Information Visualization

Visualization Research

Dr. David Koop

Visualization Tools & Tradeoffs

- Fast, turnkey approaches
- Control over all visual elements

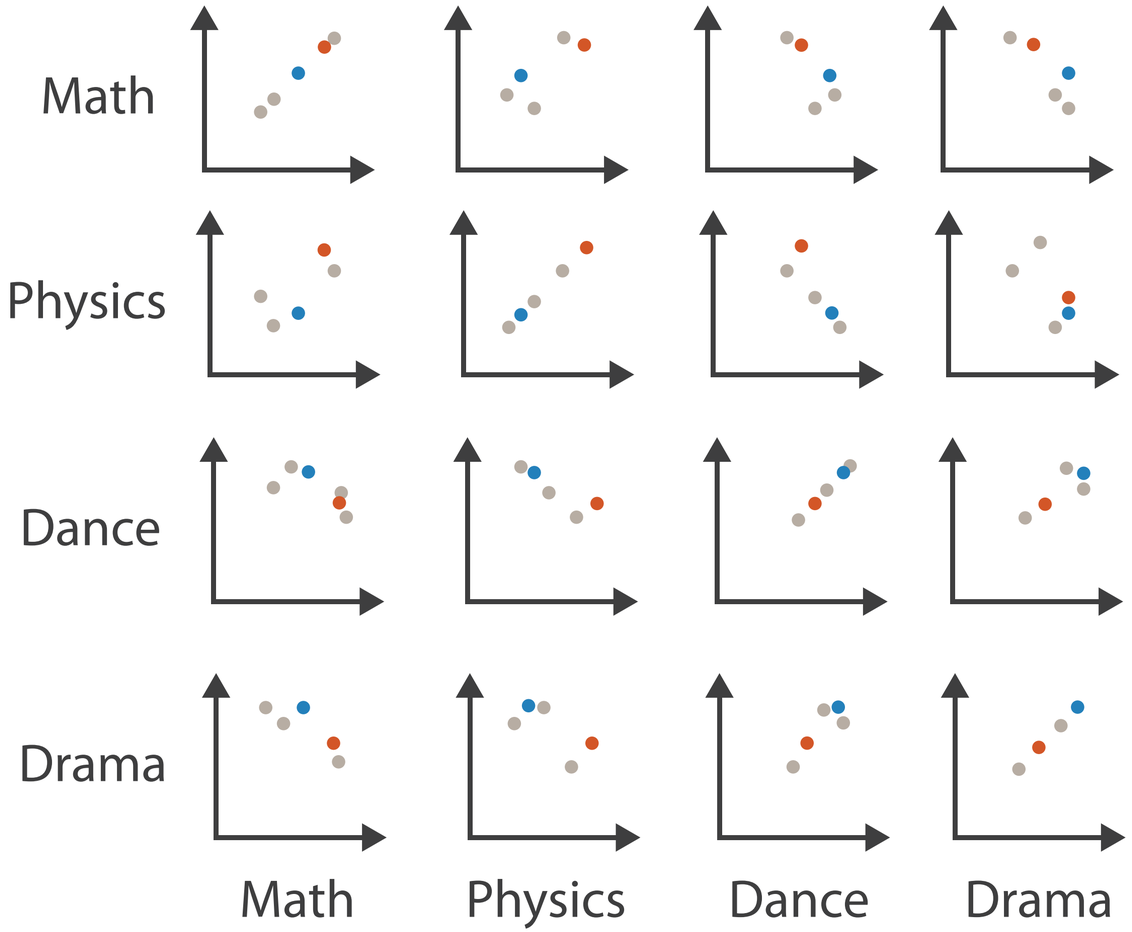
- You can use **multiple** tools! Think about purpose
  - Exploration
  - Explanation (custom design, handle interaction)

Scatterplot Matrices and Parallel Coordinates

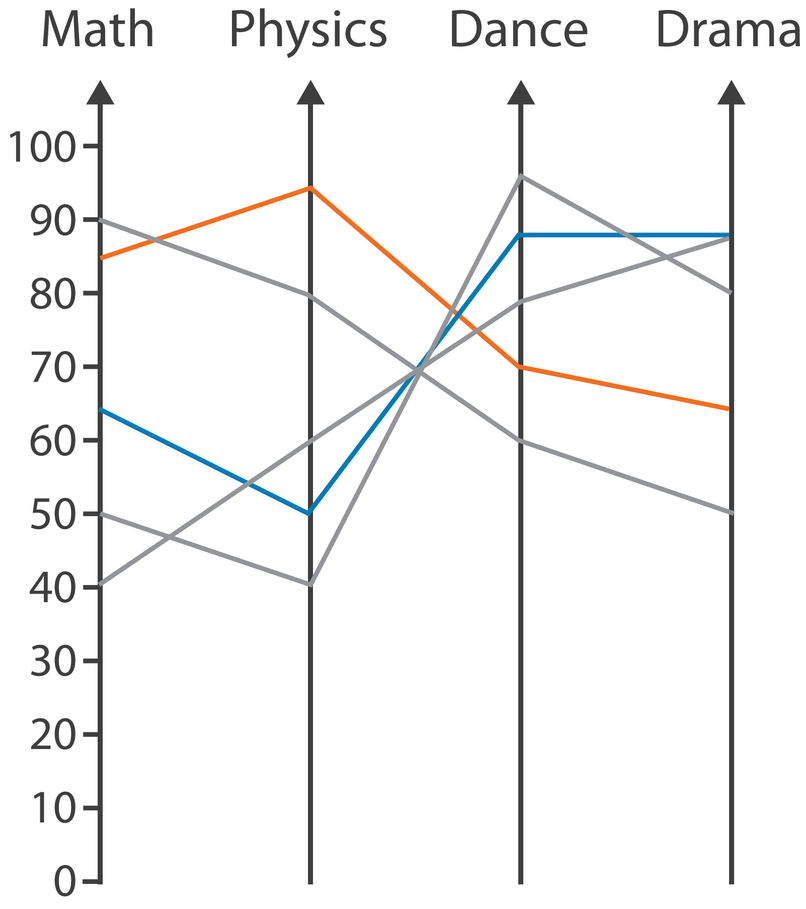
[Munzner (ill. Maguire), 2014]

Scatterplot Matrices and Parallel Coordinates

Scatterplot Matrix

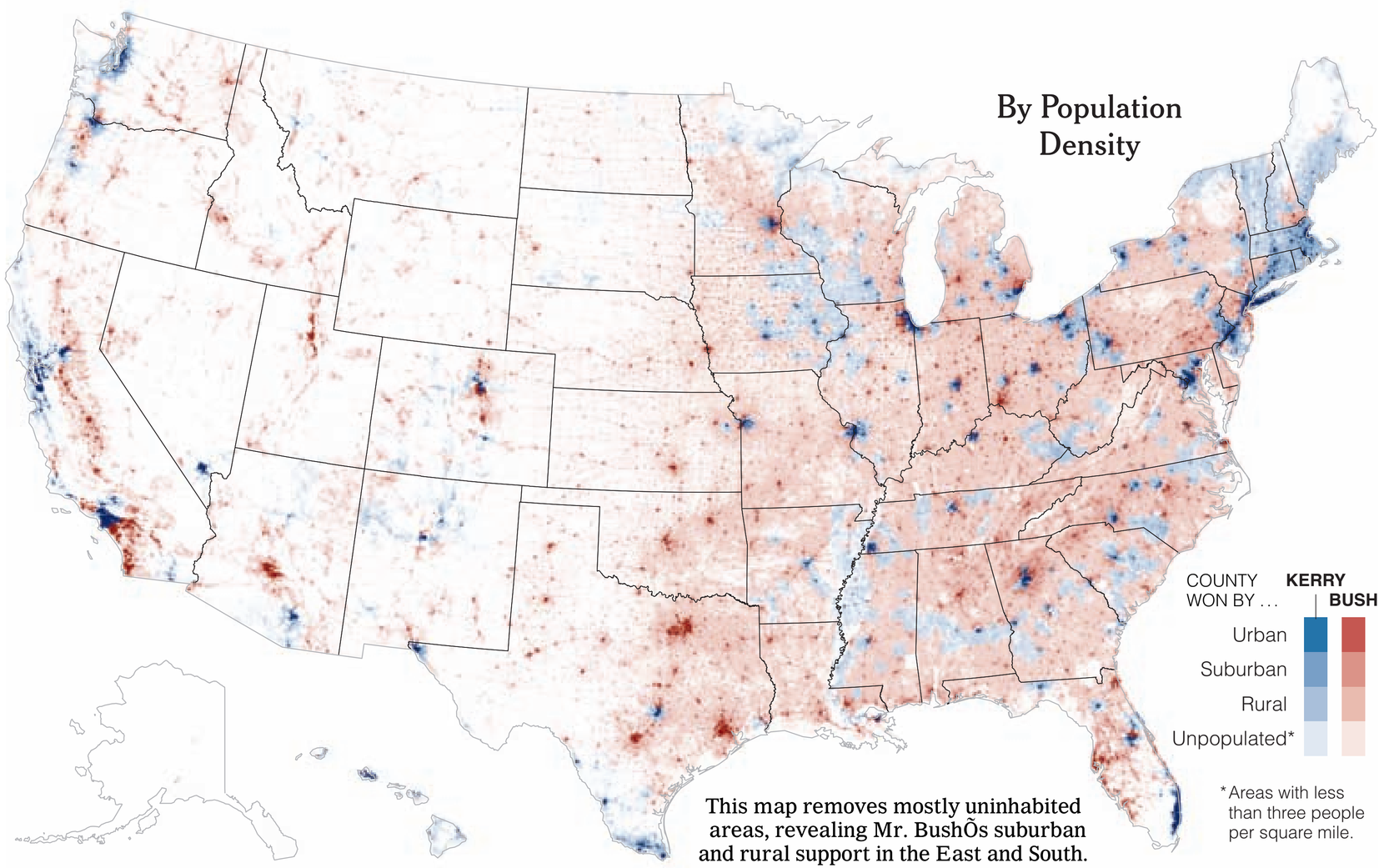


Parallel Coordinates



[Munzner (ill. Maguire), 2014]

