CS-5630 / CS-6630 Visualization for DataScience
Tables

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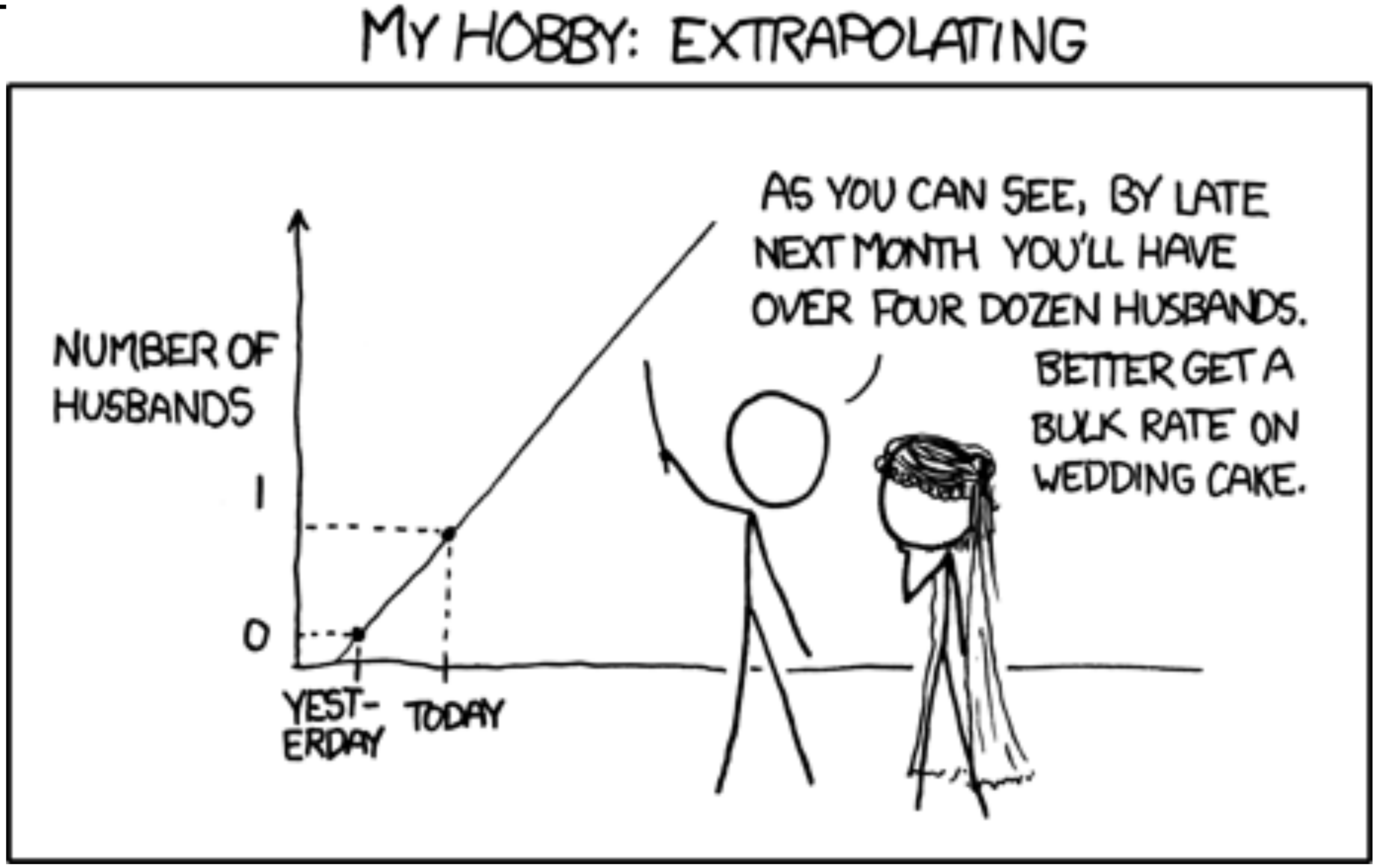


[xkcd]

Organizational

Review exam in my office hours starting Oct 29

HW Lab: Wed, 6pm, L110

Make sure to form your project teams!

- If you can't find a team, e-mail me

Develop project idea

Set up your github repo

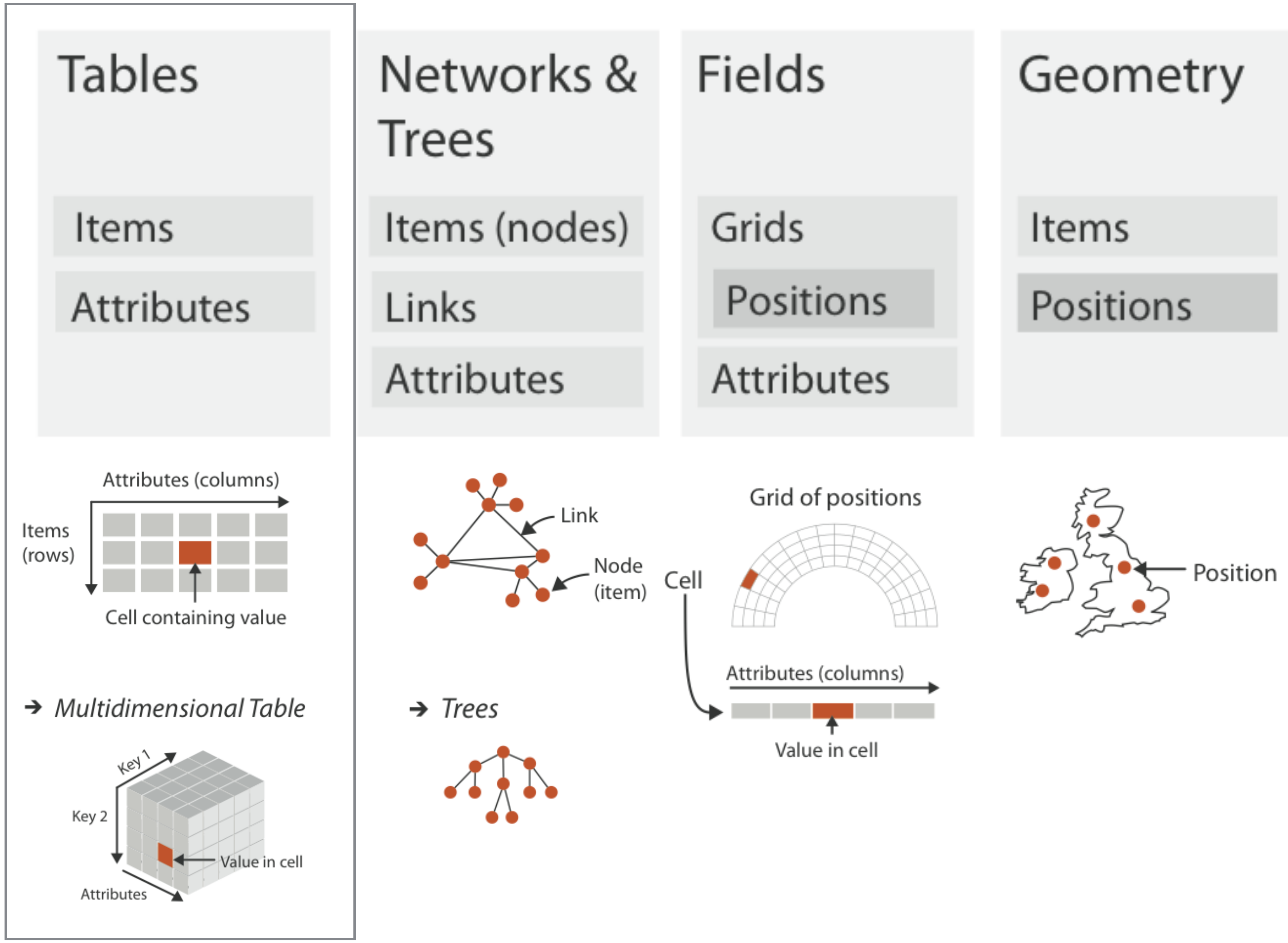
Proposal and HW6 due Oct 25

Peer review session (mandatory attendance) on Oct 29

Need to submit this info by Friday!

https://forms.gle/aj6CwRRBNVnNzVqy5

Dataset Types



Exercise: Sketch 2 Ways to Vis. Each Table

	Age	Best 100 m	Furthest Jump	Sex
Amy	16	13.2	5.2	F
Basil	18	12.4	4.2	F
Clara	14	14.1	2.5	F
Desmond	22	10.01	6.3	M
Charles	19	11.3	5.3	M

	BPM T1	BPM T2	BPM T3
Amy	90	130	150
Basil	70	110	109
Clara	60	140	141
Desmond	84	100	108
Charles	81	110	130

Scale of Tables

Need different approaches for "normal" and "high-dimensional" tables.

How many dimensions?

~50 – tractable with "just" vis

~1000 – need analytical methods

How many records?

~ 1000 – "just" vis is fine

>> 10,000 – need analytical methods

Homogeneity

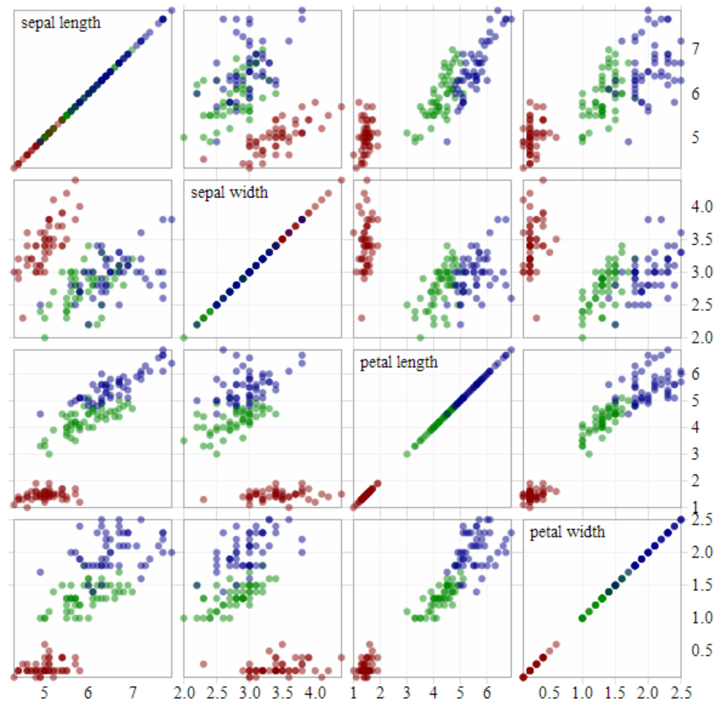
Same data type?

Same scales?

