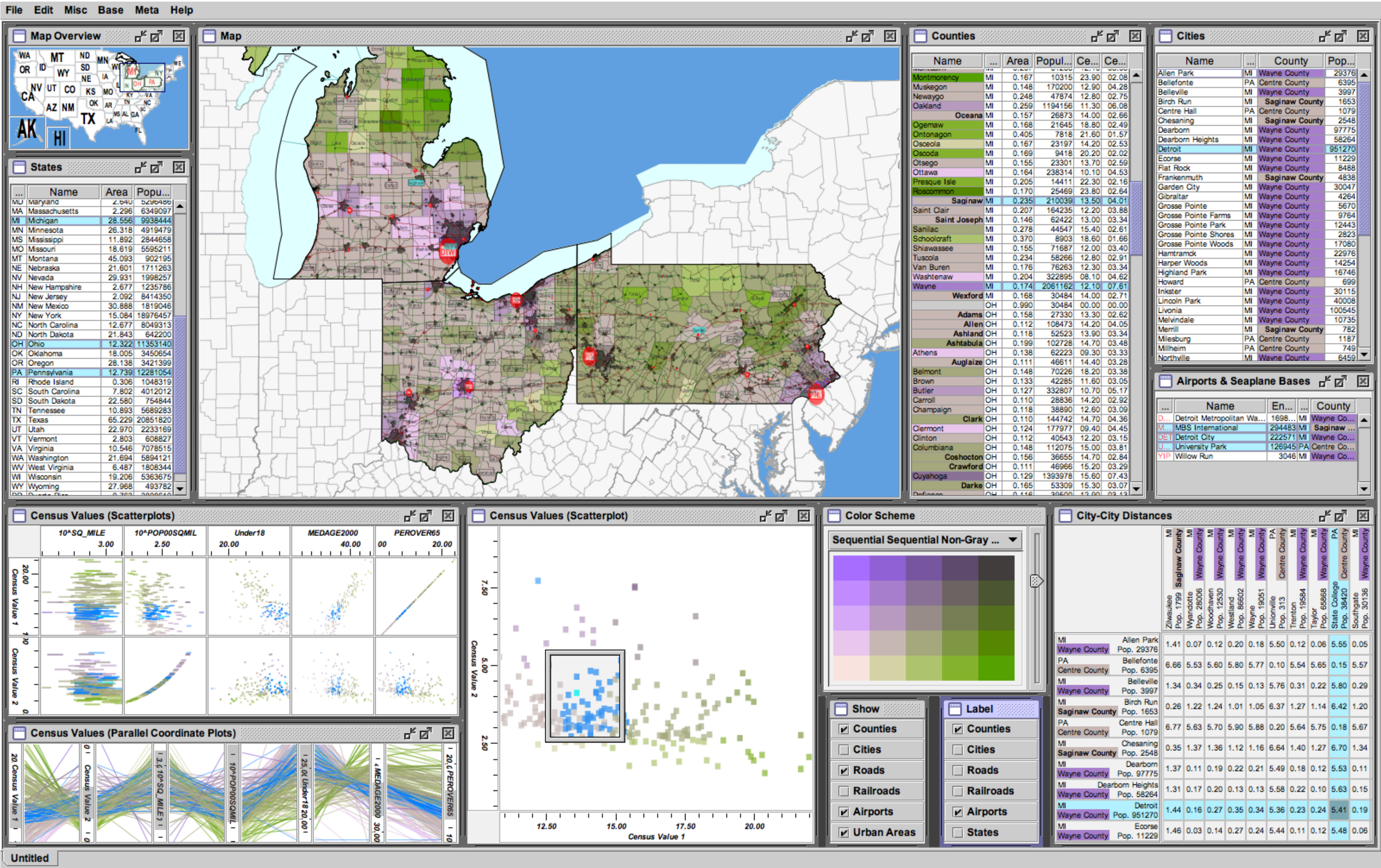
van Wijk Smooth Zooming
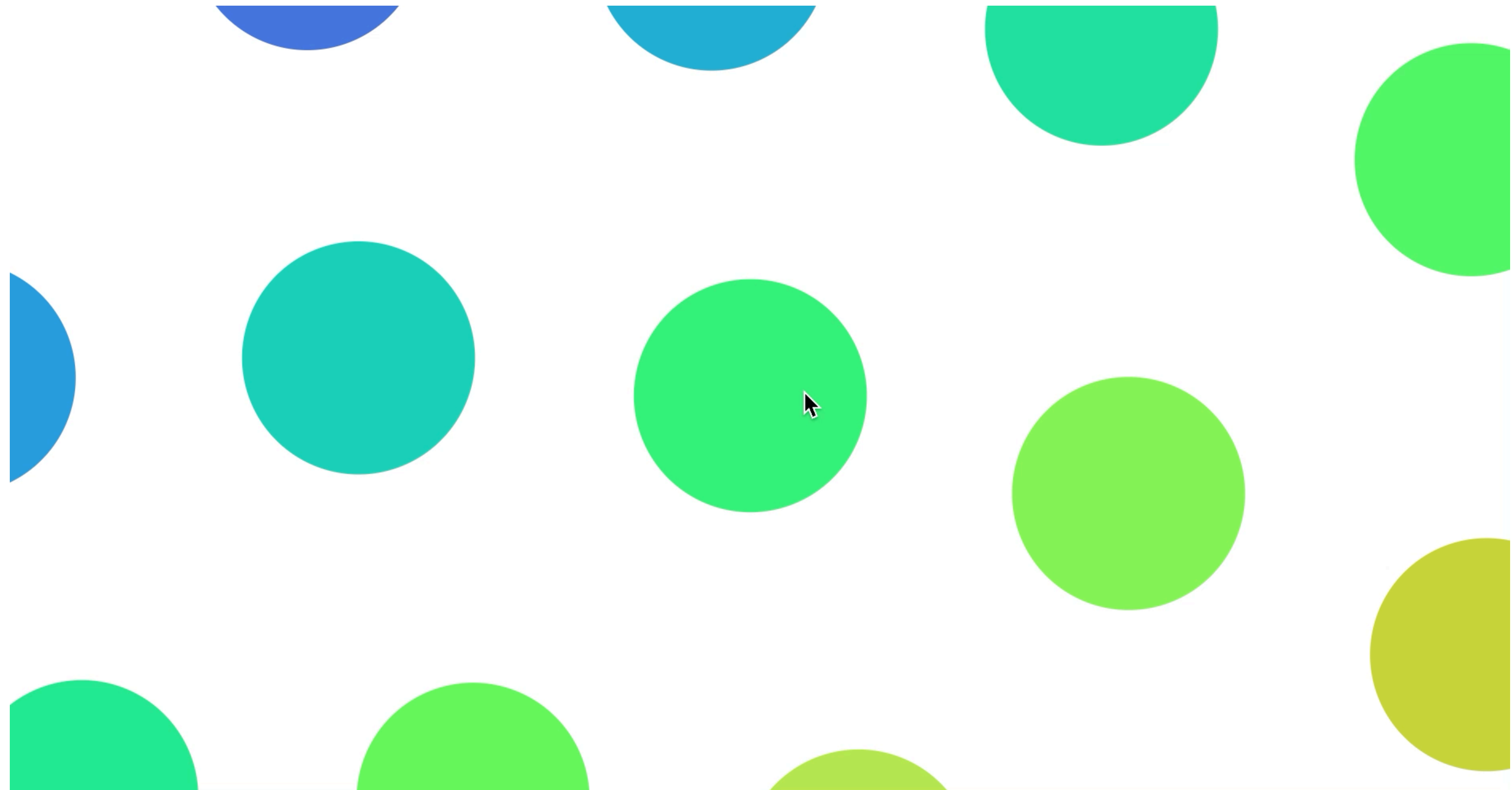
[van Wijk, 2003, M. Bostock]