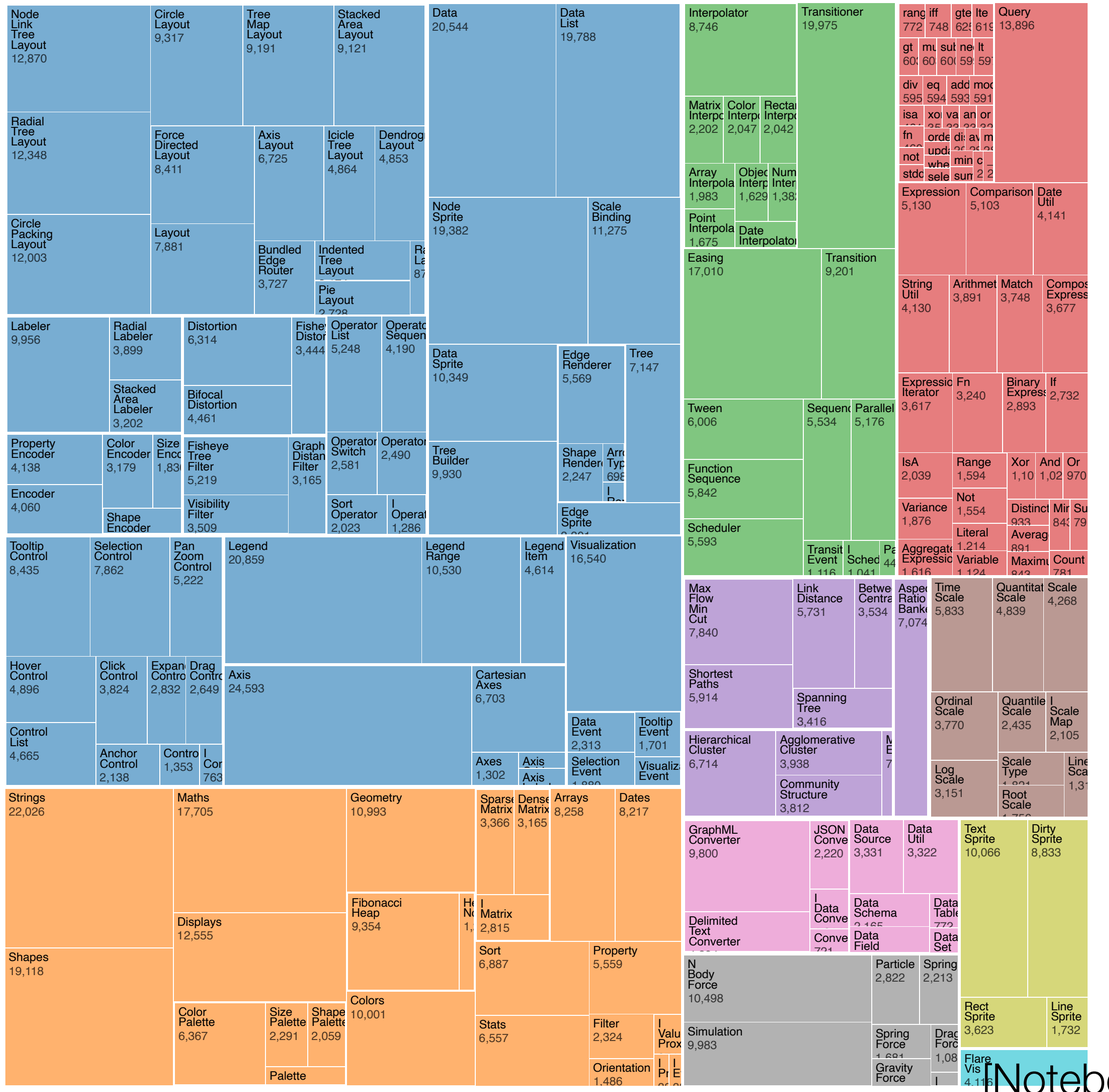
Map with Two Variables



[M. Ericson, New York Times]

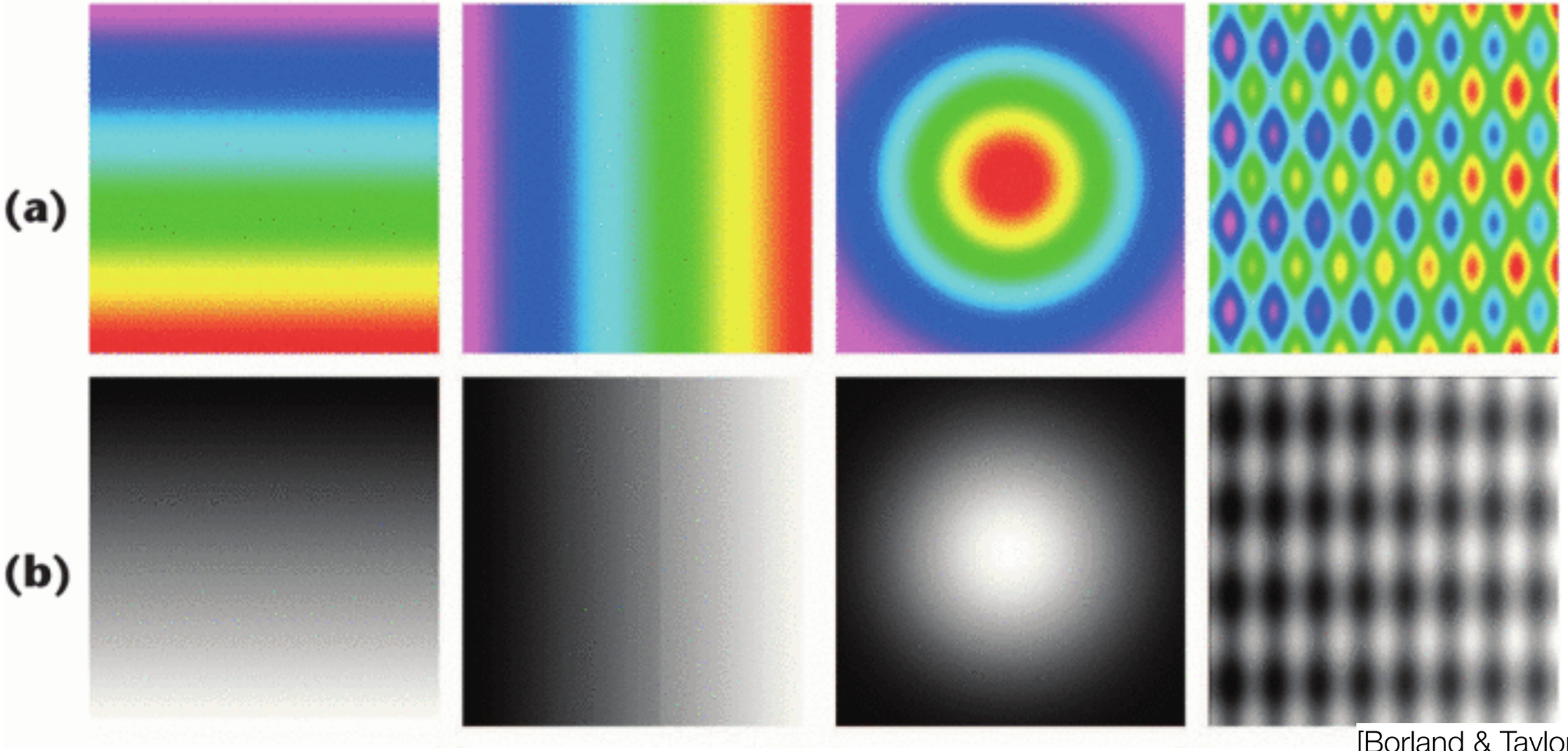
Treemaps

- Containment marks instead of connection marks
- Encodes some attribute of the items as the **size** of the rectangles
- Not as easy to see the intermediate rectangles
- Scalability: millions of leaf nodes and links possible
- Need a layout algorithm!
  - Slice-and-Dice vs. Squarify
- Viewing Hierarchy: Cushion Treemap



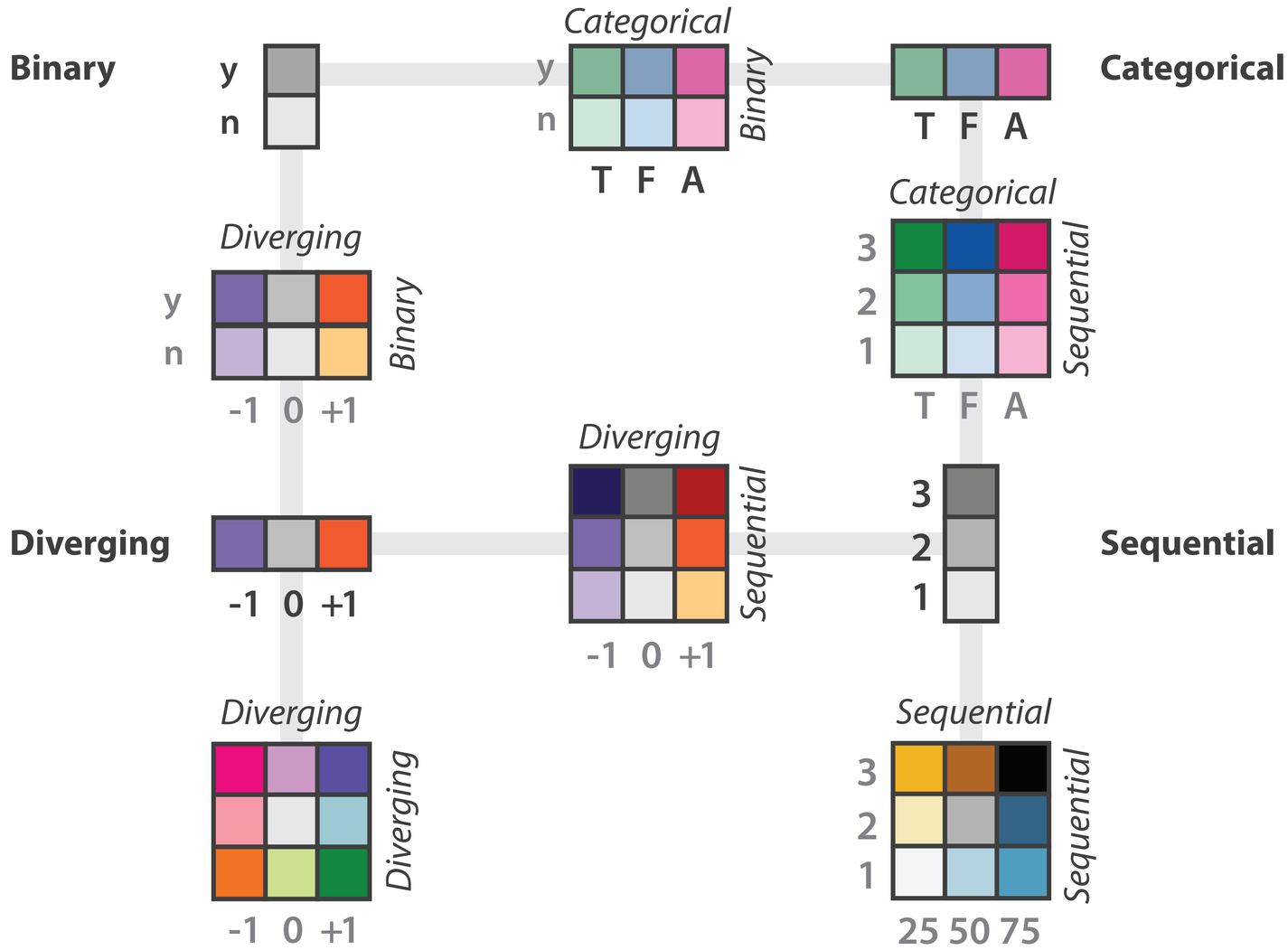
[Notebook]

Avoid Rainbow Colormaps!