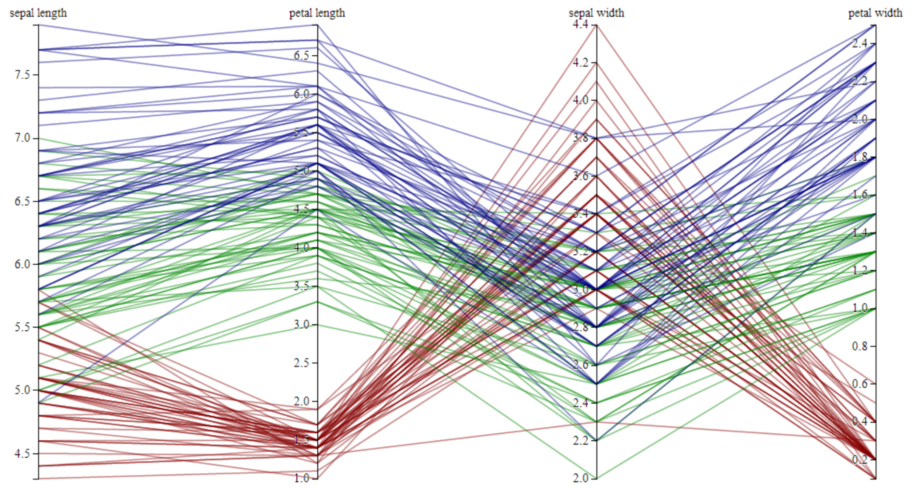
	Age	Gender	Height
Bob	*25*	*M*	*181*
Alice	*22*	*F*	*185*
Chris	*19*	*M*	*175*

	BPM 1	BPM 2	BPM 3
Bob	*65*	*120*	*145*
Alice	*80*	*135*	*185*
Chris	*45*	*115*	*135*

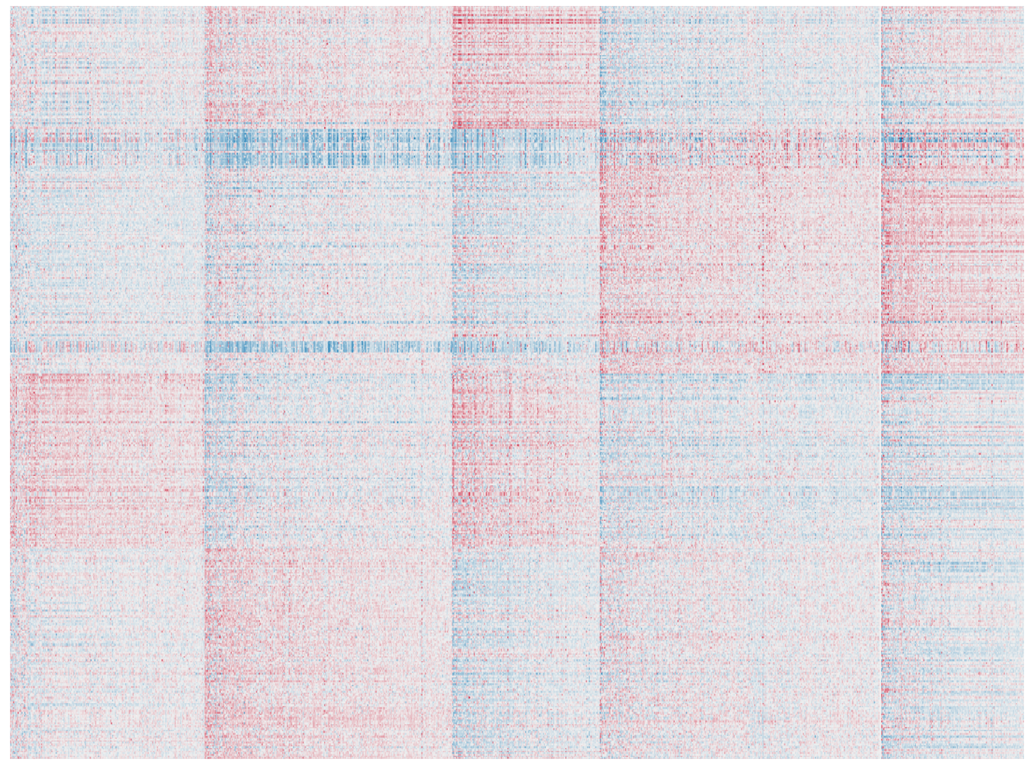
Analytic Component



Scatterplot Matrices
[Bostock]

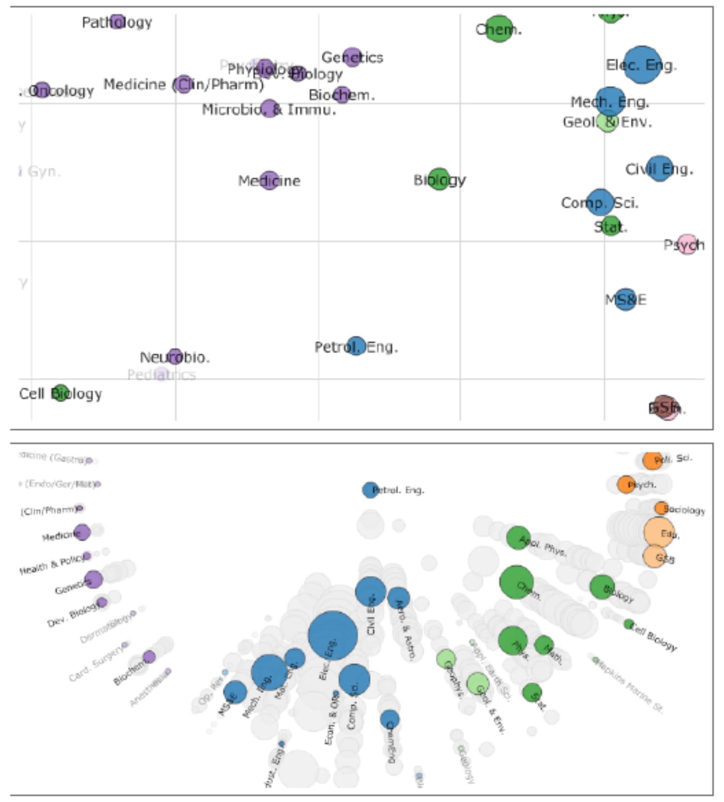


Parallel Coordinates
[Bostock]



Pixel-based visualizations / heat maps

Multidimensional Scaling
[Doerk 2011]



[Chuang 2012]