van Wijk Smooth Zooming
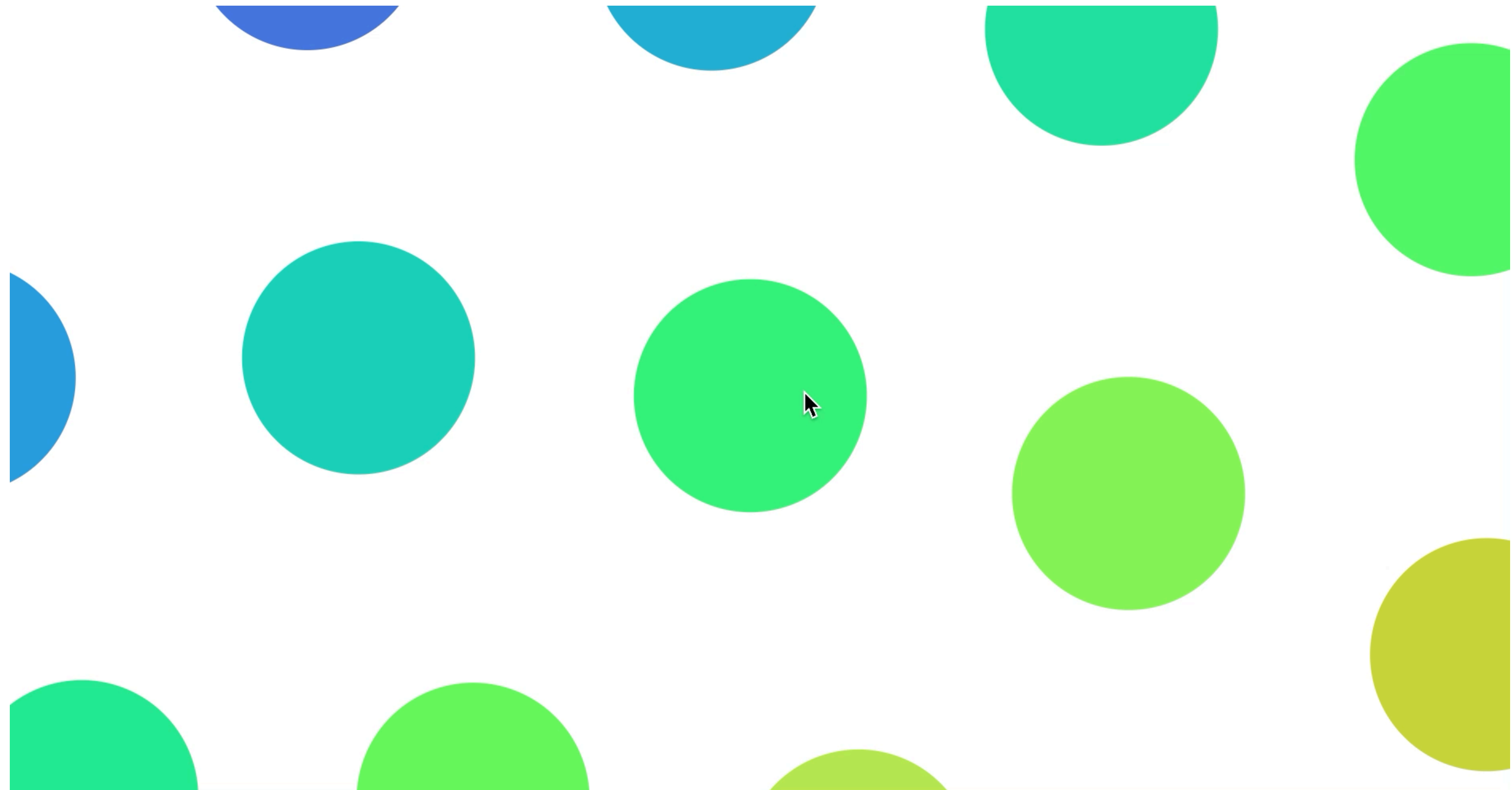
[van Wijk, 2003, M. Bostock]