[Borland & Taylor, 2007]

Colormaps

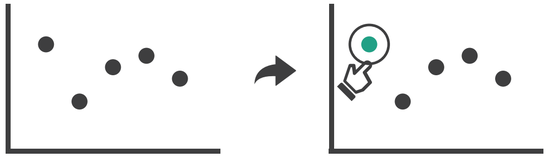


[Munzner (ill. Maguire), 2014]

Interaction Overview

Change over Time

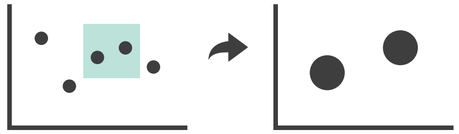
Select



Navigate

Item Reduction

- *Zoom*
  Geometric or *Semantic*



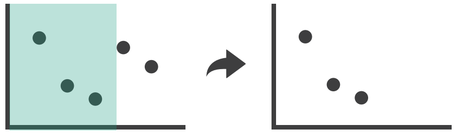
- *Pan/Translate*

- *Constrained*

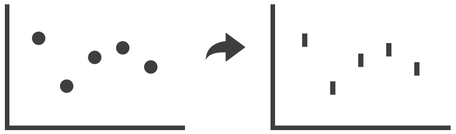
Attribute Reduction

- *Slice*

- *Cut*

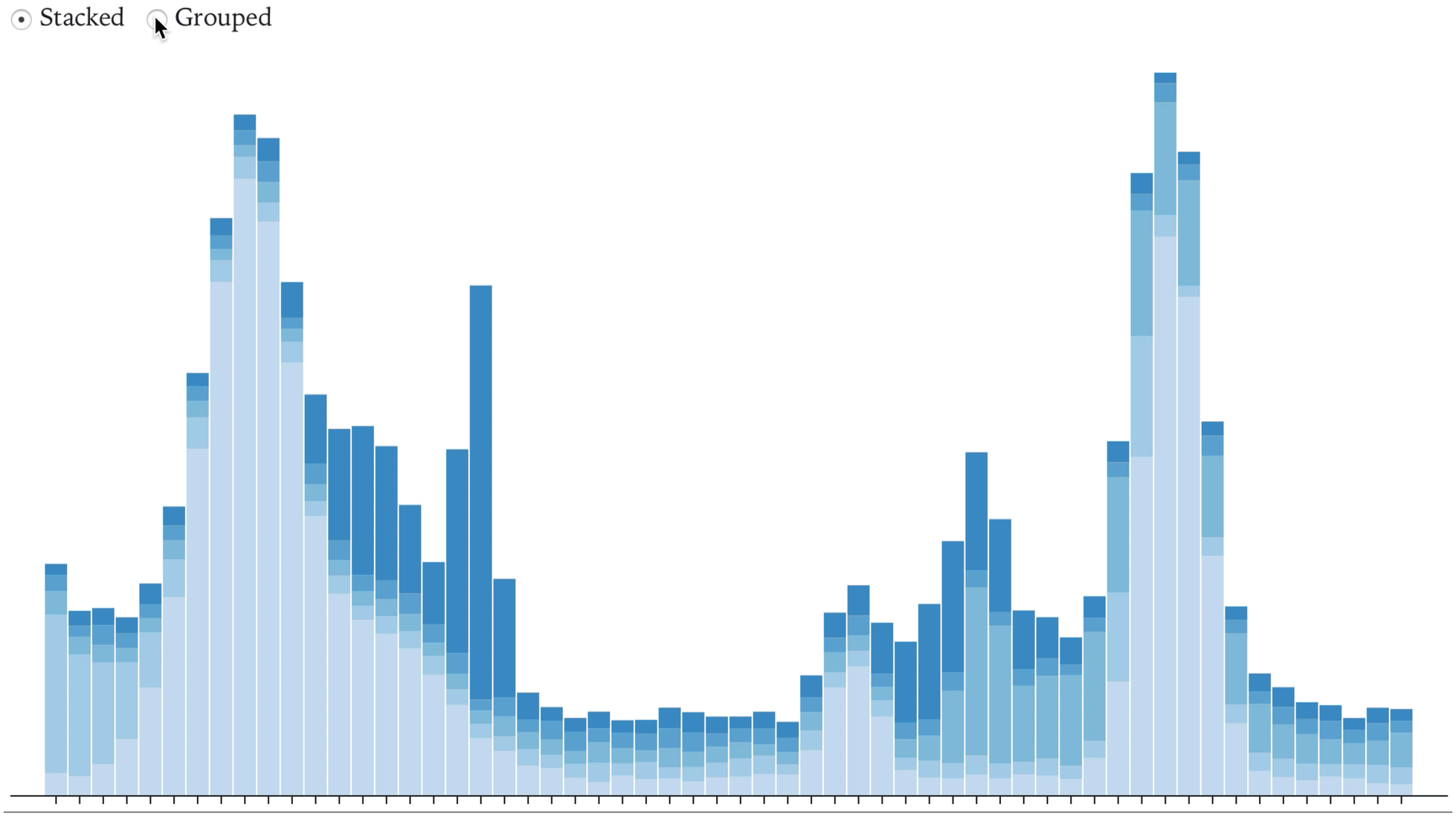


- *Project*



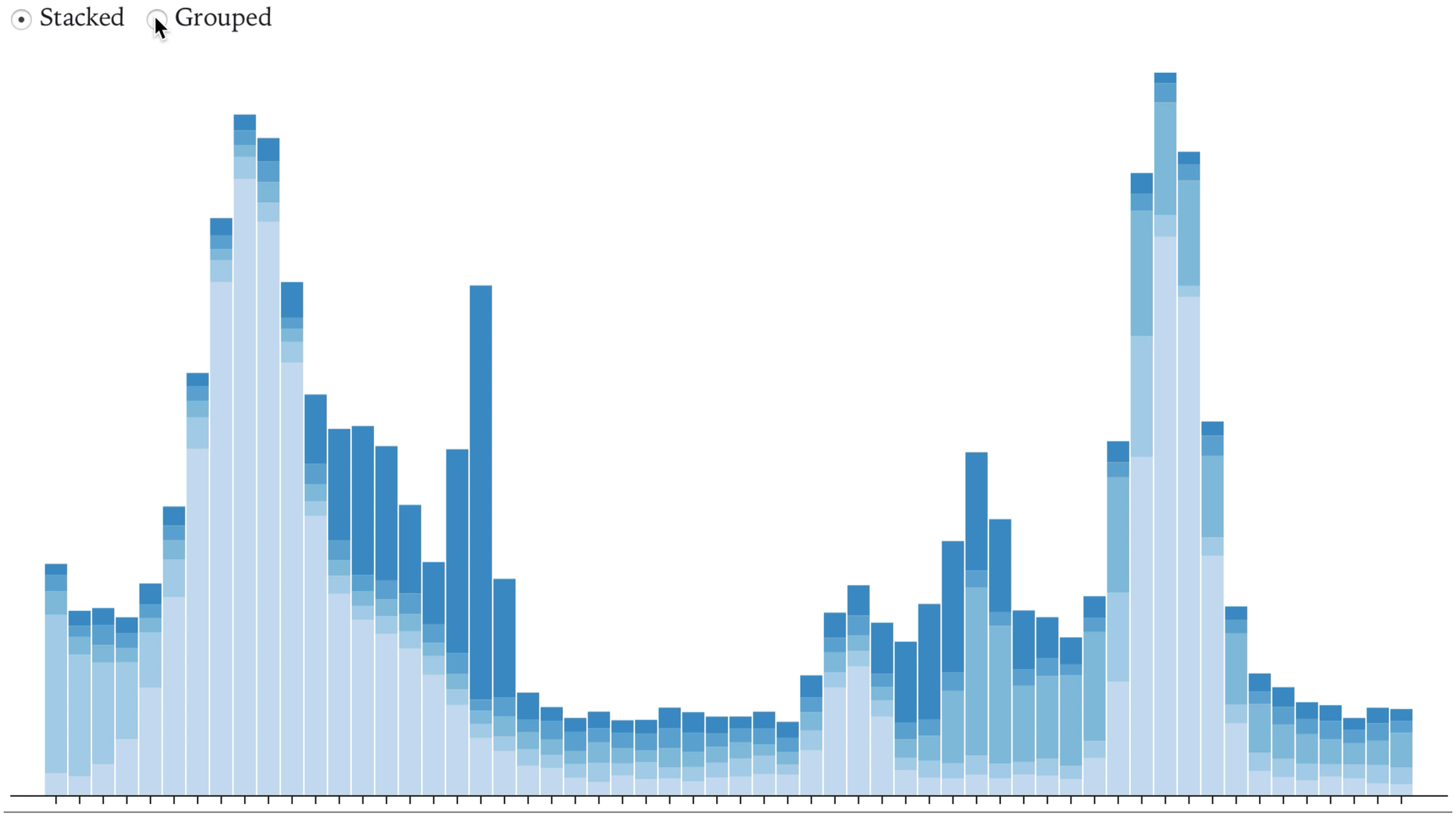
[Munzner (ill. Maguire), 2014]

Animated Transitions



[M. Bostock]

Animated Transitions



[M. Bostock]

Multiple Views

Juxtapose and Coordinate Multiple Side-by-Side Views

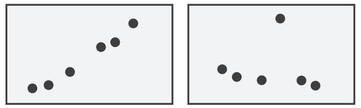
- Share Encoding: Same/Different
  - *Linked Highlighting*

- Share Data: All/Subset/None

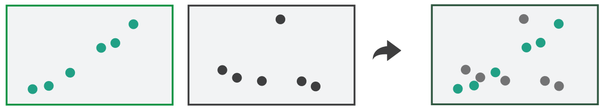
- Share Navigation

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

Partition into Side-by-Side Views

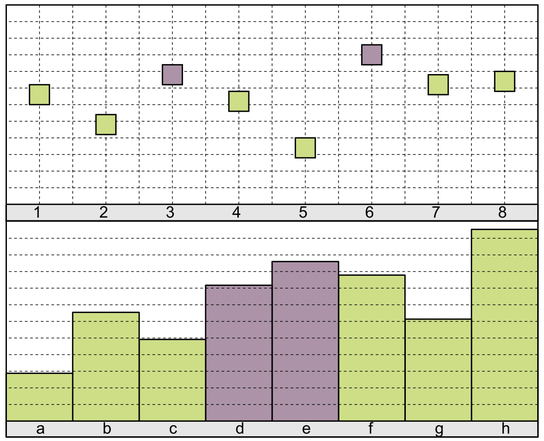


Superimpose Layers

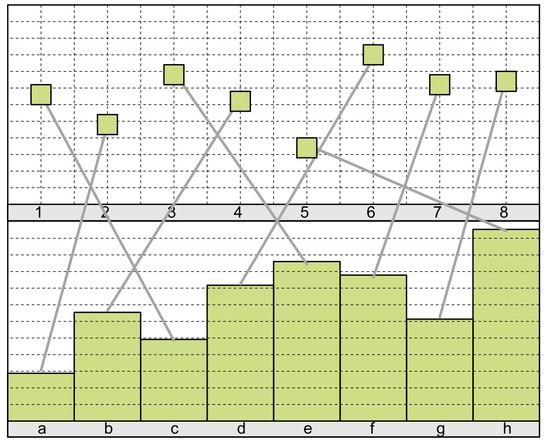


[Munzner (ill. Maguire), 2014]

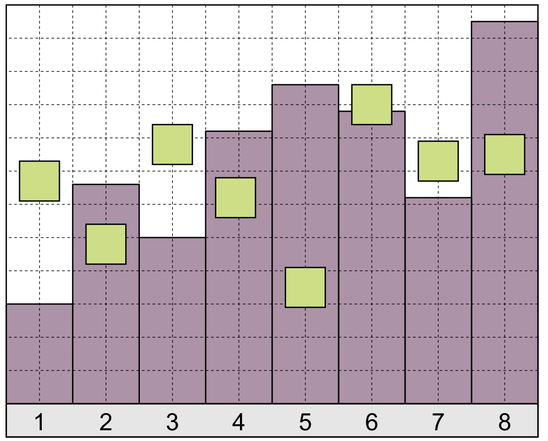
Composite Visualization Techniques



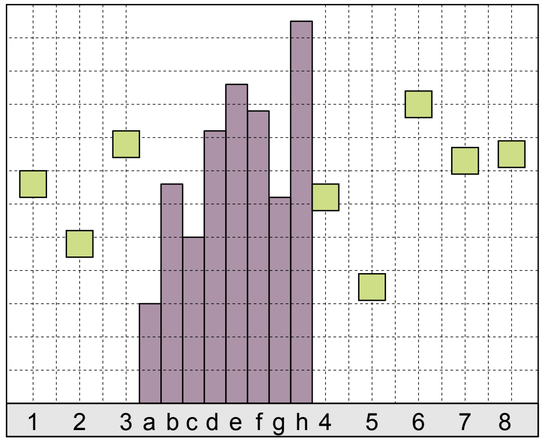
(a) Juxtaposed views.



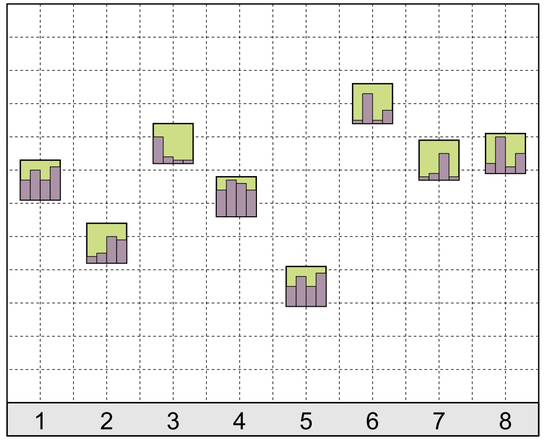
(b) Integrated views.