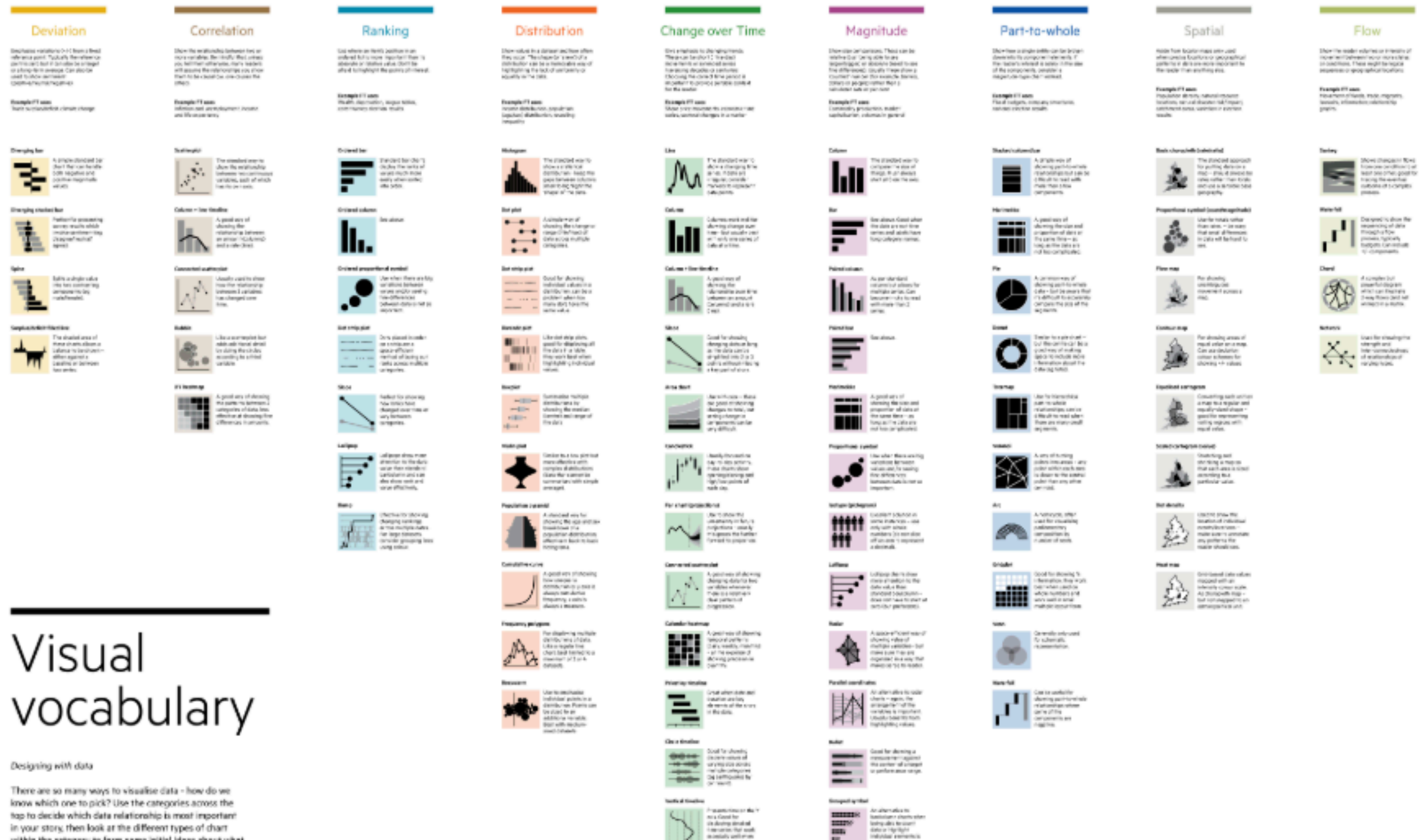
no / little analytics

strong analytics component

Techniques and Tasks

Magnitude Distribution Deviation Correlation

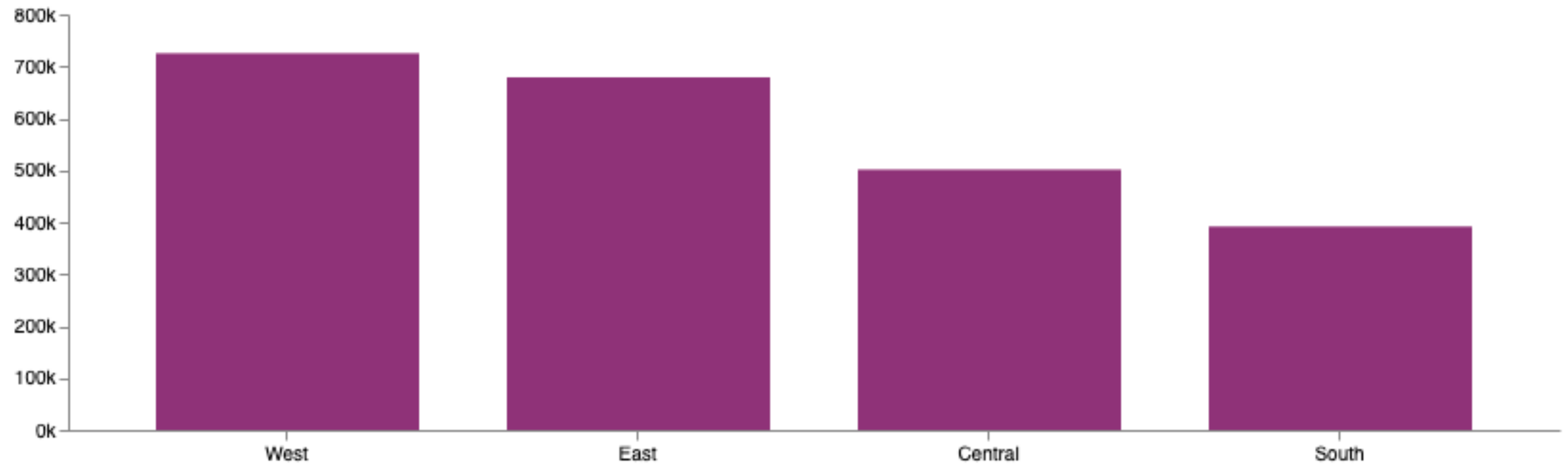
Ranking Part to whole Change over Time



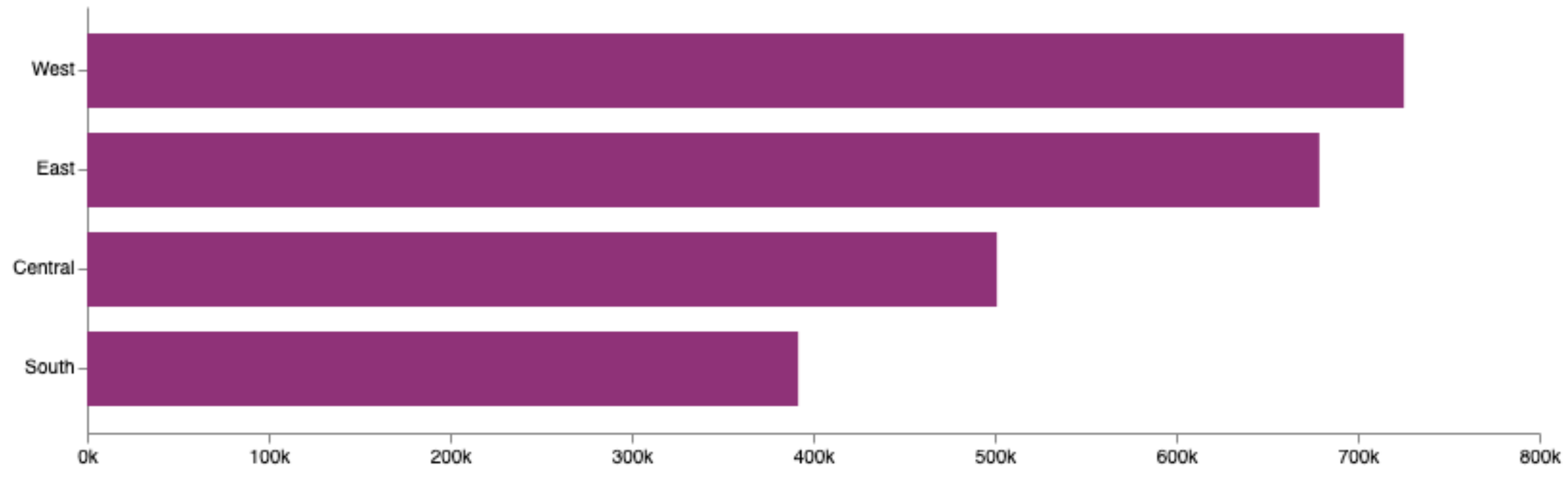
https://github.com/ft-interactive/chart-doctor/tree/master/visual-vocabulary
https://gramener.github.io/visual-vocabulary-vega/#/Magnitude/