Multiple Views

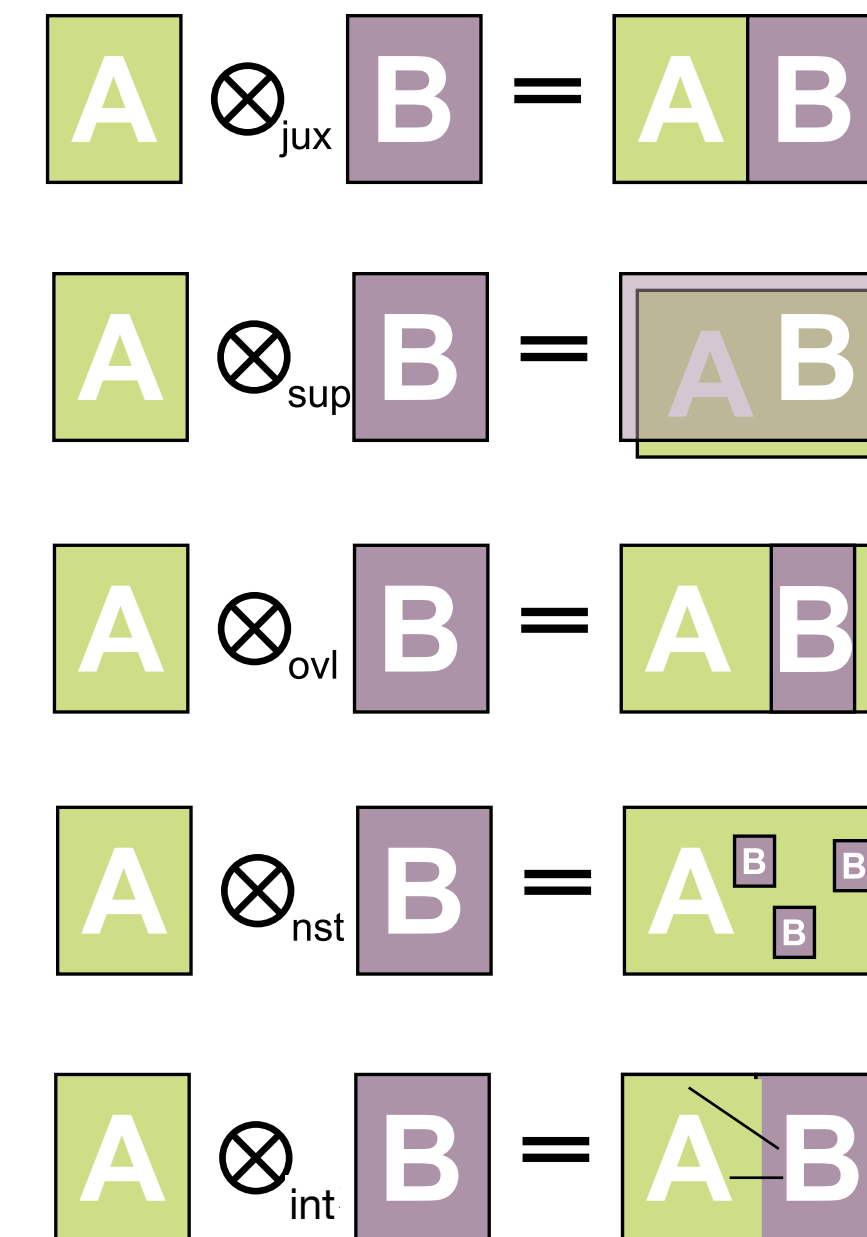[Improvise, Weaver, 2004]

Multiple Views

- Why have just one visualization?
- Sometimes data is best examined in more than one view
  - Clutter/visual overload
  - Different attributes (cannot show all attributes in one view)
  - Different scales (task requires overview or detail)
  - Different encodings (no single encoding is optimal for all tasks)
- Eyes Beat Memory (Ch. 6)
  - Aiding working memory:
    side-by-side/layers > animated > jump cuts
  - Showing all visual elements at once → don't need to remember

Multiple Views

- Big questions:
  - How to partition display or layer views?
  - How to coordinate views (e.g. navigation, selection)?
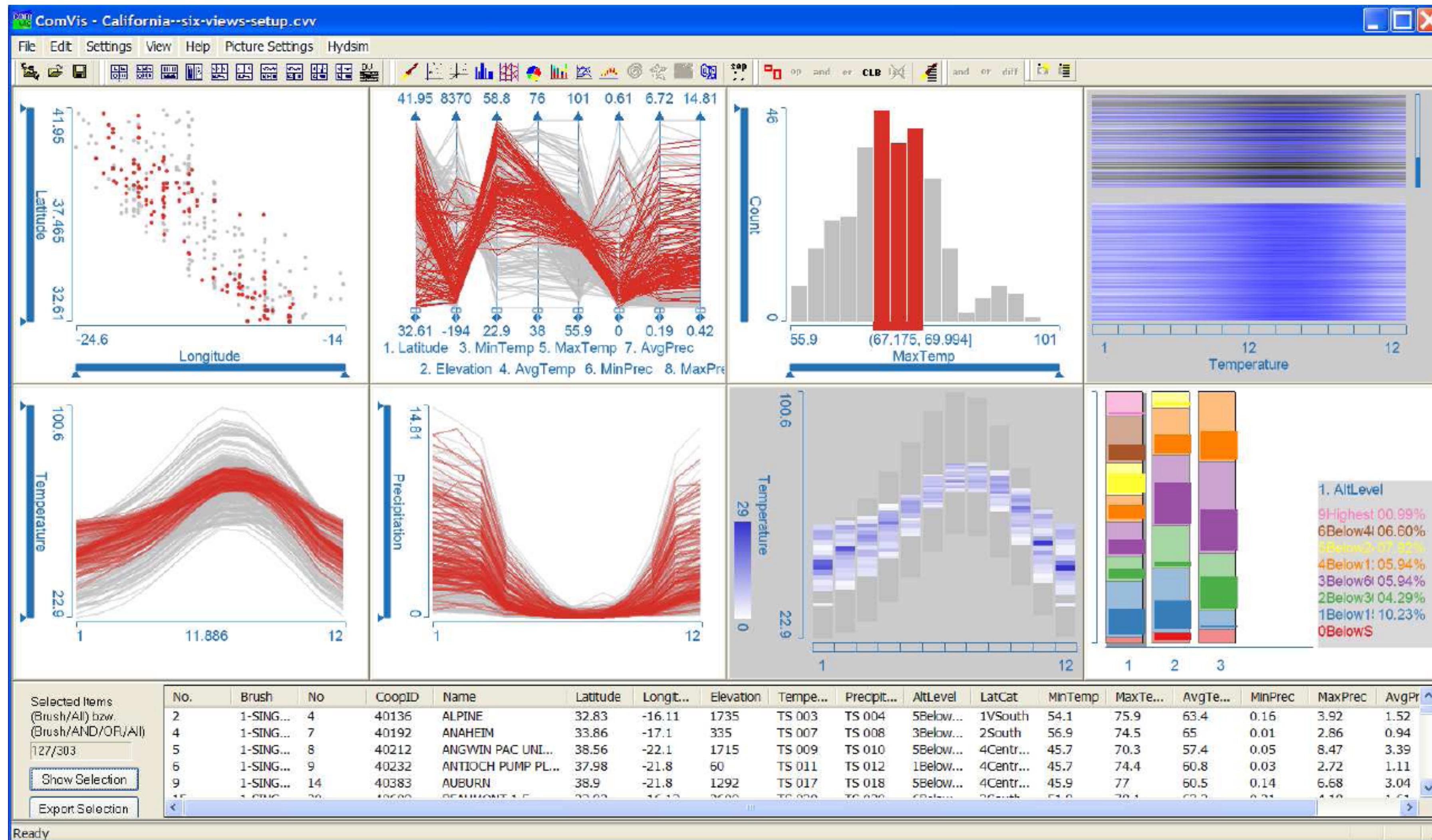 - What data is shared?