(c) Superimposed views.



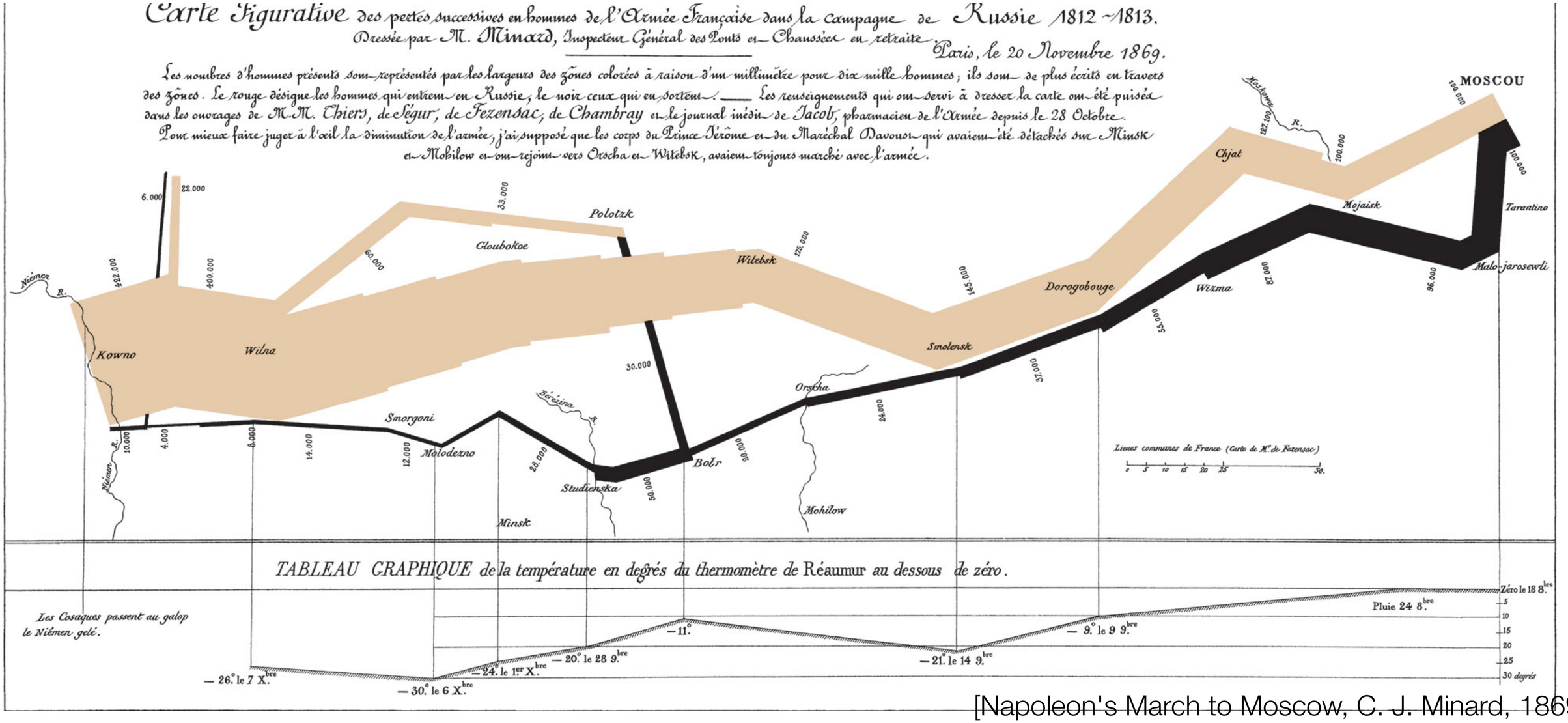
(d) Overloaded views.



(e) Nested views.

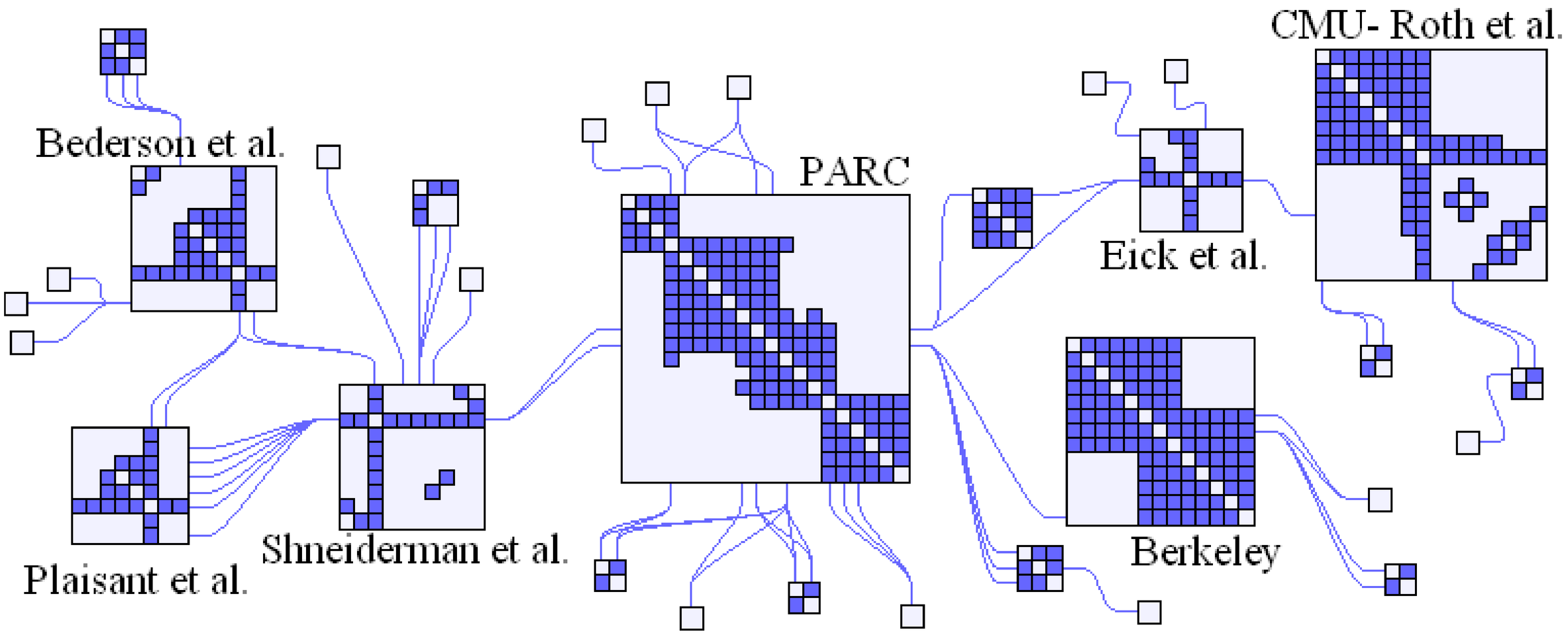
[W. Javed and N. Elmqvist, 2012]

Integration



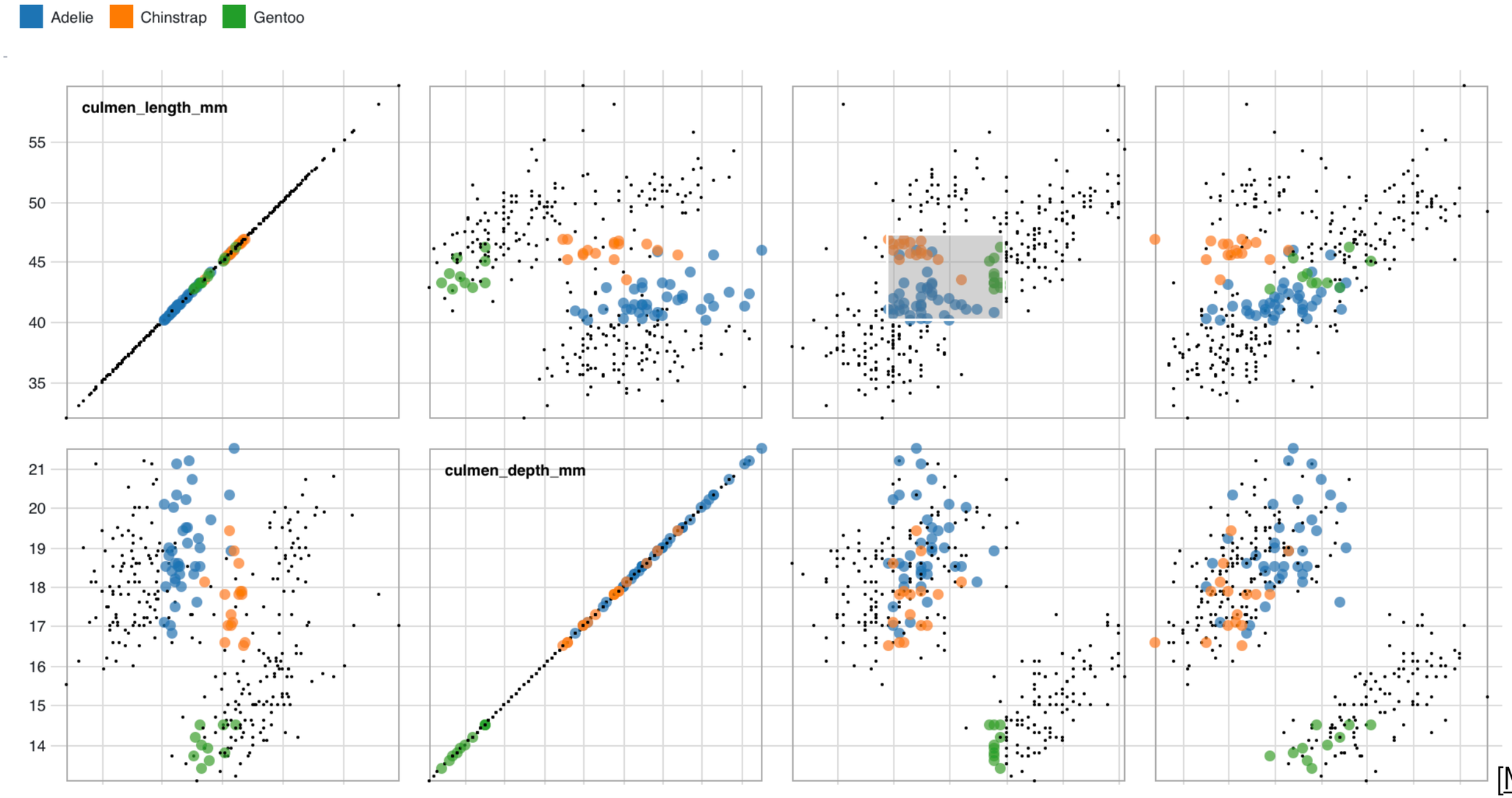
[Napoleon's March to Moscow, C. J. Minard, 1869]