Magnitude

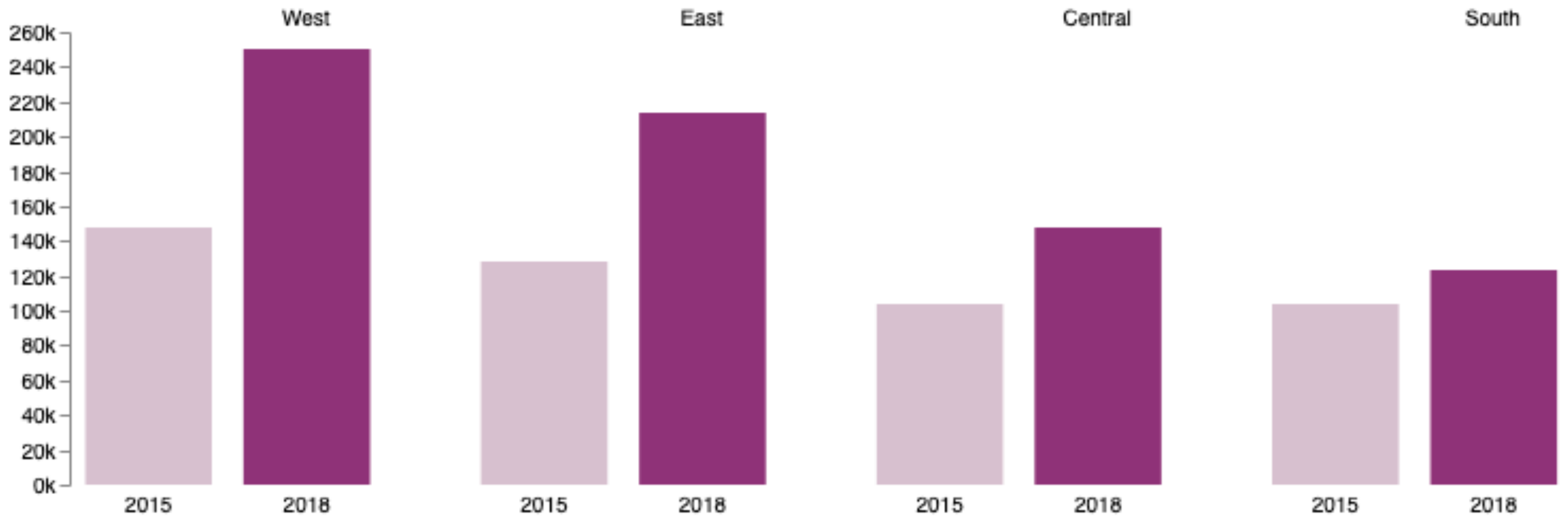
Bar Chart Variants



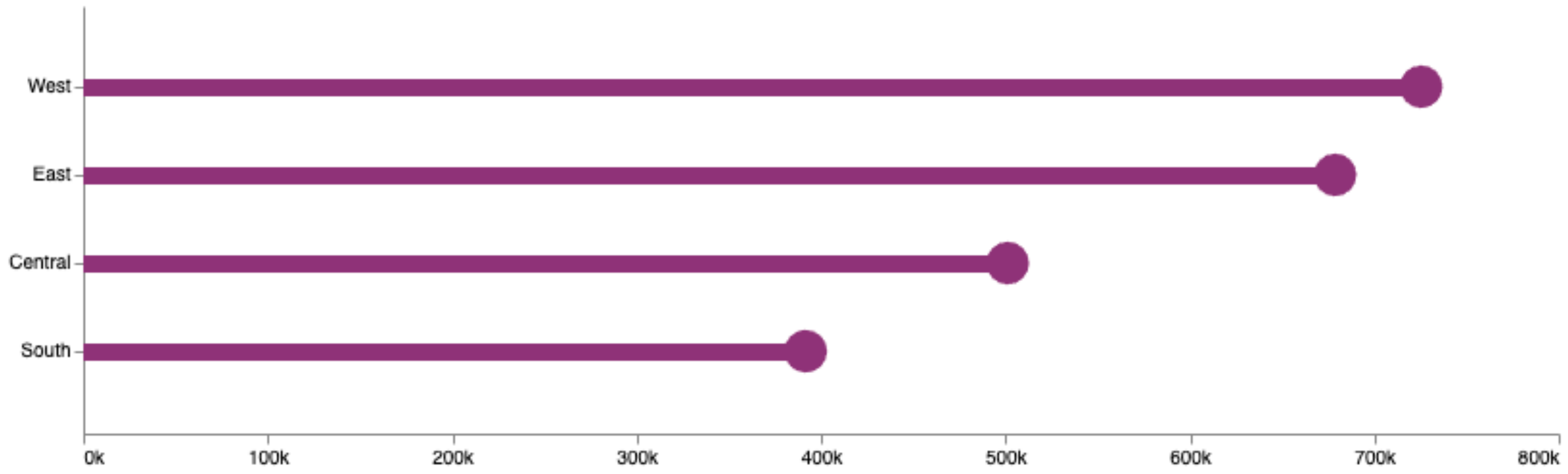
Vertical Bar Chart / Column Chart



Horizontal Bar Chart

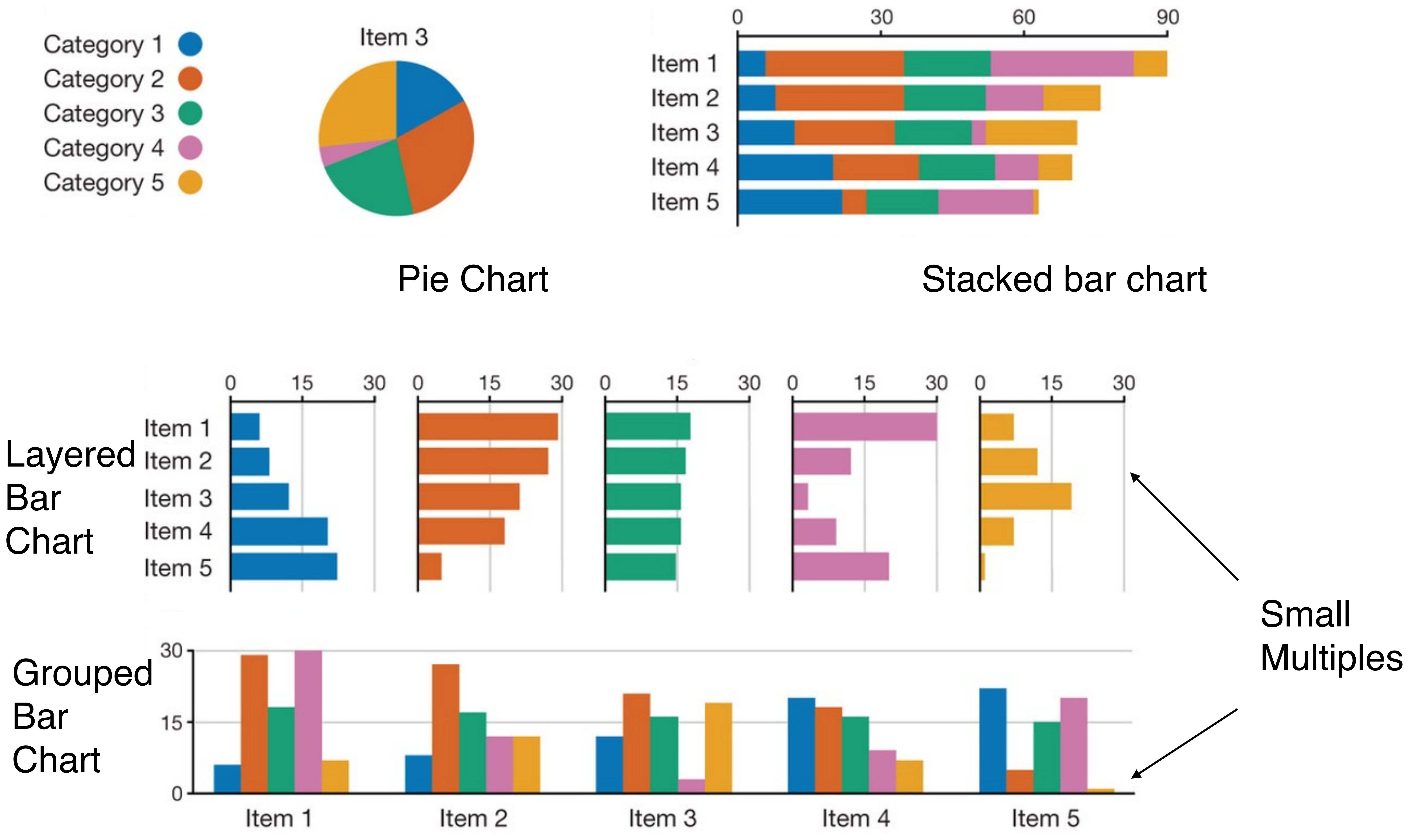


Grouped Bar Chart



Lollipop Chart

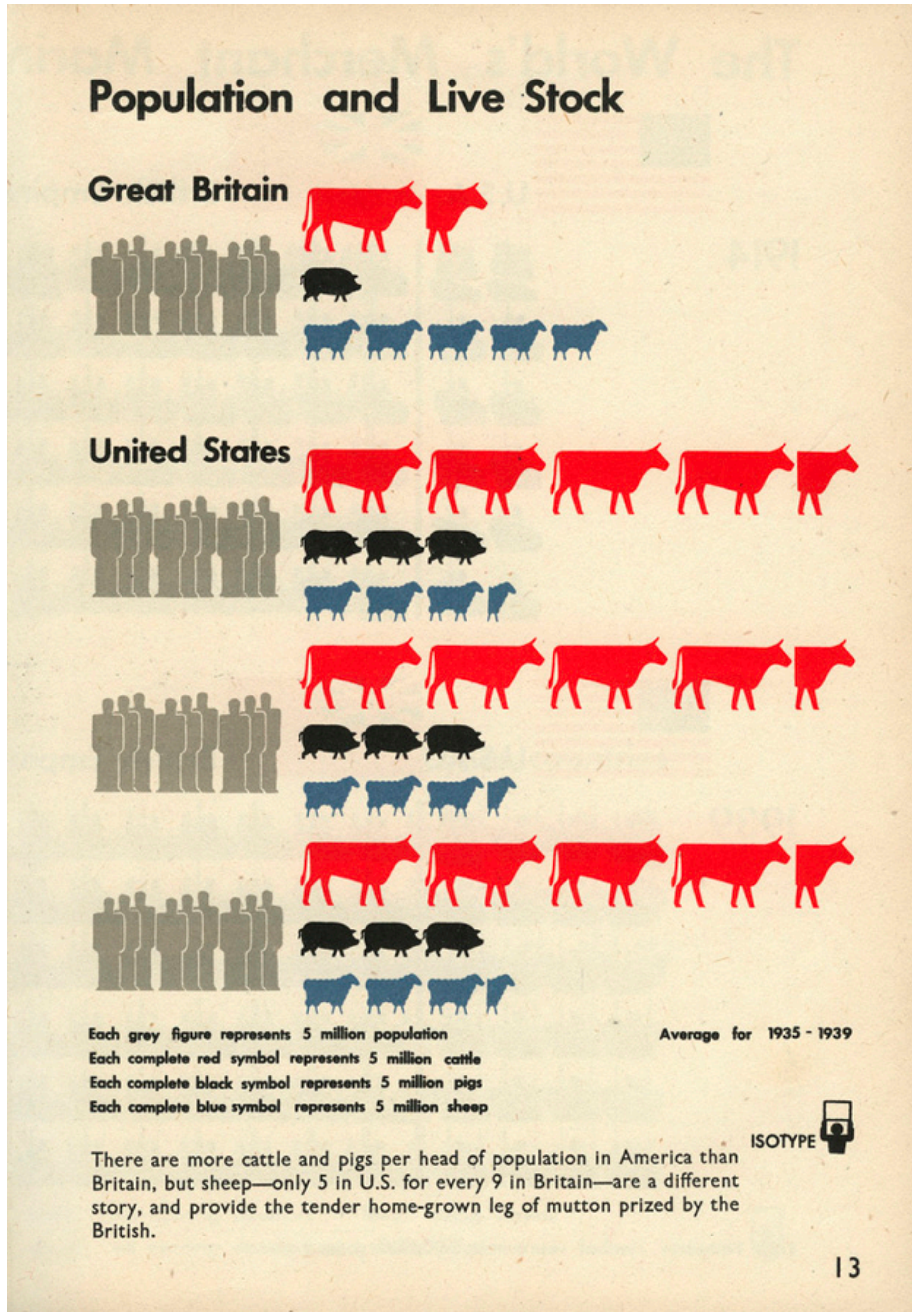
Comparison of bar chart types



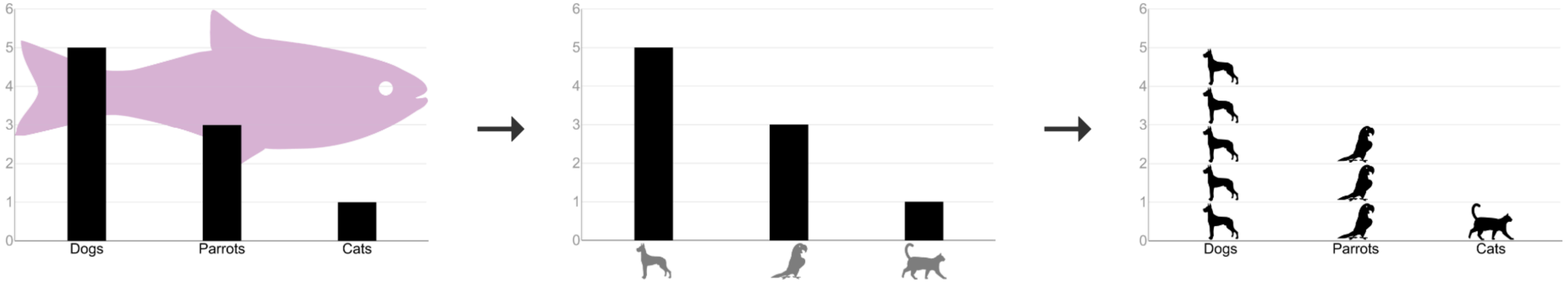
Streit & Gehlenborg, PoV, Nature Methods, 2014

Rank	Player	Current League	Current Club	Position	Foot	Age	Height	Goals	Games
				CF W	both left right	0.00 38.00	160.00 210.00	0.00 61.0	0.00 66.0
1	Dmitri Poloz	RUS - Premier Liga	Zenit St. Petersburg	W	right				
2	Emiliano Rigoni	RUS - Premier Liga	Zenit St. Petersburg	W	both				
3	Sebastián Driussi	RUS - Premier Liga	Zenit St. Petersburg	CF	both				
4	Aleksandr Kokorin	RUS - Premier Liga	Zenit St. Petersburg	CF	right				
5	Anton Zabolotnyi	RUS - Premier Liga	Zenit St. Petersburg	CF	right				
6	Quincy Promes	RUS - Premier Liga	Spartak Moscow	W	both				
7	Pedro Rocha	RUS - Premier Liga	Spartak Moscow	W	right				
8	Lorenzo Melgarejo	RUS - Premier Liga	Spartak Moscow	W	left				
9	Zelimkhan Bakaev	RUS - Premier Liga	Spartak 2 Moscow	W	left				
10	Luiz Adriano	RUS - Premier Liga	Spartak Moscow	CF	right				
11	Zé Luís	RUS - Premier Liga	Spartak Moscow	CF	left				
12	Ahmed Musa	RUS - Premier Liga	CSKA Moscow	CF	both				
13	Fedor Chalov	RUS - Premier Liga	CSKA Moscow	CF	right				
14	Timur Zhamaletdinov	RUS - Premier Liga	CSKA Moscow	CF	right				
15	Wanderson	RUS - Premier Liga	FK Krasnodar	W	right				
16	Joãozinho	RUS - Premier Liga	FK Krasnodar	W	left				
17	Andrei Ivan	RUS - Premier Liga	FK Krasnodar	W	right				
18	Ricardo Laborde	RUS - Premier Liga	FK Krasnodar	W	right				
19	Magomed-Shapi Suleyn	RUS - Premier Liga	FK Krasnodar	W	left				
20	Fedor Smolov	RUS - Premier Liga	FK Krasnodar	CF	right				
21	Ivan Ignatjev	RUS - Premier Liga	FK Krasnodar	CF	right				
22	Alan Kasaev	RUS - Premier Liga	Lokomotiv Moscow	W	right				
23	Jefferson Farfán	RUS - Premier Liga	Lokomotiv Moscow	W	right				
24	Arshak Koryan	RUS - Premier Liga	Lokomotiv Moscow	W	right				
25	Éder	RUS - Premier Liga	Lokomotiv Moscow	CF	both				
26	Ari	RUS - Premier Liga	Lokomotiv Moscow	CF	both				
27	Gökdeniz Karadeniz	RUS - Premier Liga	Rubin Kazan	W	right				
28	Rifat Zhemaletdinov	RUS - Premier Liga	Rubin Kazan	W	right				
29	Sardar Azmoun	RUS - Premier Liga	Rubin Kazan	CF	both				
30	Léo Jabá	RUS - Premier Liga	Akhmat Grozny	W	right				
31	Bernard Berisha	RUS - Premier Liga	Akhmat Grozny	W	right				
32	Magomed Mitrishev	RUS - Premier Liga	Akhmat Grozny	W	right				
33	Odise Roshi	RUS - Premier Liga	Akhmat Grozny	W	right				