Design Space of Composite Visualization

- Composite visualization views (CVVs)

  - Includes Coordinated multiple views (CMV)

  - + More!

- Design Patterns:

  - Juxtaposition: side-by-side

  - Superimposition: layers

  - Overloading: vis meshed with another

  - Nesting: vis inside a vis (recursive vis)

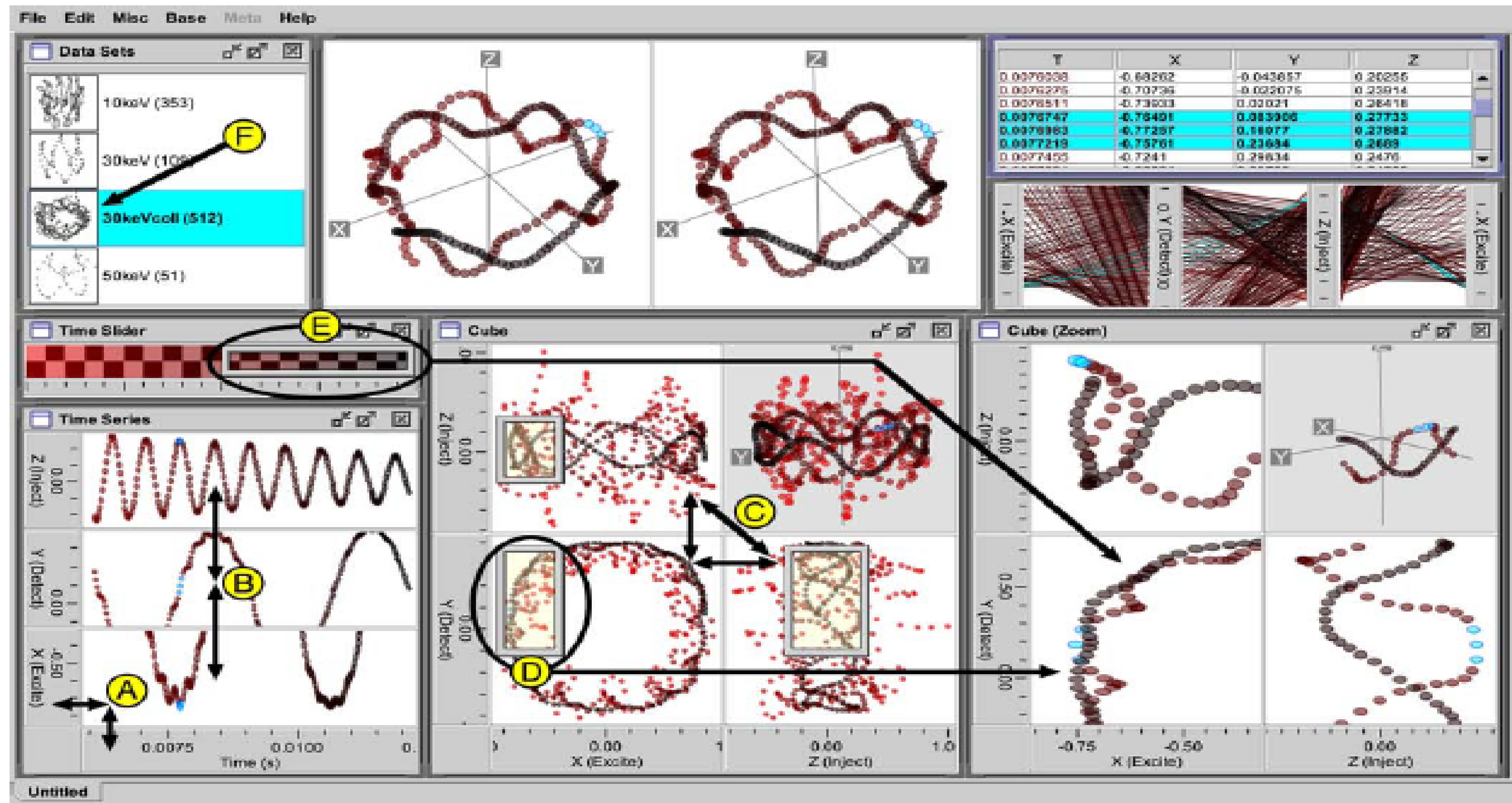 - Integration: "merge" views + links

$A \otimes_{jux} B = A B$

$A \otimes_{sup} B = A B$

$A \otimes_{ovl} B = A B$

$A \otimes_{nst} B = A$

$A \otimes_{int} B = A B$

[W. Javed and N. Elmqvist, 2012]