Nesting



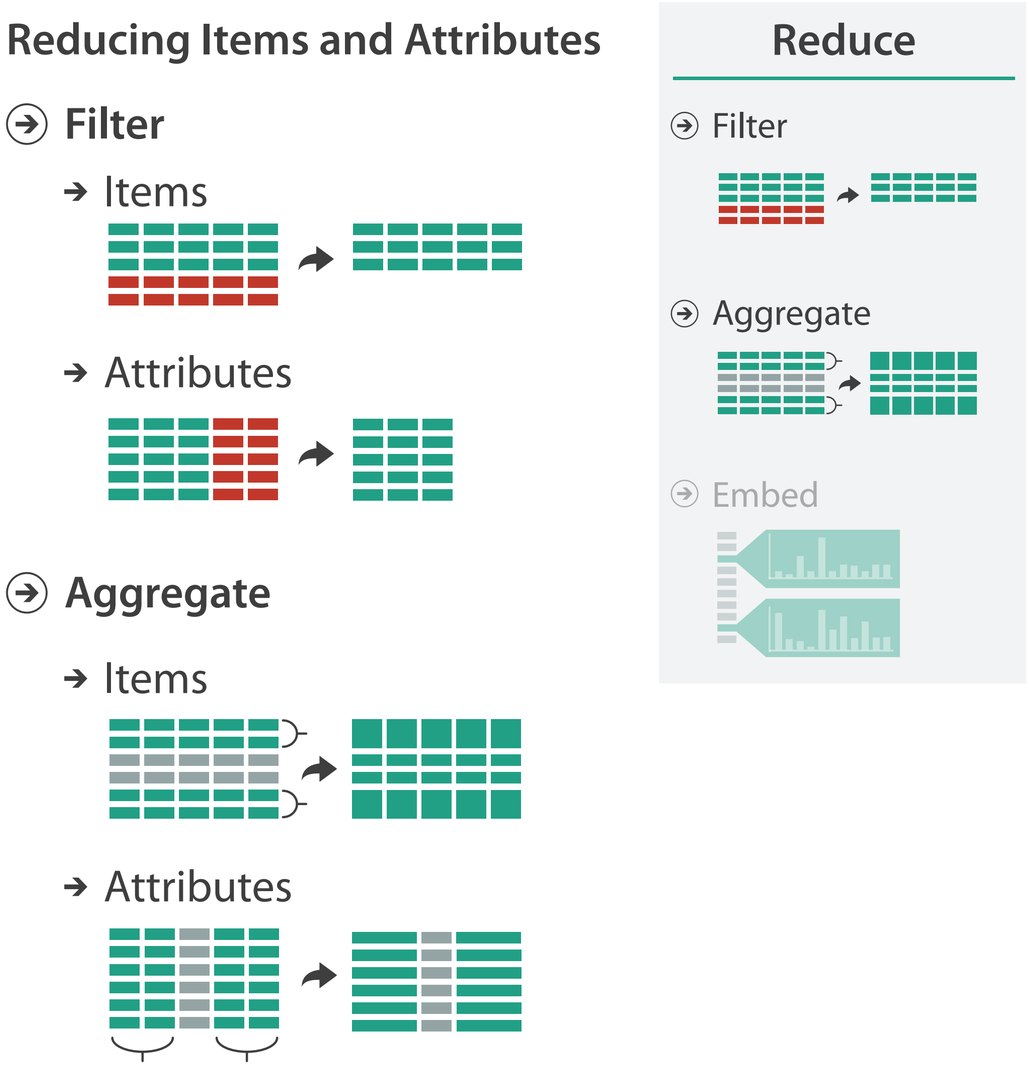
[NodeTrix, N. Henry et al., 2007]

Brushing



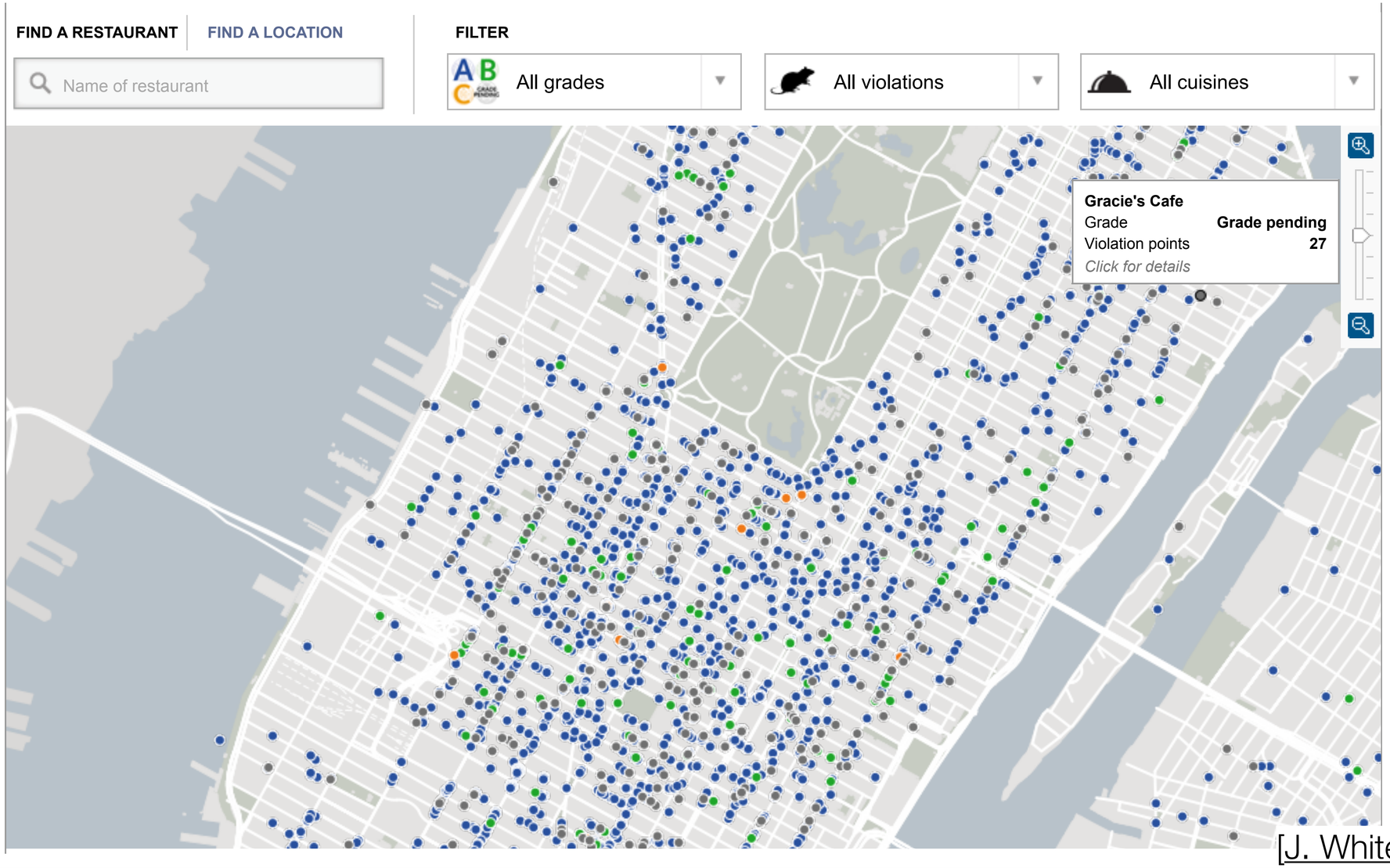
[M. Bostock]

Filtering and Aggregation



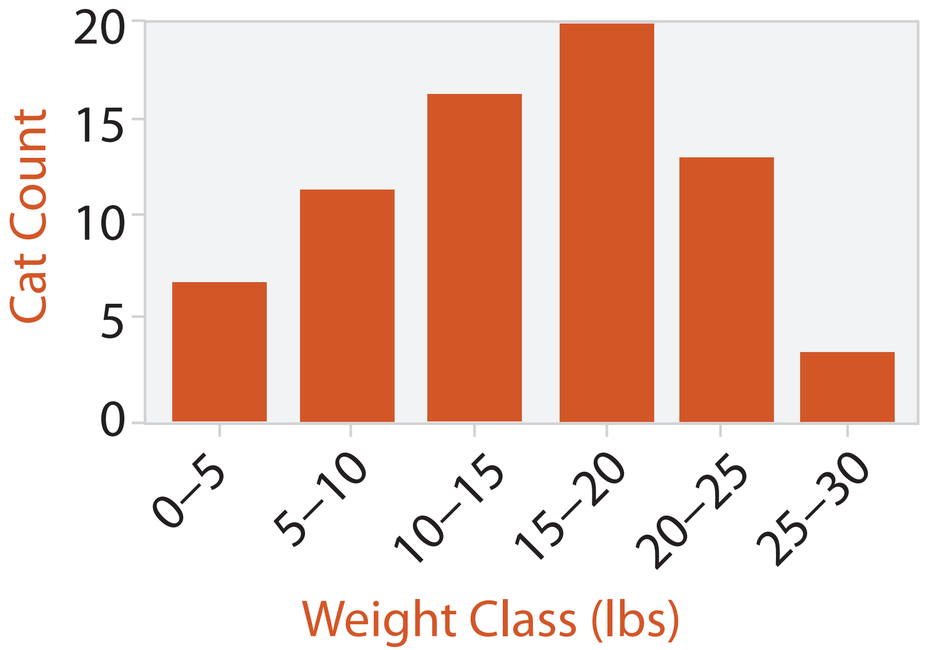
[Munzner (ill. Maguire), 2014]

Filtering using Widgets



[J. White, New York Times]

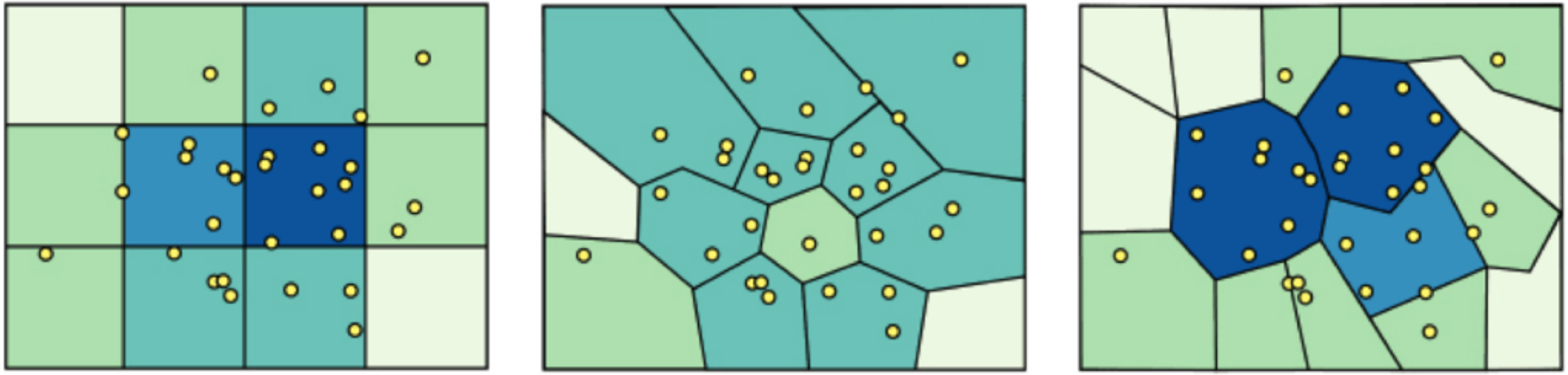
Aggregation: Histograms



- Very similar to bar charts
- Often shown without space between (continuity)
- Choice of number of bins
  - Important!
  - Viewers may infer different trends based on the layout

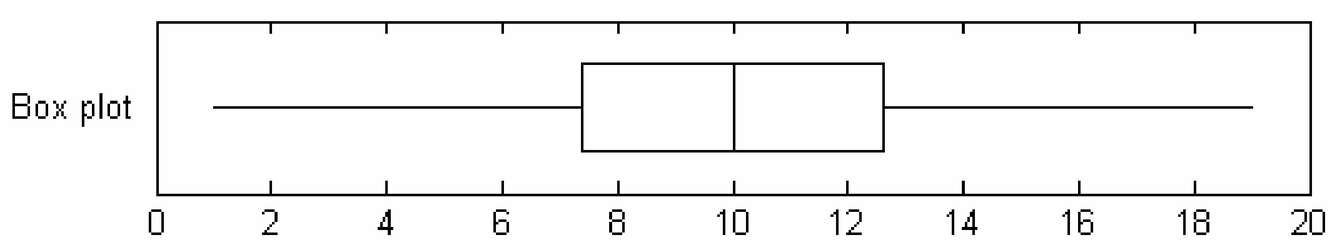
[Munzner (ill. Maguire), 2014]