IsoType Visualization



Otto and Marie Neurath



http://steveharoz.com/research/isotype/

Part of Whole

Stacked Bar Chart

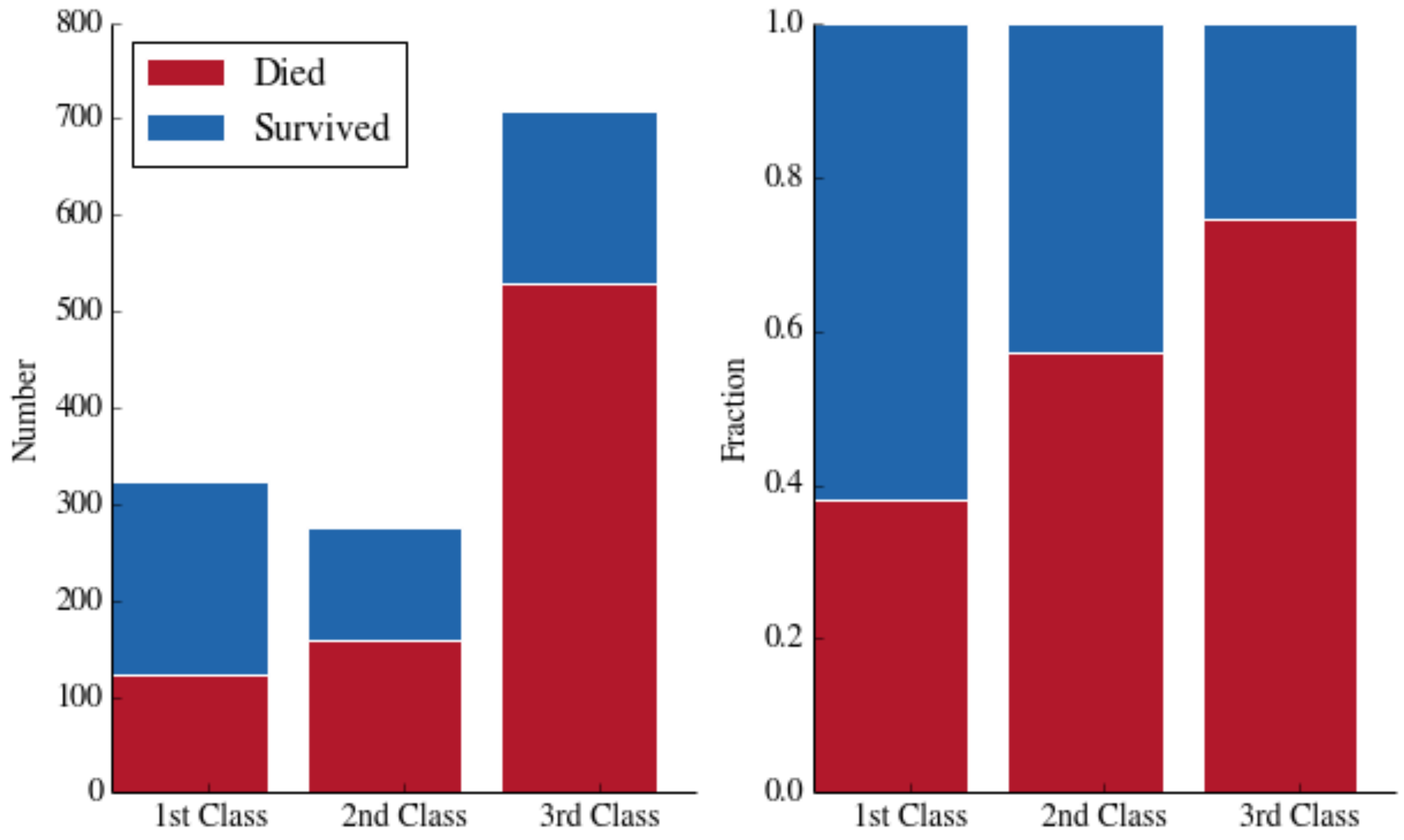
Keys: Class, Survival

Class is spatial

Survival is color

Left: absolute values

Right: proportional values

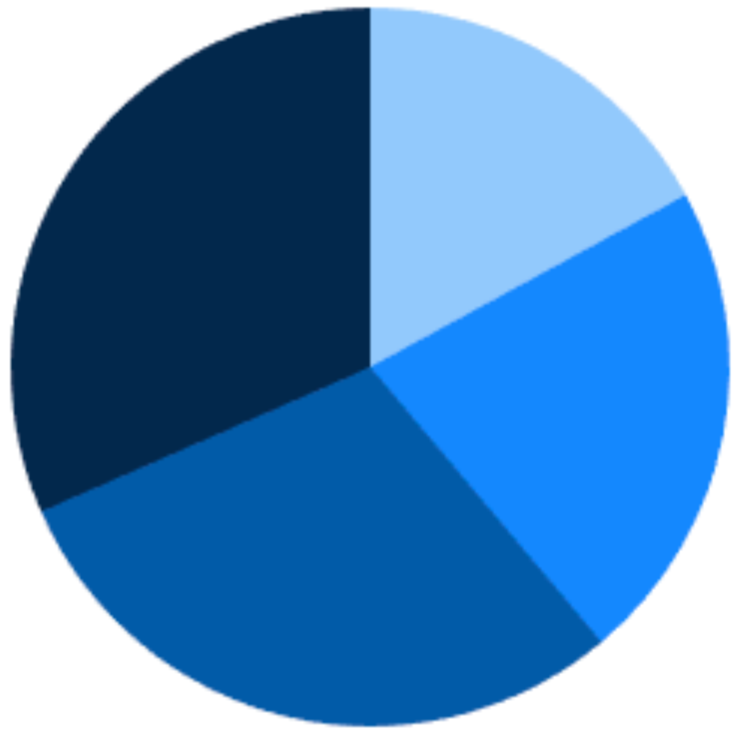


Pie and Donut Charts

Pie

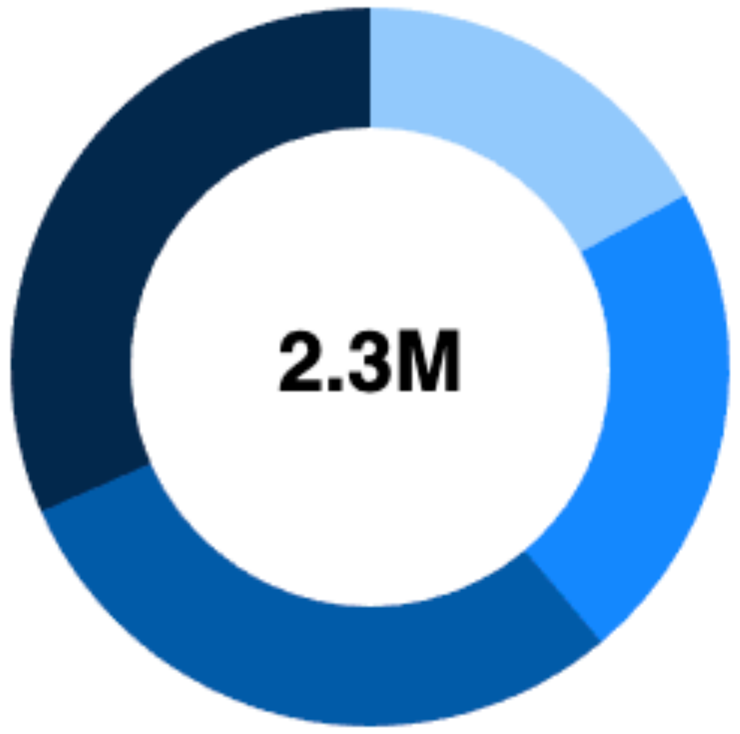
Edit

A common way of showing part-to-whole data - but be aware that it's difficult to accurately compare the size of the segments.

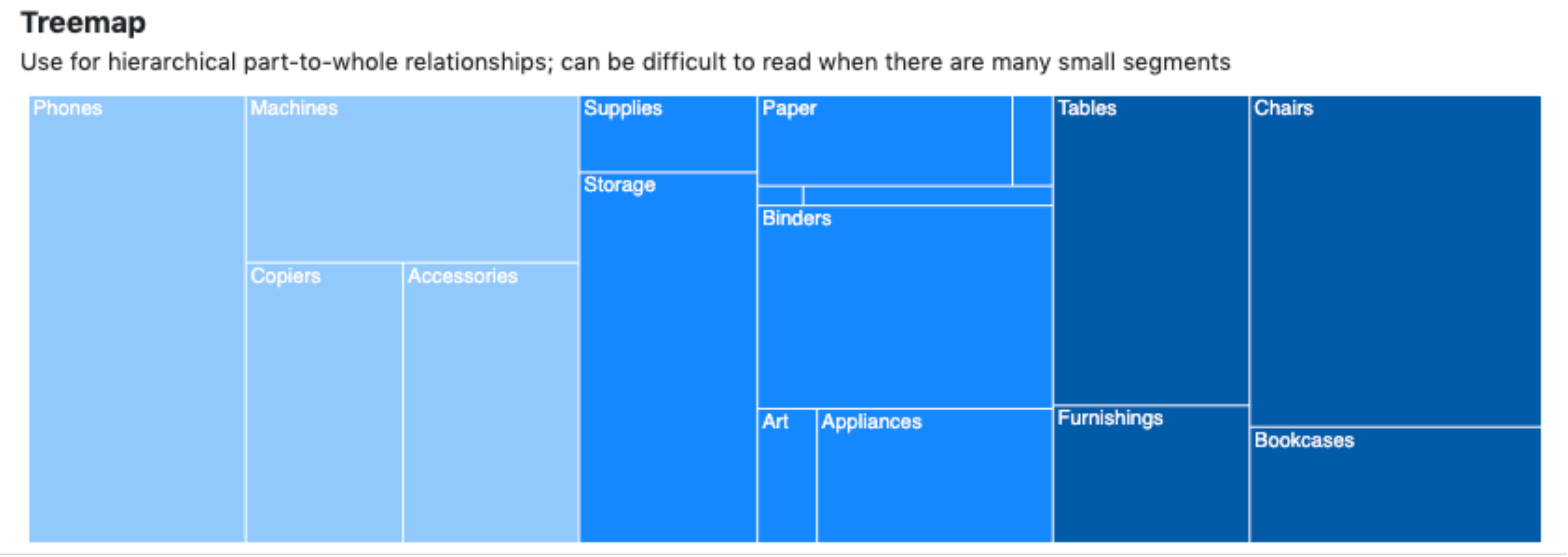


Donut

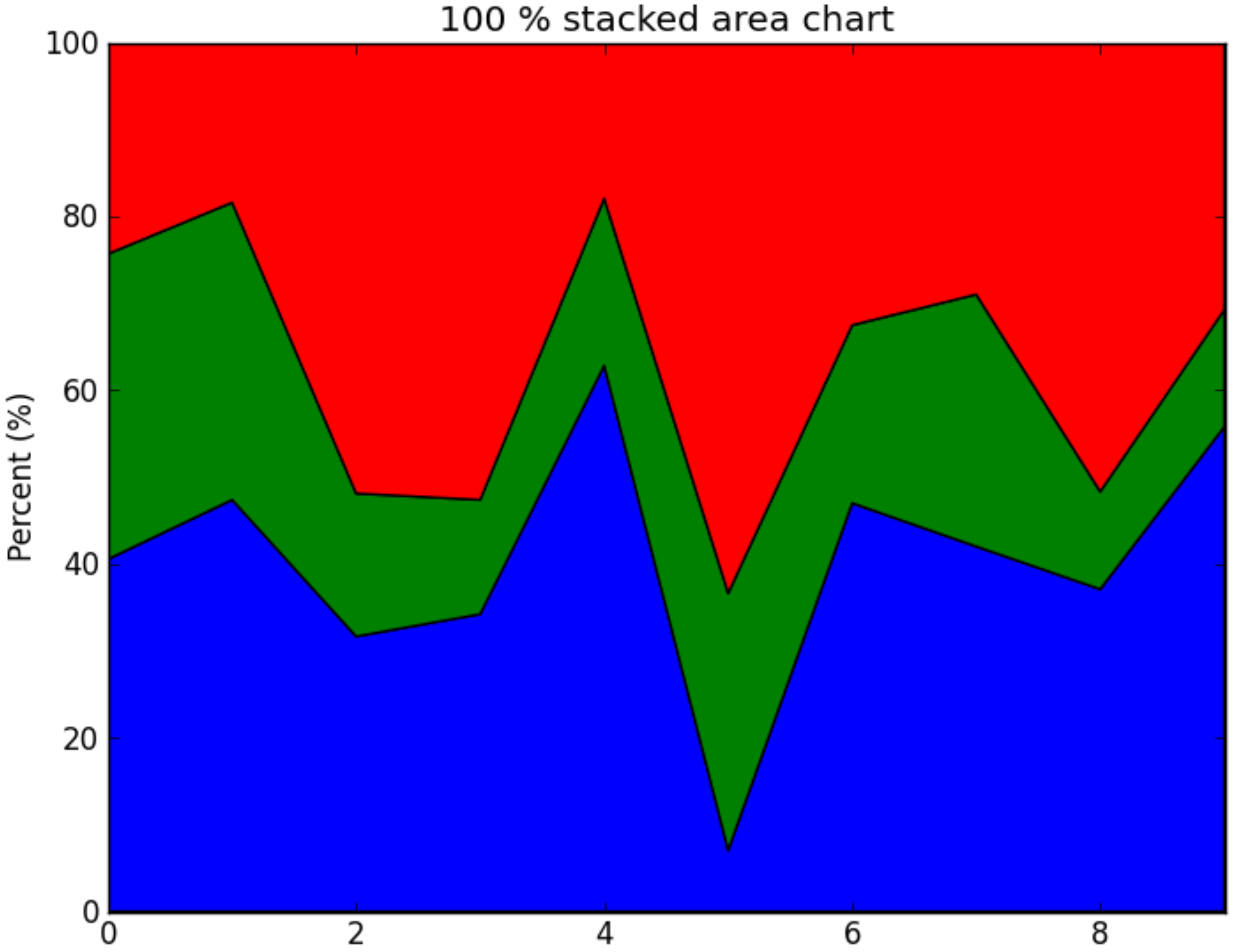
Similar to a pie chart - but the centre can be a good way of making space to include more information about the data (eg. total)



TreeMap


Treemap
Use for hierarchical part-to-whole relationships; can be difficult to read when there are many small segments
Phones
Machines
Copiers
Accessories
Supplies
Storage
Paper
Binders
Art
Appliances
Tables
Furnishings
Chairs
Bookcases