Juxtaposition

[ComVis, K. Matkovic et al., 2008]

Juxtaposition

[Improvise, C. Weaver, 2004]

Juxtaposition Guidelines

- Benefits:

  - The component visualizations are independent and can be composed without interference

  - Easy to implement

- Drawbacks:

  - Implicit visual linking is not always easy to see, particularly when multiple objects are selected

  - Space is divided between the views, yielding less space for each view

- Applications: Use for heterogeneous datasets consisting of many different types of data, or for where different independent visualizations need to be combined.
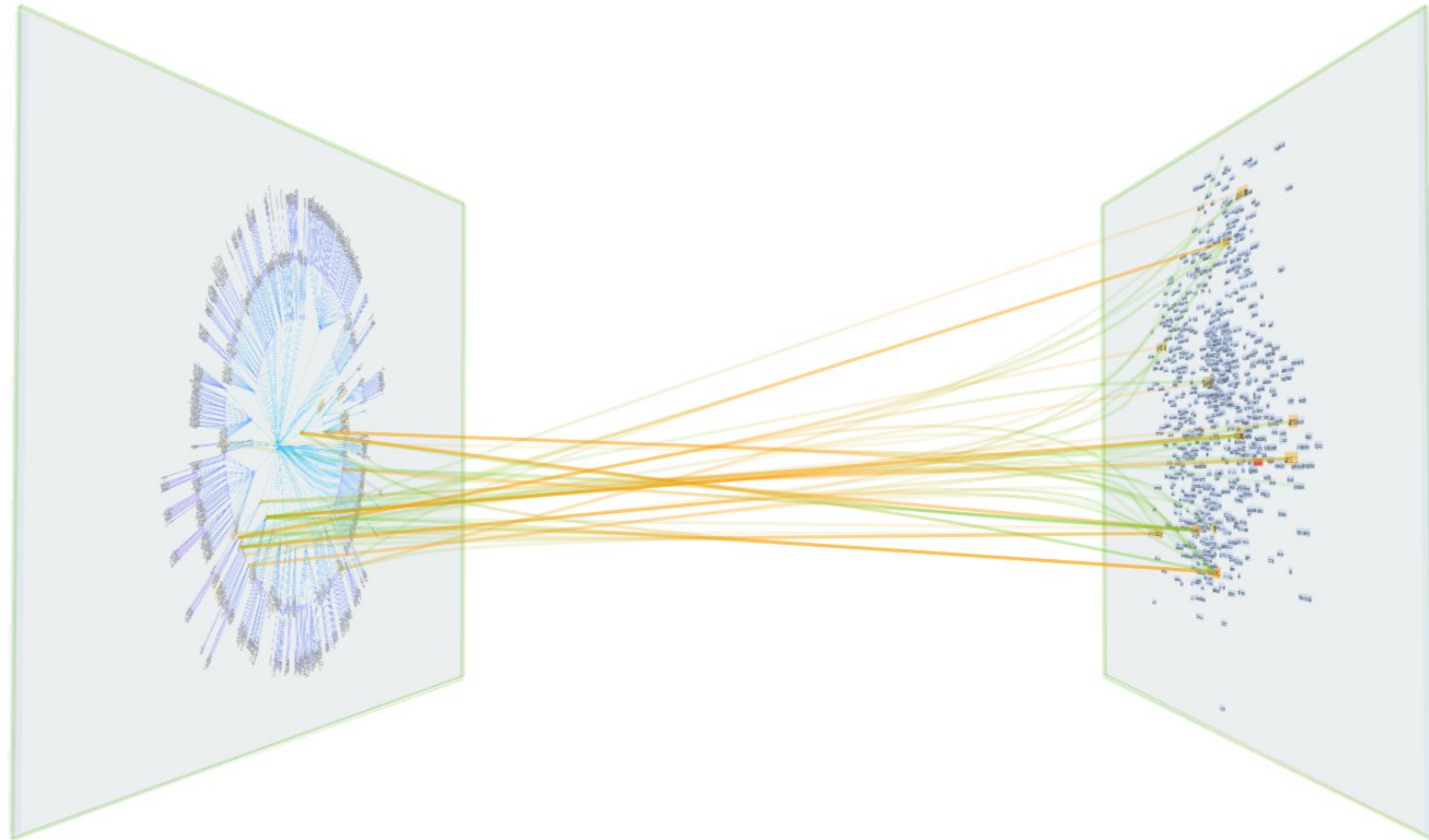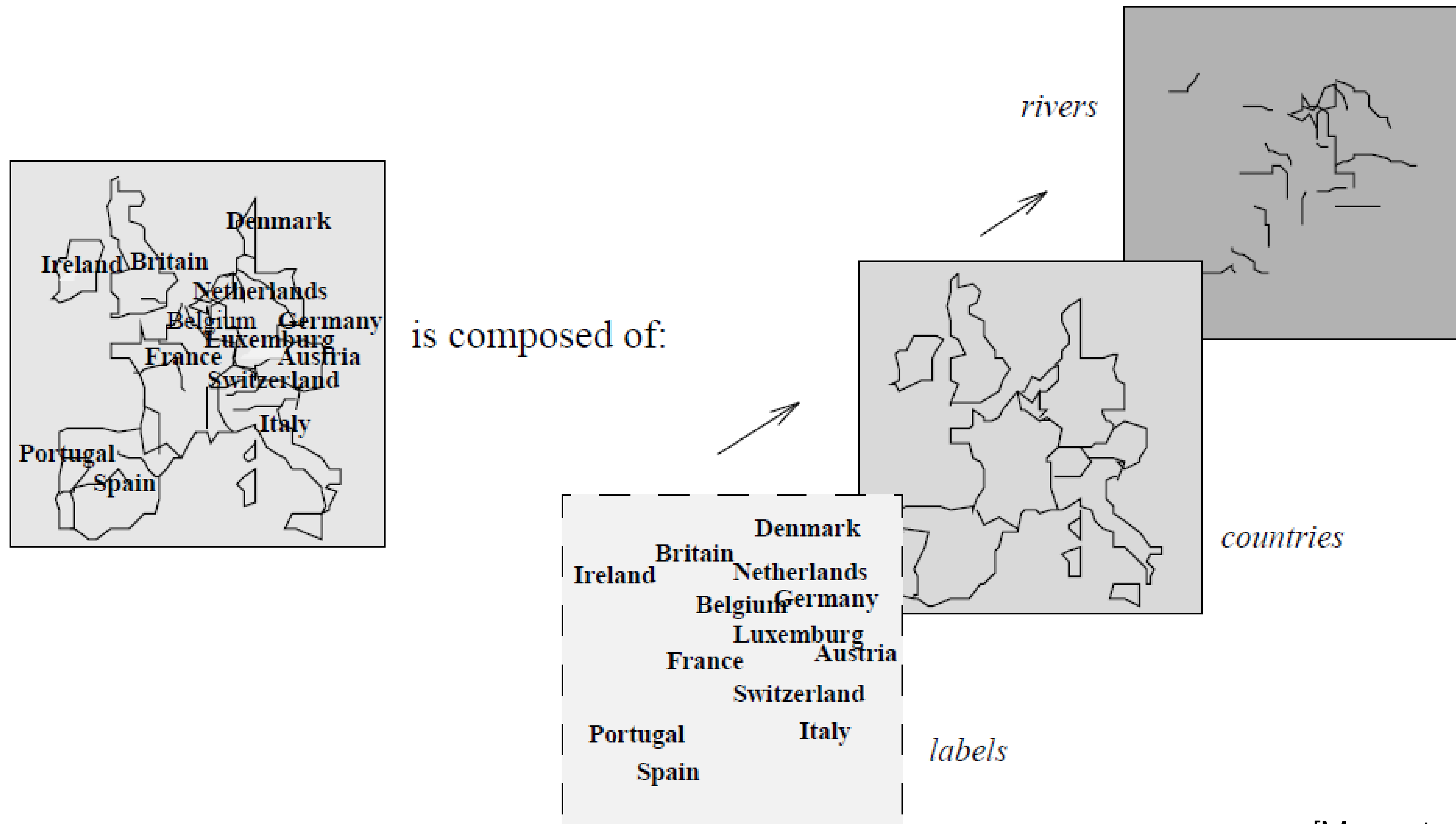
[W. Javed and N. Elmqvist, 2012]