Spatial Aggregation



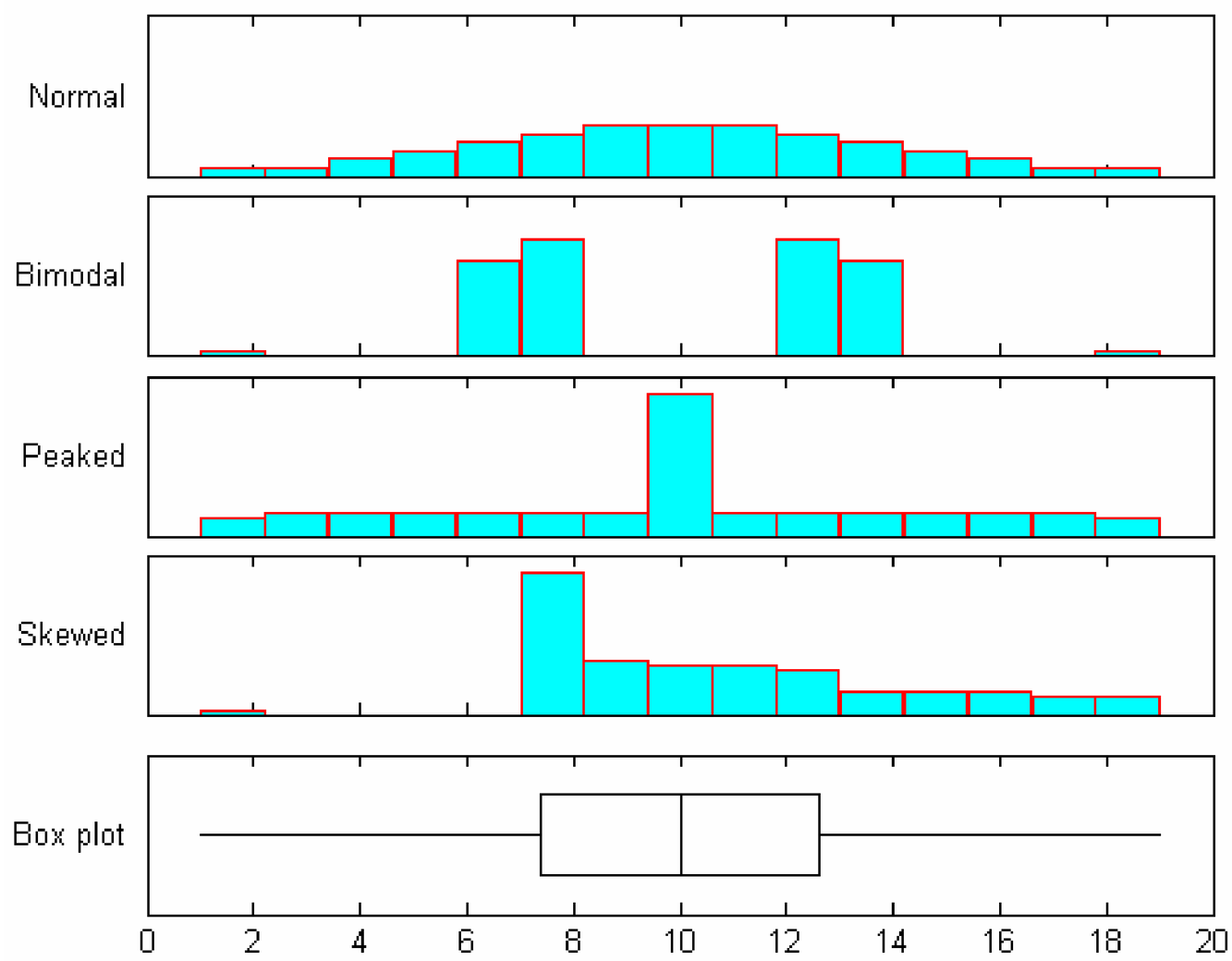
[Penn State, GEOG 486]

Aggregation: Boxplot



[C. Choonpradub and D. McNeil, 2005]

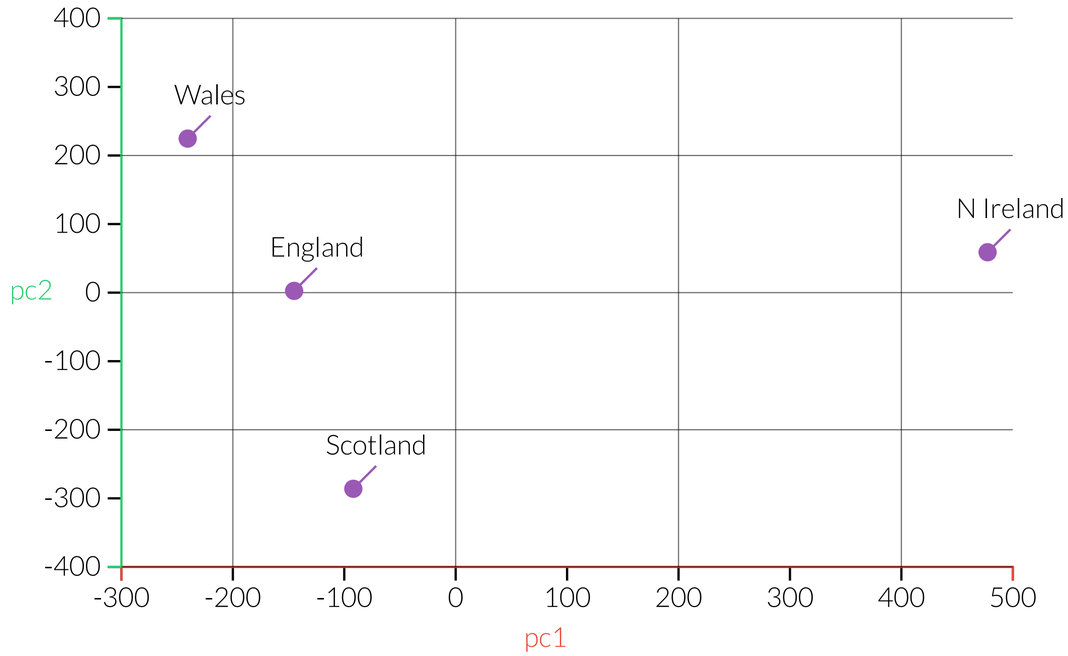
Aggregation: Boxplot



[C. Choonpradub and D. McNeil, 2005]

Dimensionality Reduction: PCA

	England	N Ireland	Scotland	Wales
Alcoholic drinks	375	135	458	475
Beverages	57	47	53	73
Carcase meat	245	267	242	227
Cereals	1472	1494	1462	1582
Cheese	105	66	103	103
Confectionery	54	41	62	64
Fats and oils	193	209	184	235
Fish	147	93	122	160
Fresh fruit	1102	674	957	1137
Fresh potatoes	720	1033	566	874
Fresh Veg	253	143	171	265
Other meat	685	586	750	803
Other Veg	488	355	418	570
Processed potatoes	198	187	220	203
Processed Veg	360	334	337	365
Soft drinks	1374	1506	1572	1256
Sugars	156	139	147	175



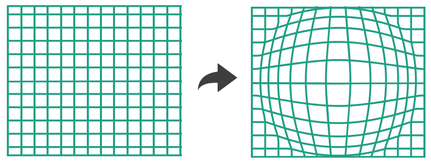
[Principle Component Analysis Explained, Explained Visually, V. Powell & L. Lehe, 2015]