Part of Whole for Time Series



Distribution

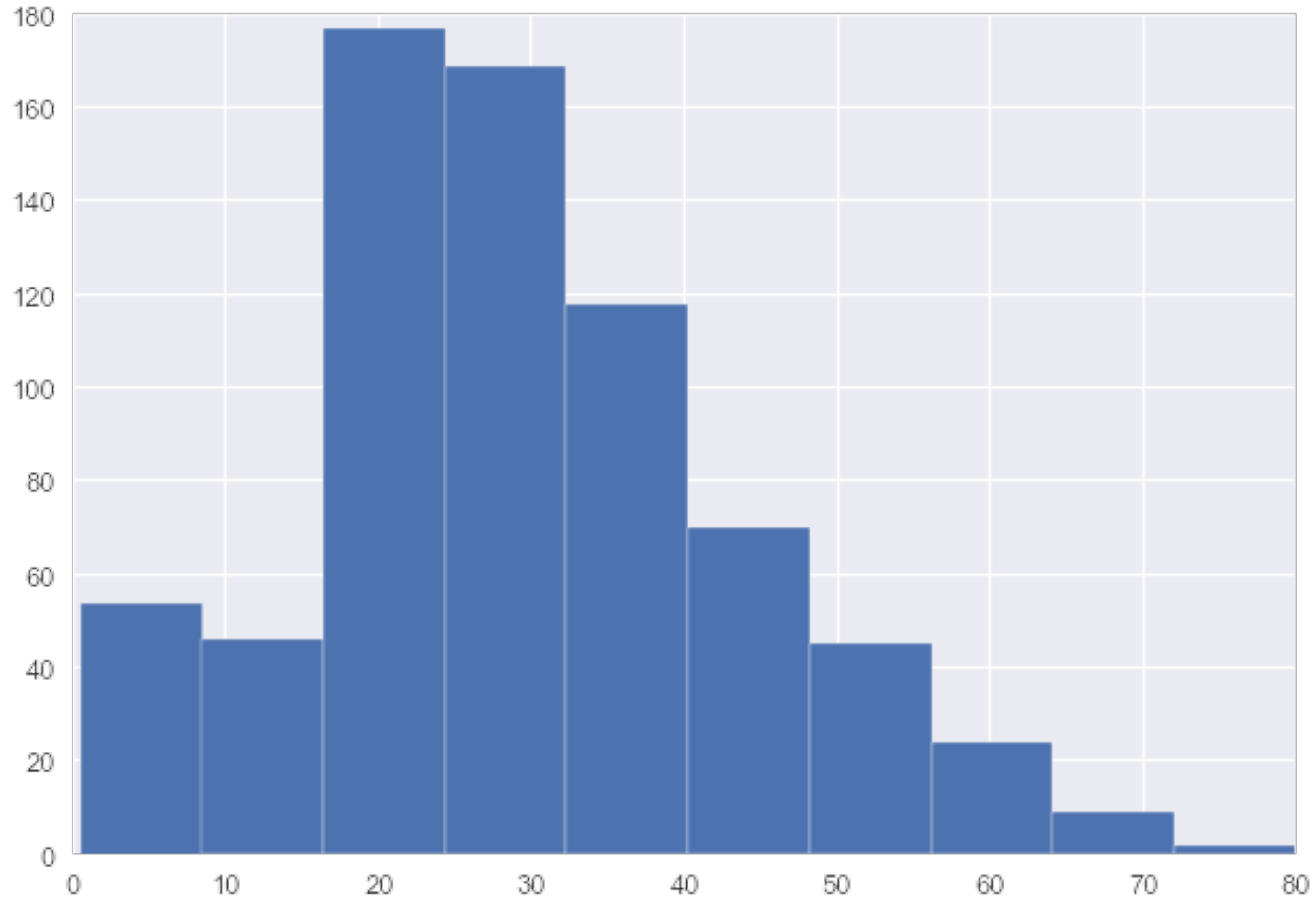
Aggregating Large Data Vectors

Instead of showing all data points, show a data's distribution

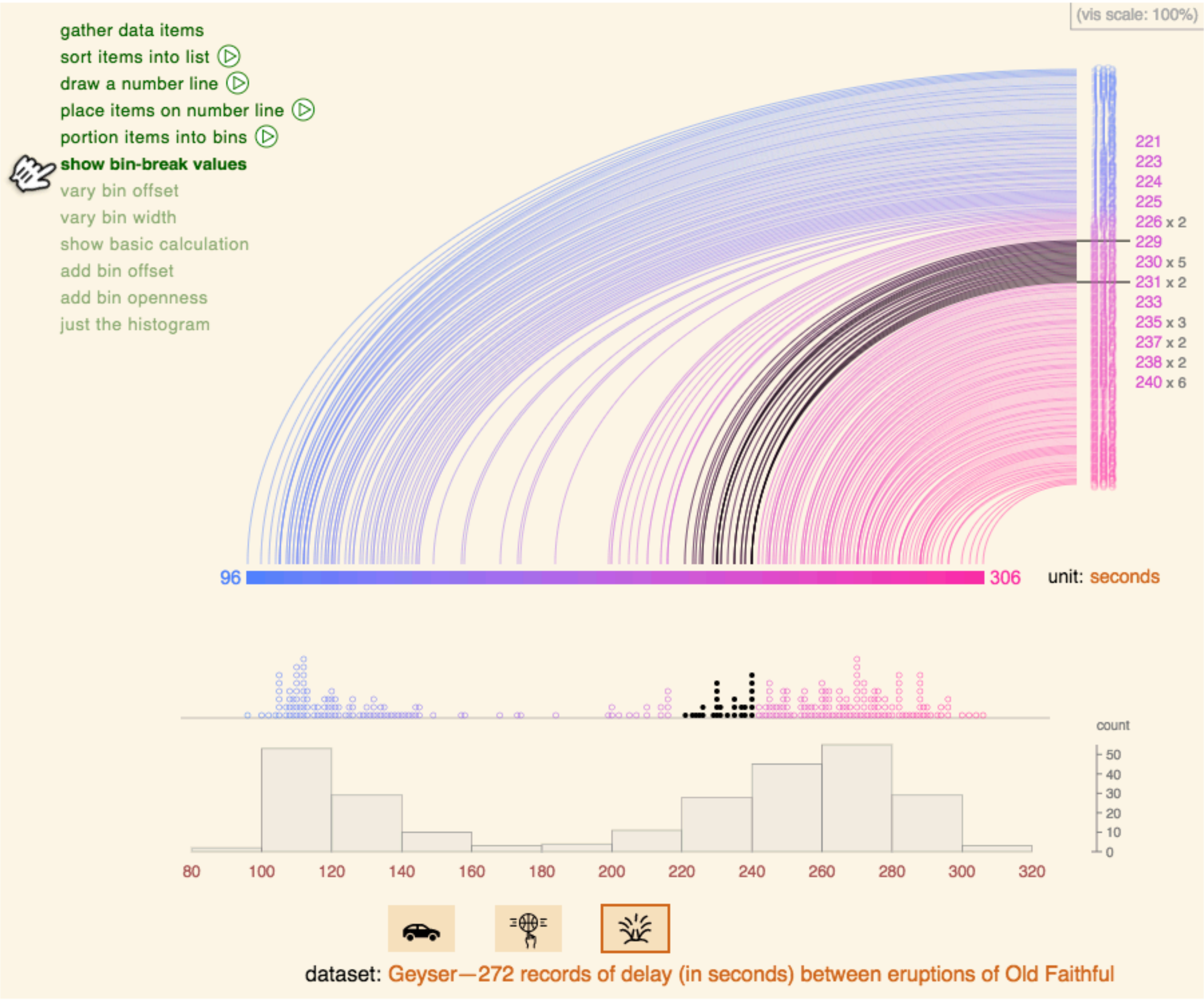
Pro: compact representation

Con: Works only if data is "well behaved" for the type of distribution visualization.

What’s a histogram?