Integration
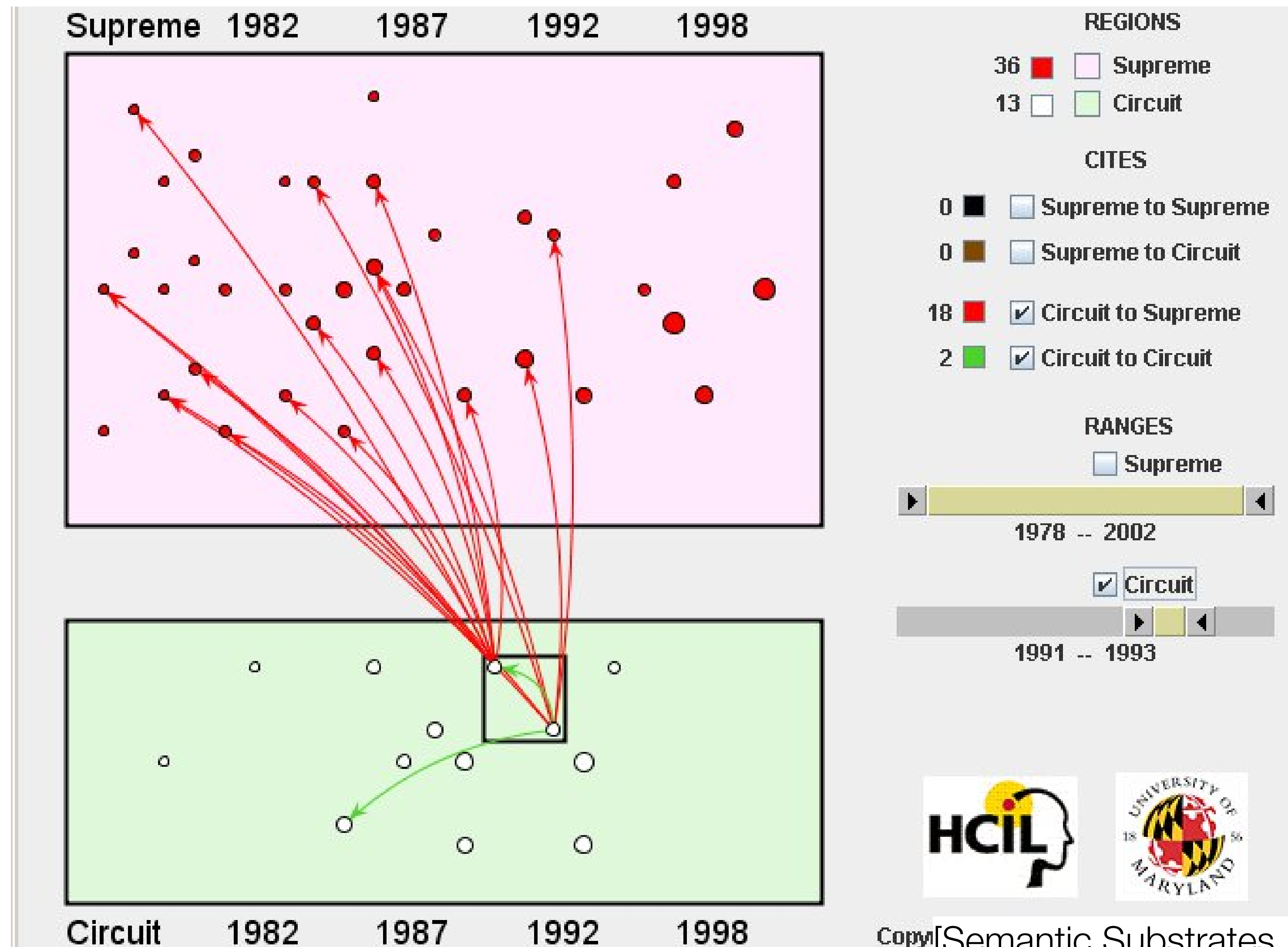
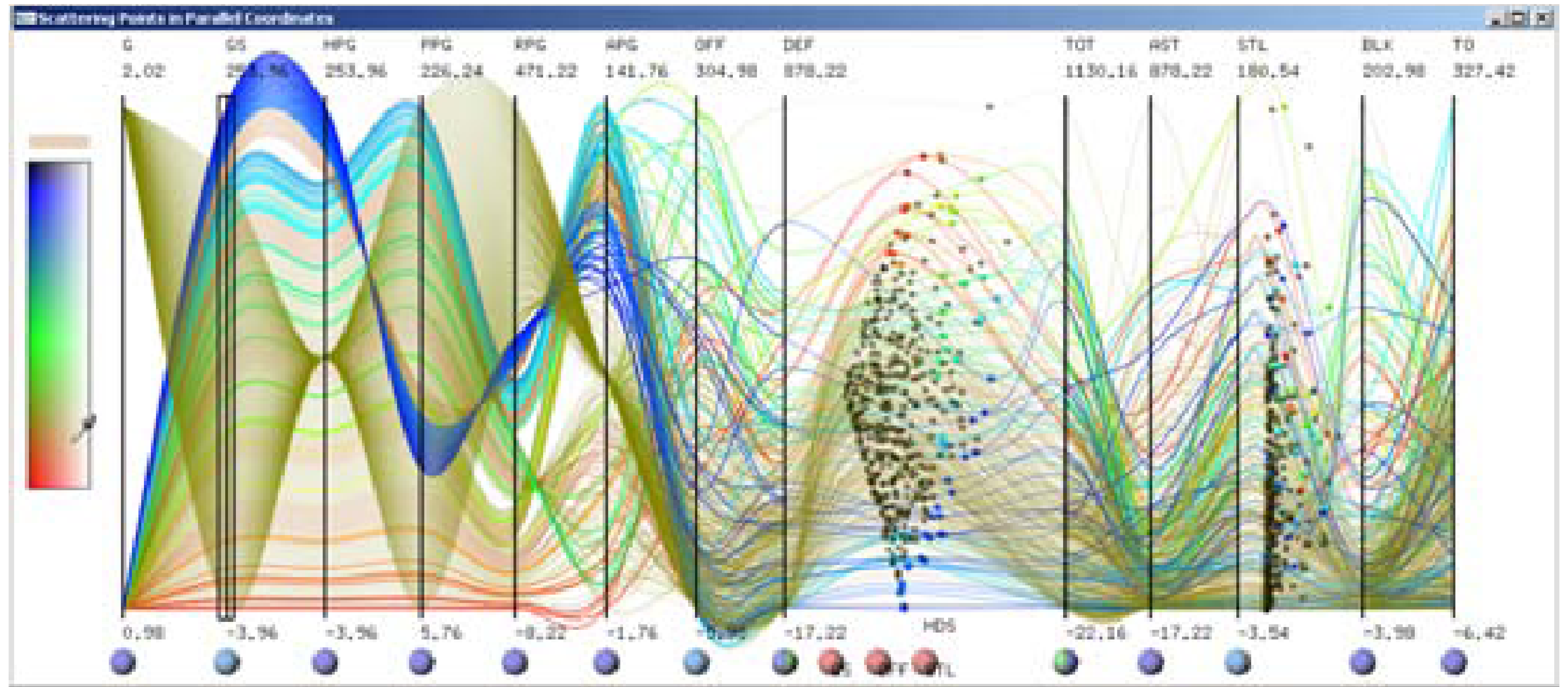[Semantic Substrates, Schneiderin and Aris, 2006]