Focus+Context

- **Embed**
  - Elide Data

  - Superimpose Layer

  - Distort Geometry



Reduce

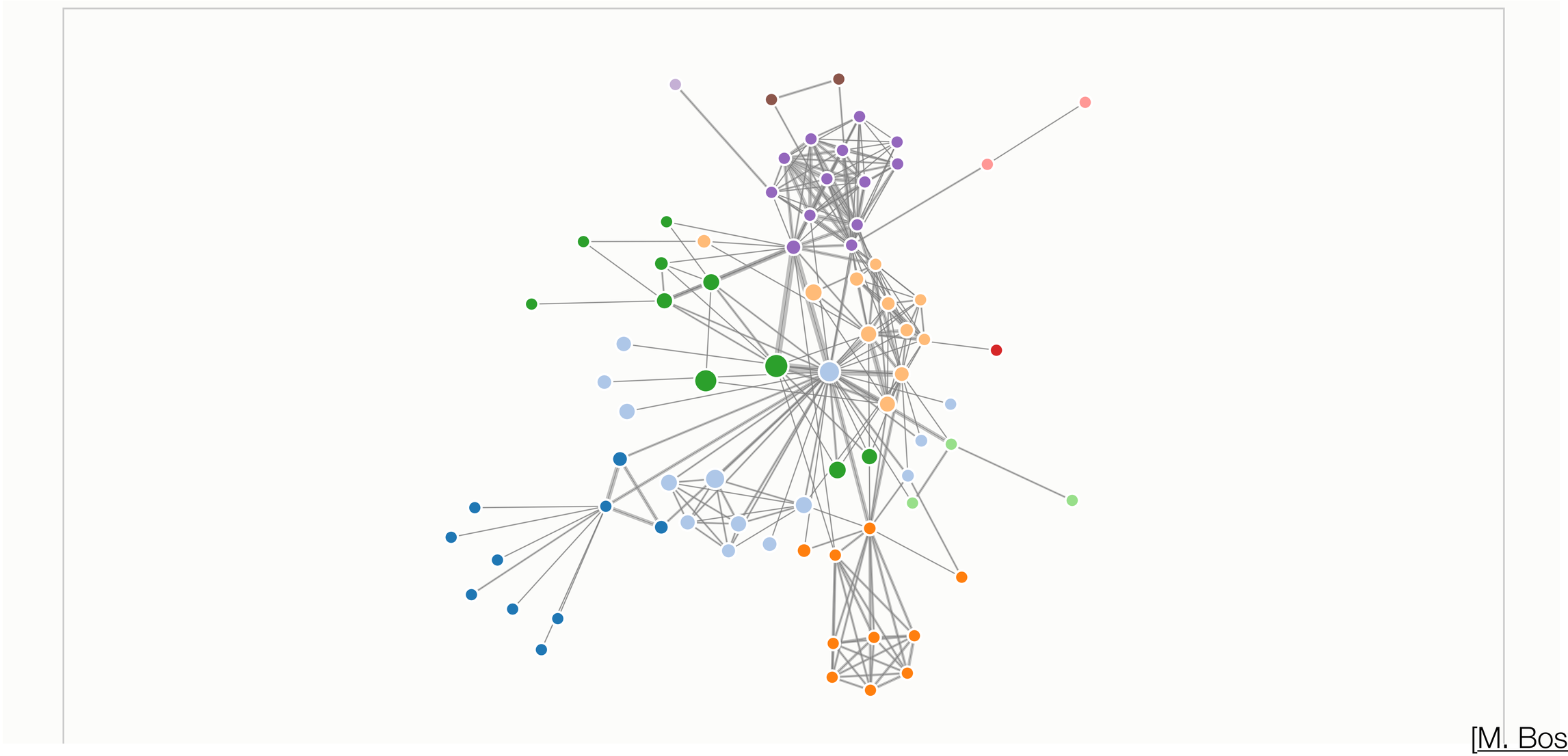
- Filter

- Aggregate

- Embed

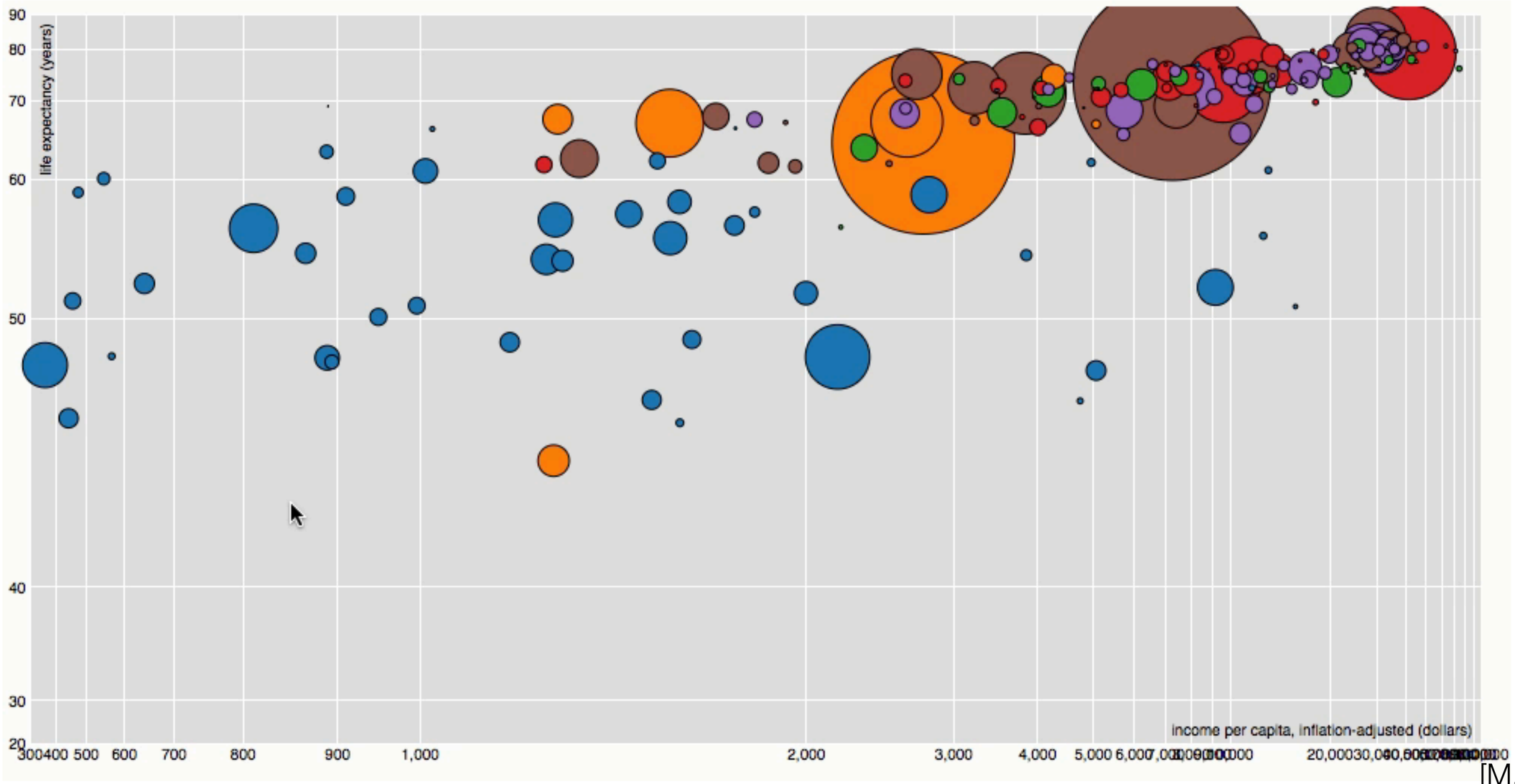
[Munzner (ill. Maguire), 2014]

Fisheye Distortion



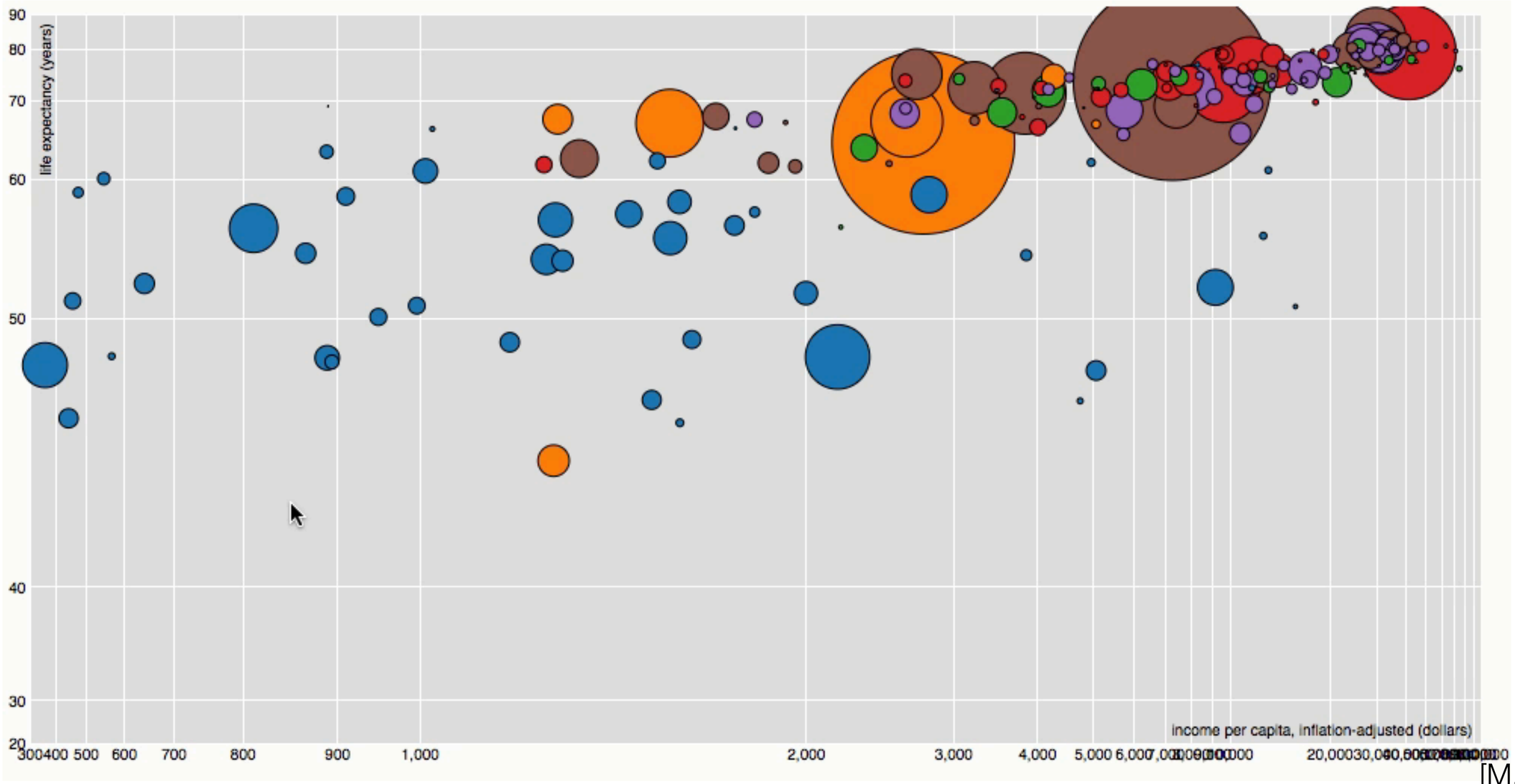
[M. Bostock]

Cartesian Distortion



[M. Bostock]

Cartesian Distortion



[M. Bostock]

The purpose of visualization is about **insight**, not pictures

– B. Shneiderman

Visualization Research

Visualization Research

- General Goals: "New visual displays, control panels, features, and workflows that improve the capabilities of users."
- Perceptual and Cognitive Theories: help accomplish goals, guide design, aid in development of new tools."
- Evaluation Methods:
  - Quantitative and Qualitative
  - Validate hypotheses, refine theories.

[B. Shneiderman, 2019]

Areas of Visualization Research

- Tools that make it easier to create visualizations
- New encodings
- Knowledge from controlled studies of visualization effectiveness
- Visualization-based communication
- Studies of visualization use in the world
- Formal theories of visualization
- Applications (Schneiderman)

[J. Hullman, 2018]

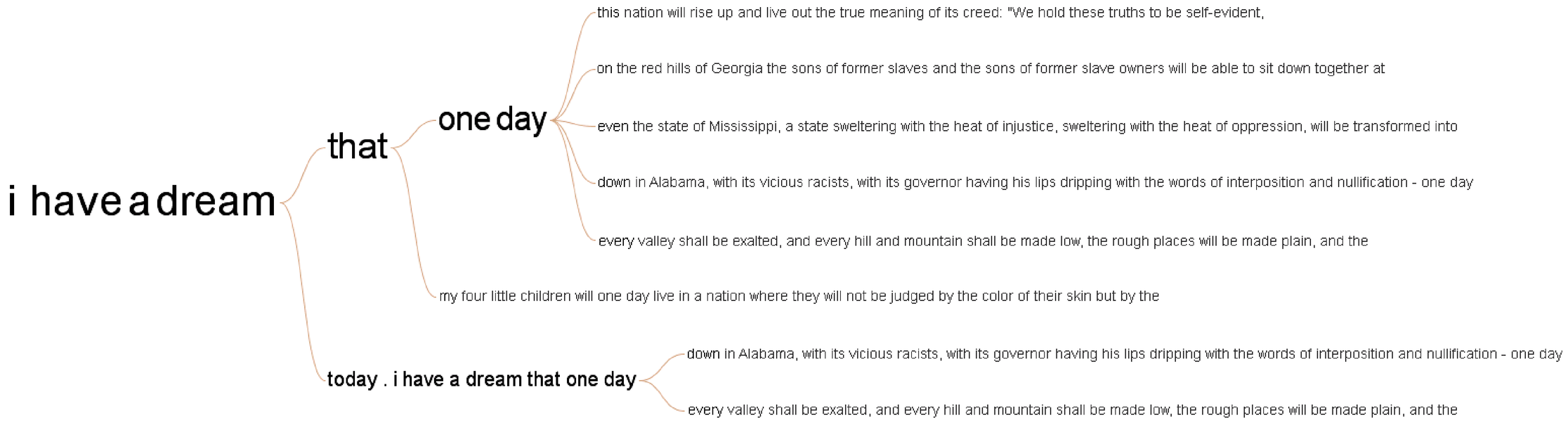
Tools that make it easier to create visualizations

- Tableau, Spotfire, D3 were all proposed and developed by visualization researchers
- Not just create visualizations, but **effective** visualizations
- Current Trends:
  - Web-based frameworks
  - Declarative, more concise specification (Vega-Lite)

[J. Hullman, 2018]

New Encodings

- Determine what cannot currently be done
- Think about how new designs can show new, interesting patterns



[[J. Hullman, 2018], Image: [Wattenberg & Viegas, 2007]

Knowledge from studies of visualization effectiveness

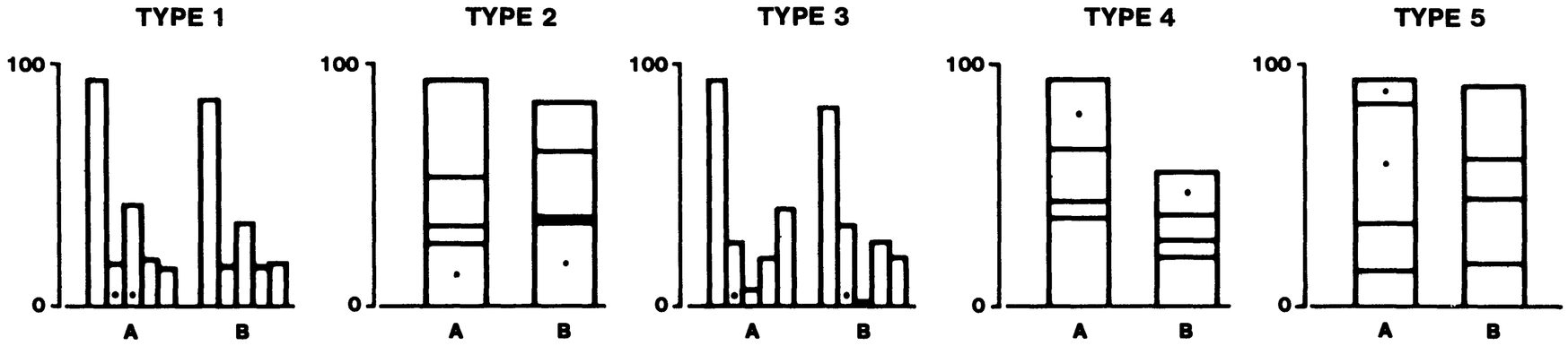


Figure 4. Graphs from position–length experiment.

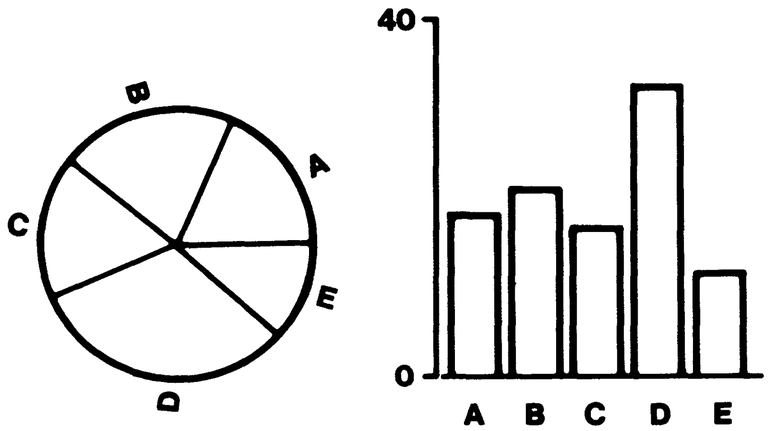
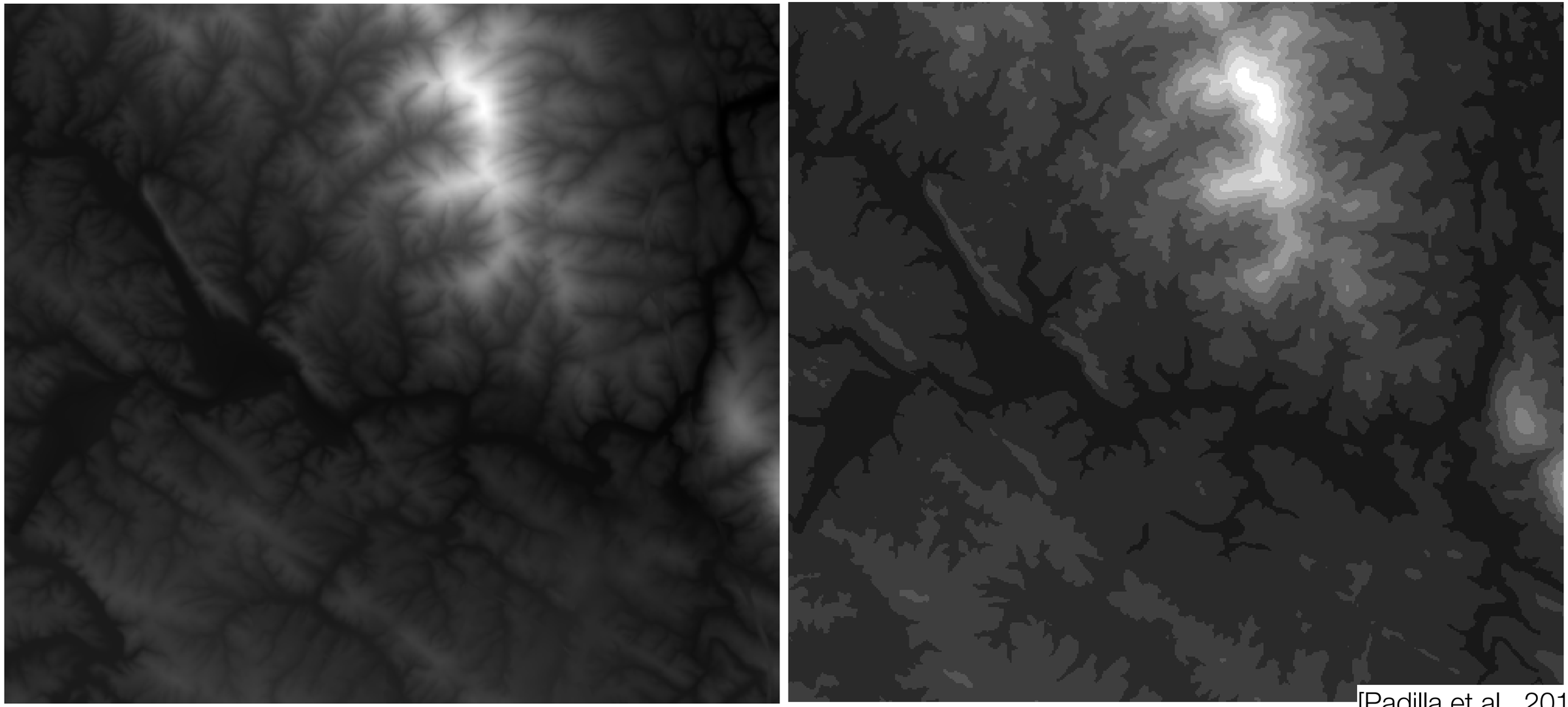


Figure 3. Graphs from position–angle experiment.

[Cleveland & McGill, 1984]

Knowledge from studies of visualization effectiveness



[Padilla et al., 2017]

Knowledge from studies of visualization effectiveness

- Controlled experiments often focus on visual building blocks
- Need not only very controlled, focused experiments. Can be impacted by
  - Different encodings
  - Framings
  - User predispositions or prior beliefs
- Holistic studies of new visualization techniques

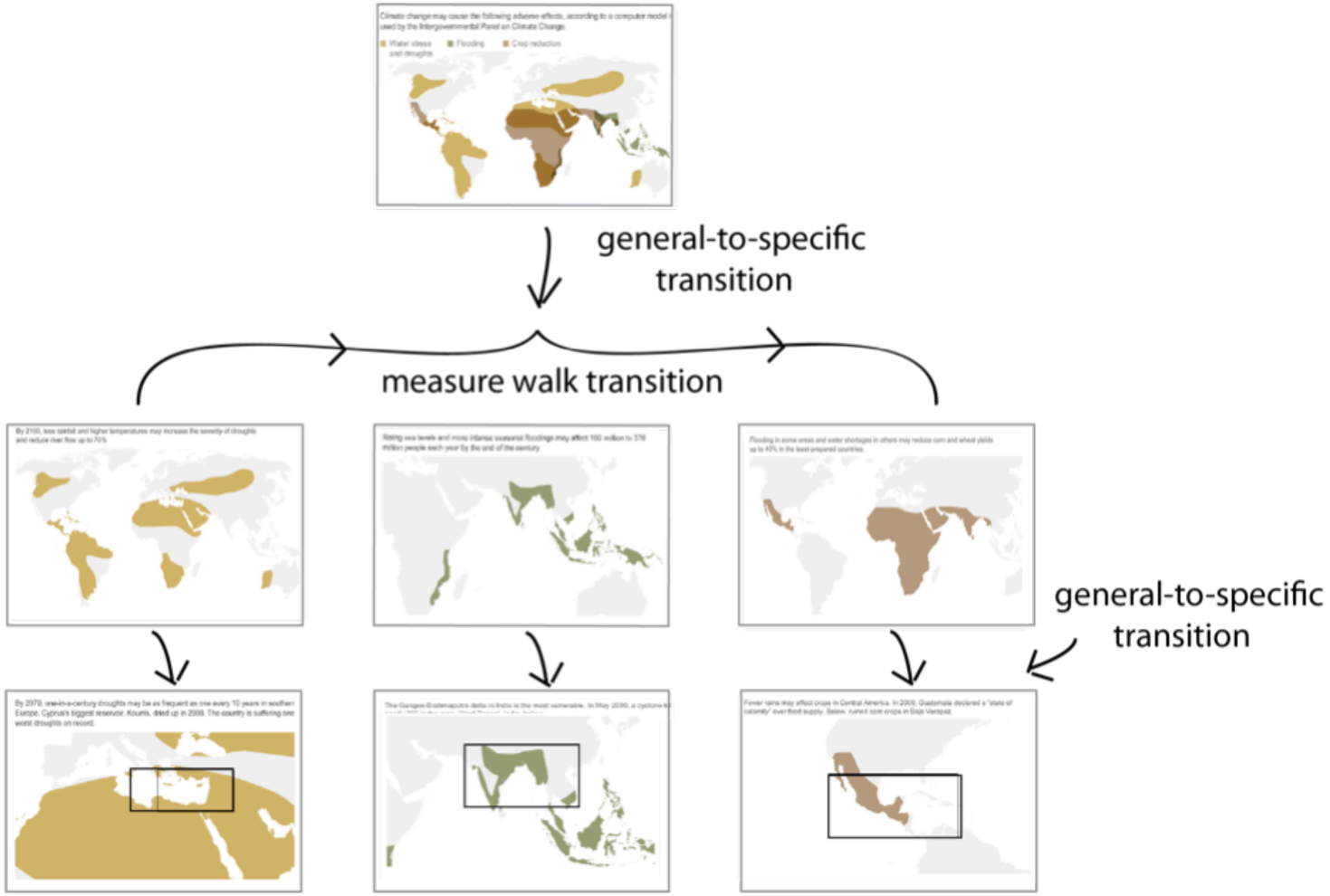
[J. Hullman, 2018]

Supporting Visual Analytics

- Exploratory Data Analysis
- Sensemaking & Meaning-making
- Interpretability of Machine Learning Models

[J. Hullman, 2018]

Visualization-based Communication



[J. Hullman, 2018]

Design Studies

- Studies of visualization in the world
- Often involve collaboration with domain specialists
- Specific problems in that domain that can provide lessons for other domains as well

[J. Hullman, 2018]

Formal Theories of Visualization

- Grammar of Graphics
- Discrete/Continuous Taxonomy
- Algebraic Visualization

[J. Hullman, 2018]

What should Visualization Research be about?

- "[V]isualization is a method for contextualizing data, enabling people to apply their prior experiences and perceptual and cognitive abilities to draw conclusions about phenomena in the real world" — J. Hullman
- Perception and cognition
- Not only that Vis A is better than Vis B, but why

[J. Hullman, 2018]

Visualization Research Boundaries?

- Interactive illustration
- Satellite imagery
- Sketching and analogical reasoning
- Understanding aesthetics independent of analytical utility
- Tables
- Uncertainty Vis: Worse than Nothing?

[J. Hullman, 2018]

Grand Challenges

- Amplifying human cognition in the exploration of data.
  - Data science
  - Explainable artificial intelligence
  - Information visualization is vital to successful outcomes for both topics.
- Improve storytelling capacity for the general public
- Engage users to explore on their own
- Support researchers in understanding causality
- Shift from rationalism, which assumes that algorithms are the answer, to empiricism, which assumes that continuous exploration, persistent questioning, and vigorous dialog will promote a deeper understanding of our world.

[B. Shneiderman, 2019]

Shneiderman's Advice to a Ph.D. Student

- "Start by working on a real problem—one that you have or that you get from someone else. Working on real problems leads to better theories and better tools."

[B. Shneiderman, 2019]