Integration

[VisLink, Collins and Carpendale, 2007]

Superimposition

is composed of:

rivers

countries

labels

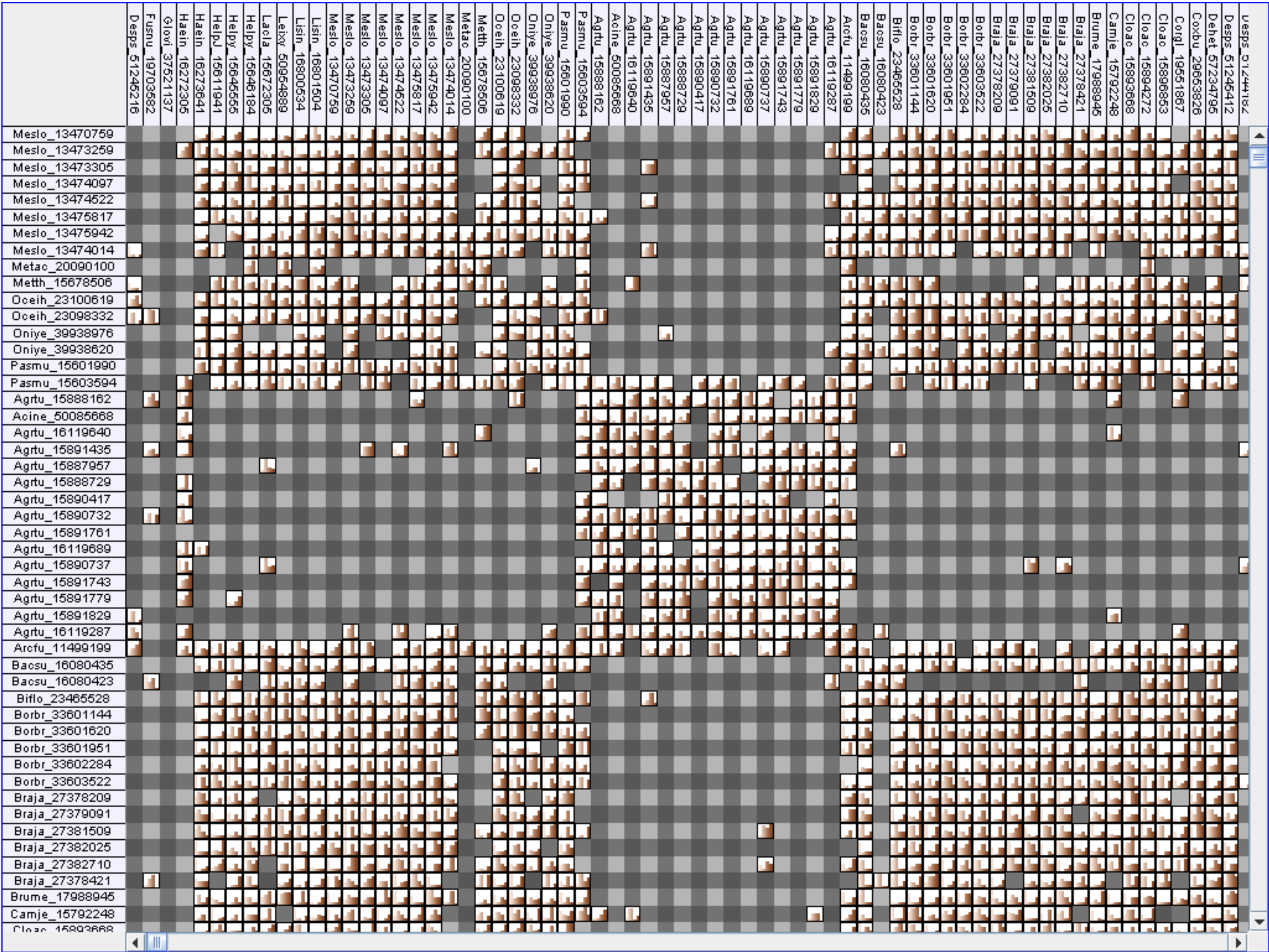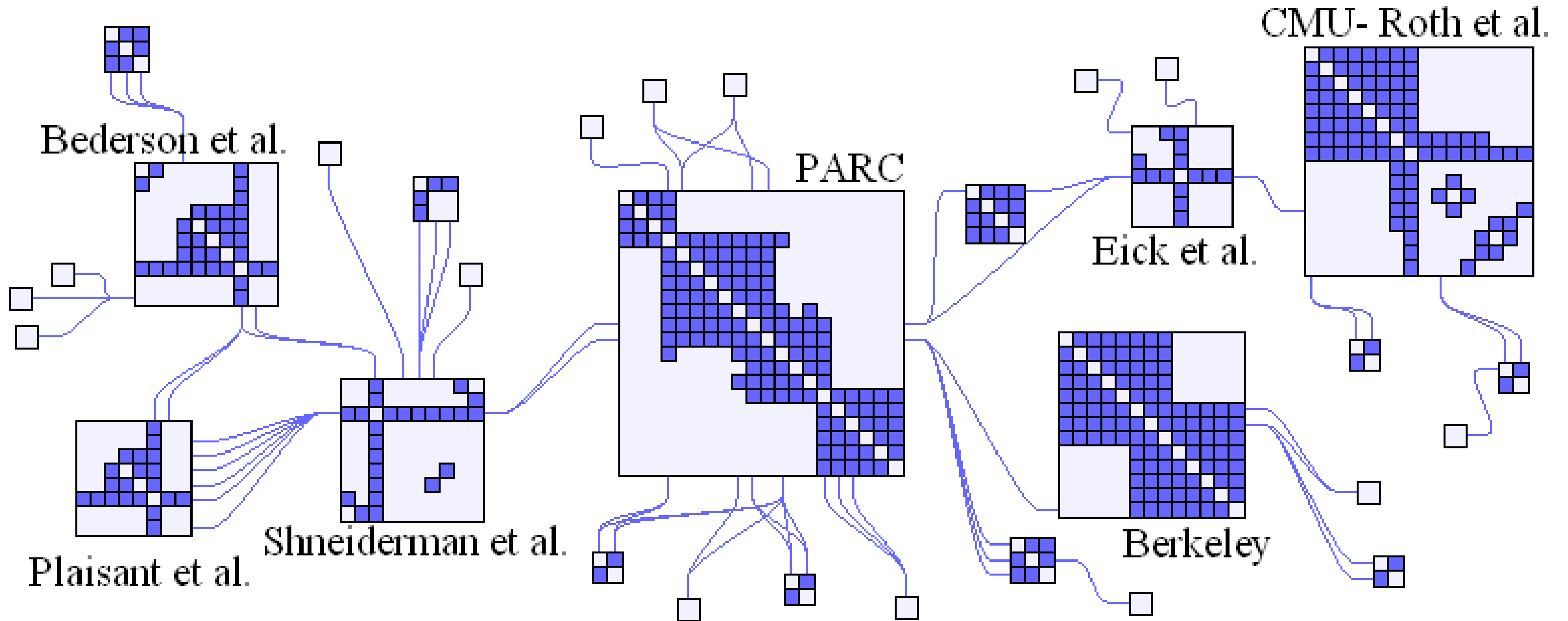# Overloading

[SPCC, X. Yuan et al., 2009]

Nesting

[ZAME, N. Elmqvist et al., 2008]

Nesting

[NodeTrix, N. Henry et al., 2007]