Histograms Explained



http://tinlizzie.org/histograms/

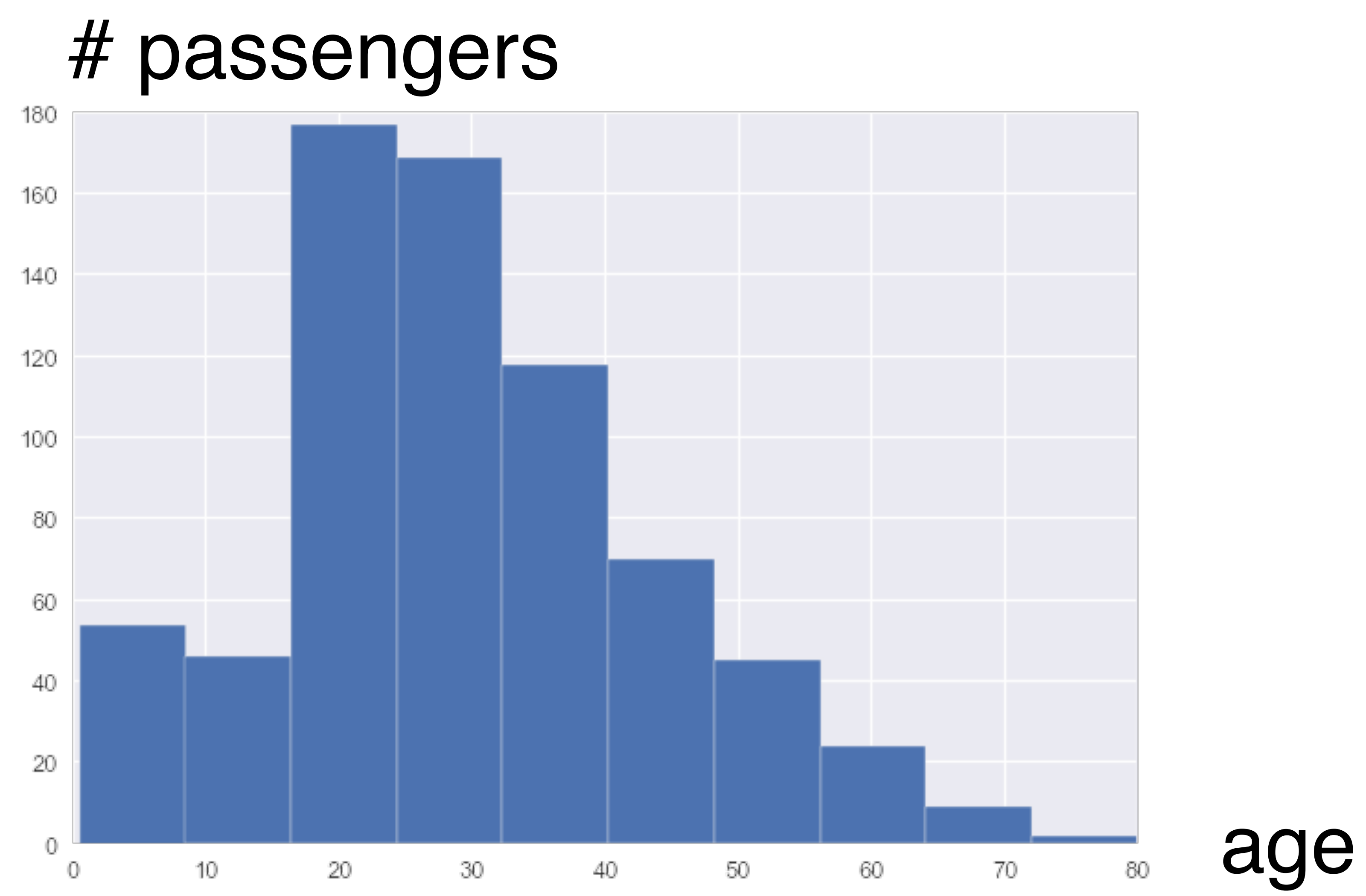
Histogram

Good #bins hard to predict

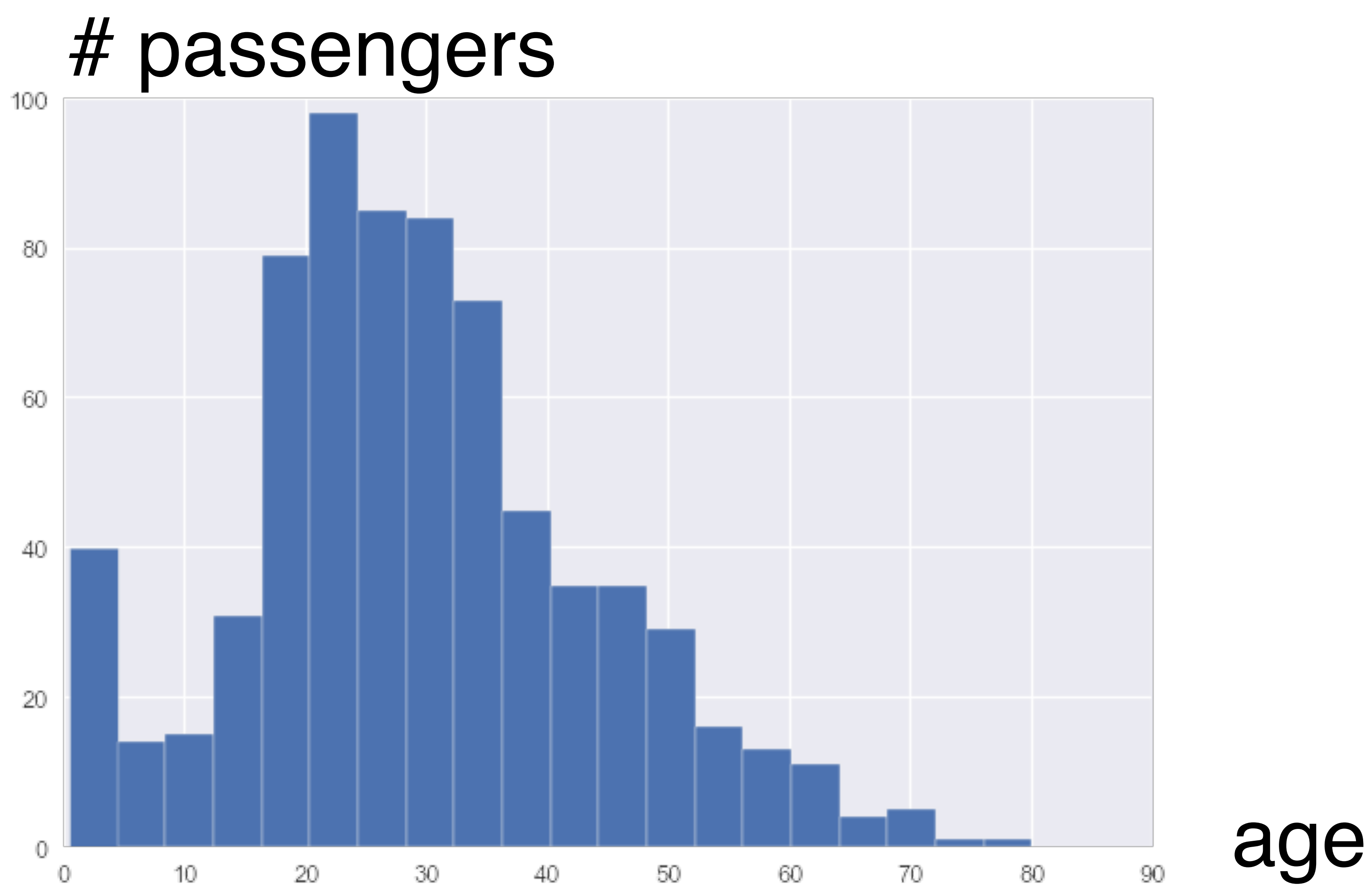
make interactive!

rules of thumb:

- #bins = sqrt(n)
- #bins = log2(n) + 1

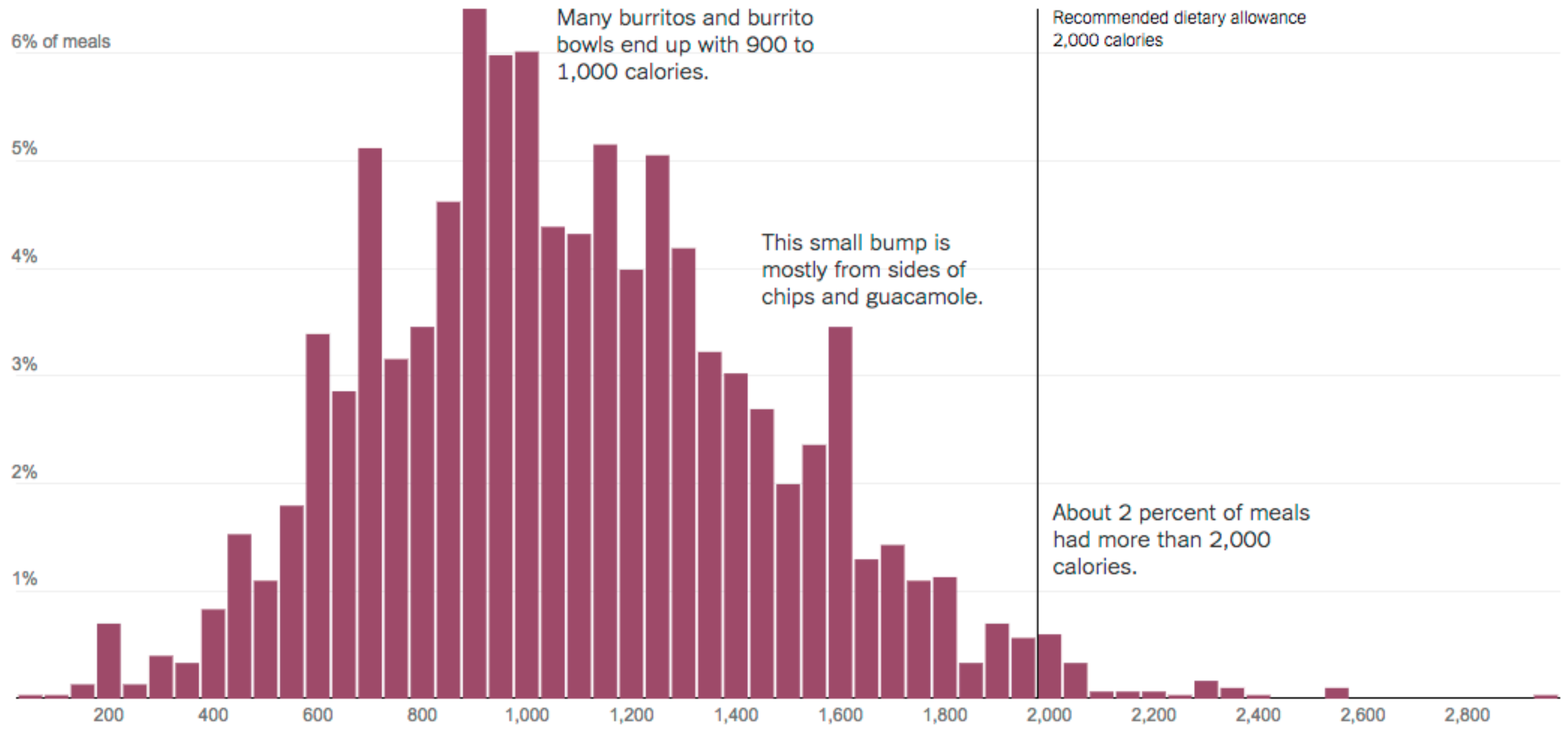


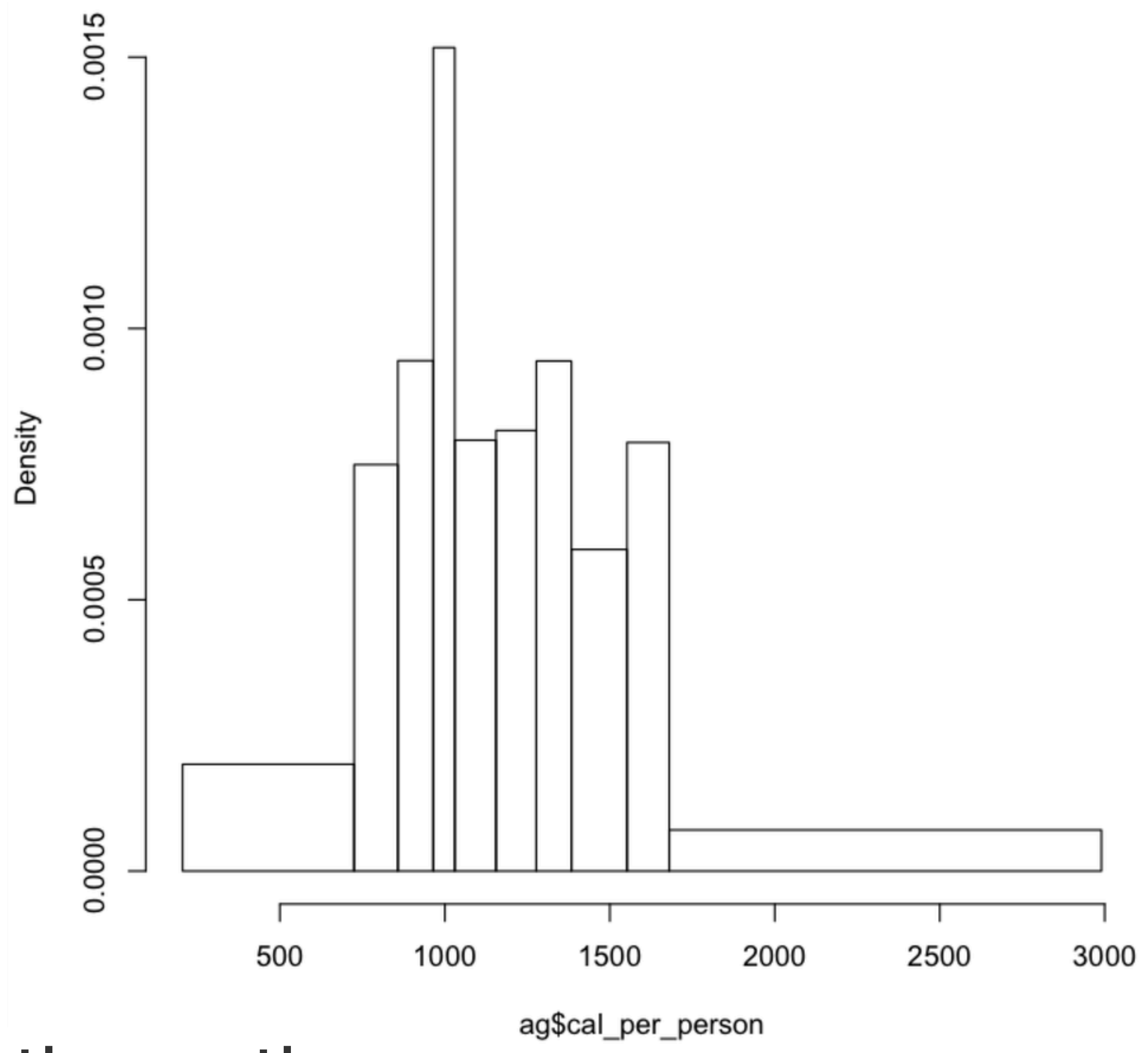
10 Bins



20 Bins

Unequal Bin Width

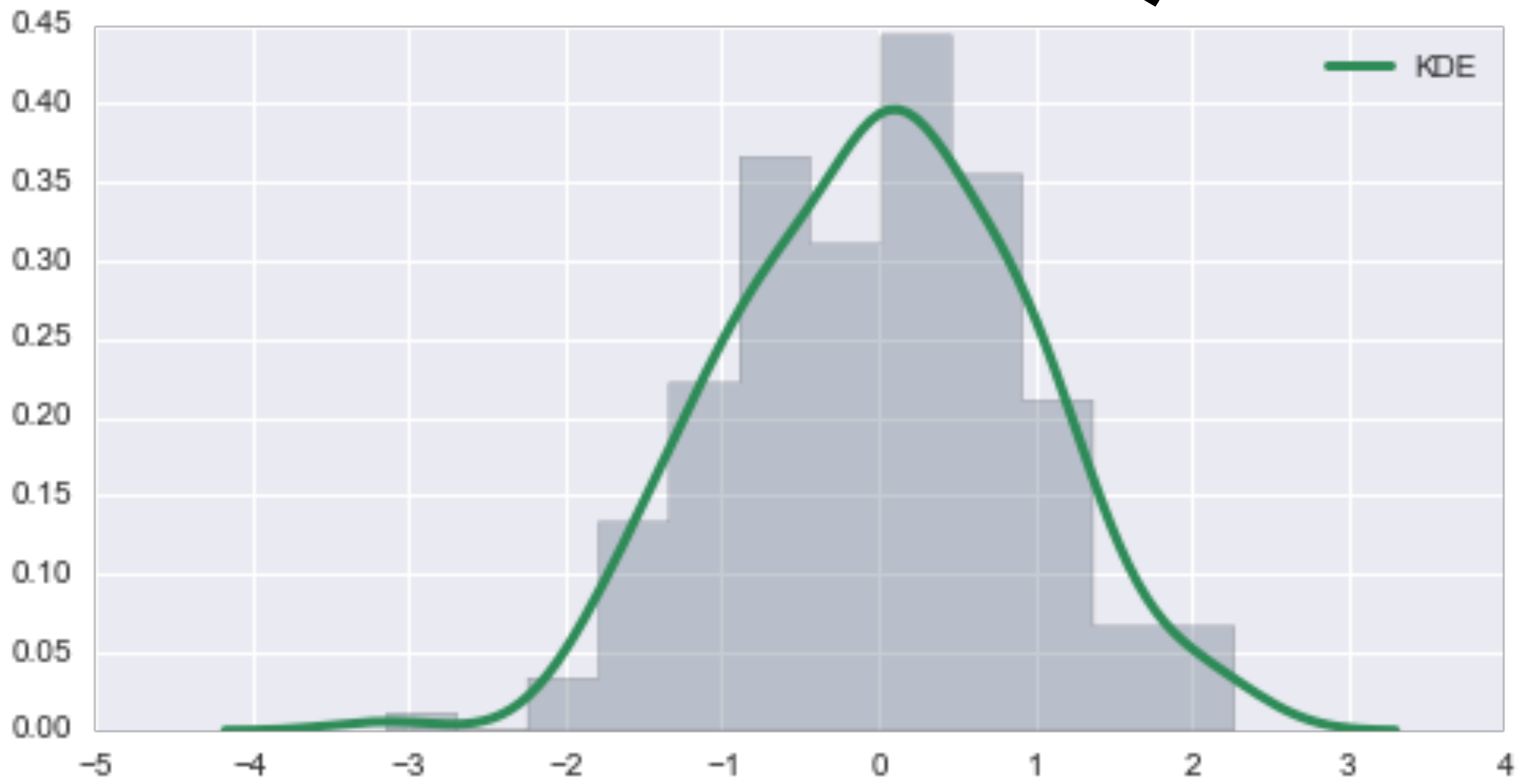


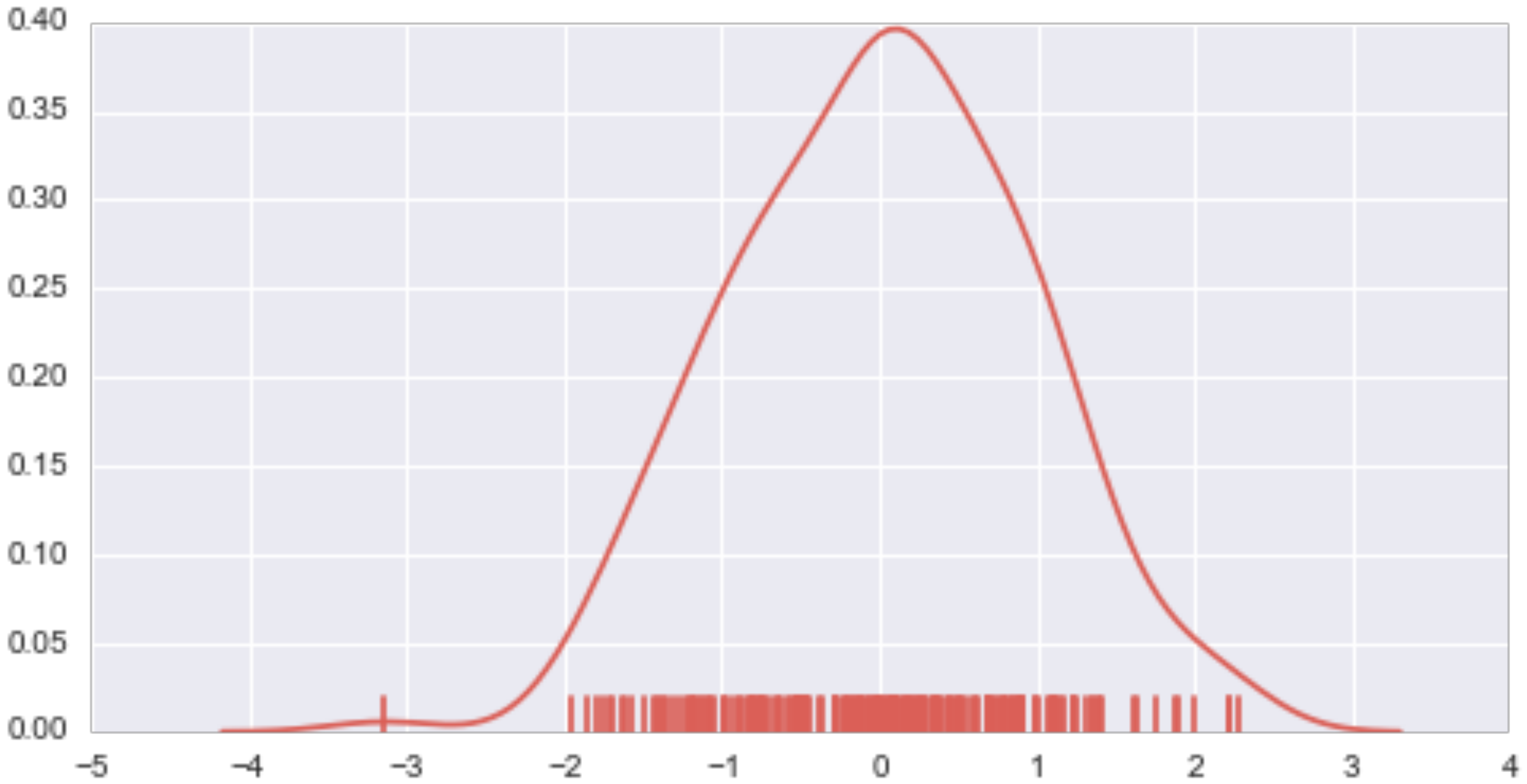


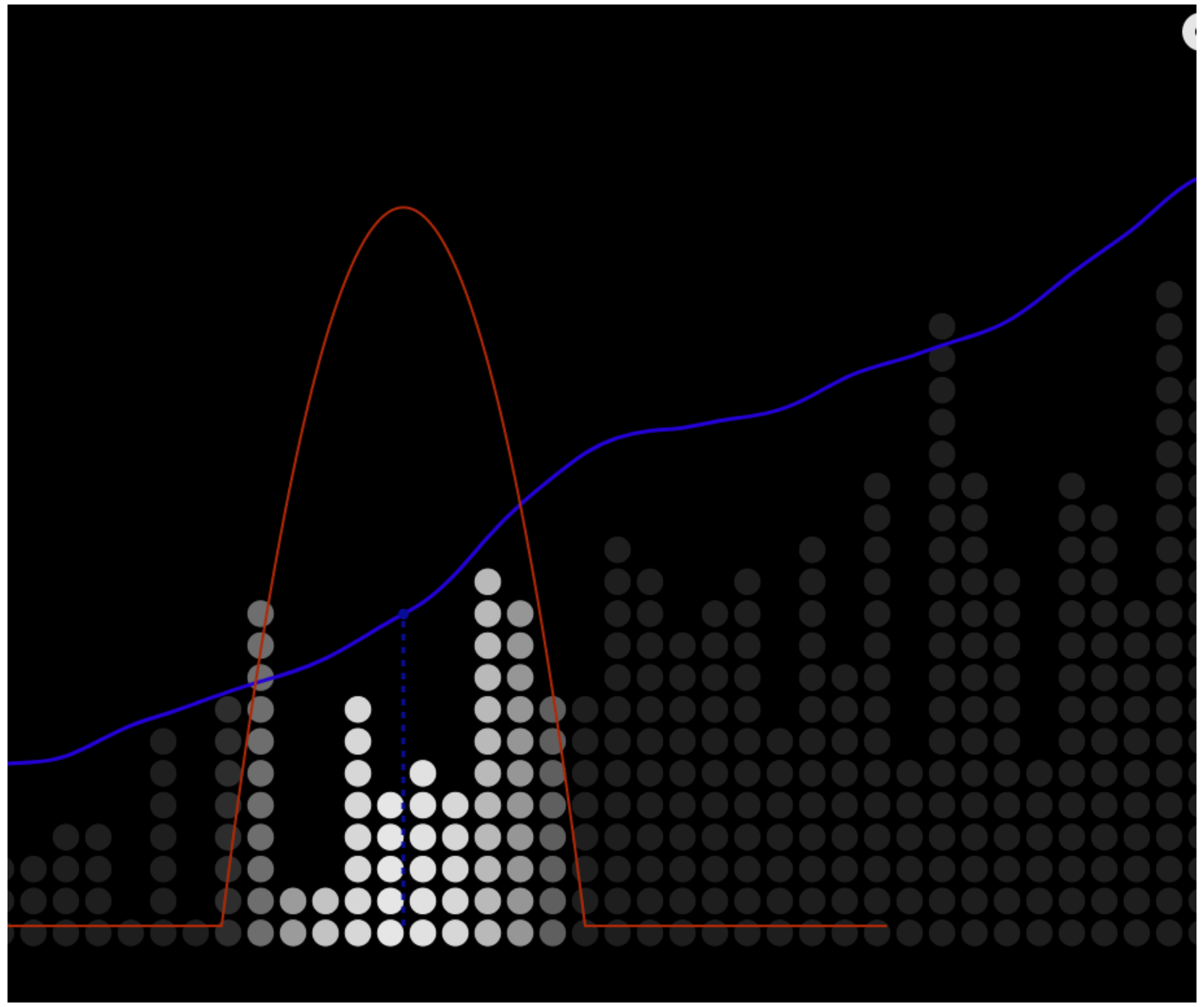
Can be useful if data is much sparser in some areas than others
Show density as area, not hight.

https://www.nytimes.com/interactive/2015/02/17/upshot/what-do-people-actually-order-at-chipotle.html?_r=1

Density Plots (Kernel Density Estimation)







http://web.stanford.edu/~mwaskom/software/seaborn/tutorial/plotting_distributions.html

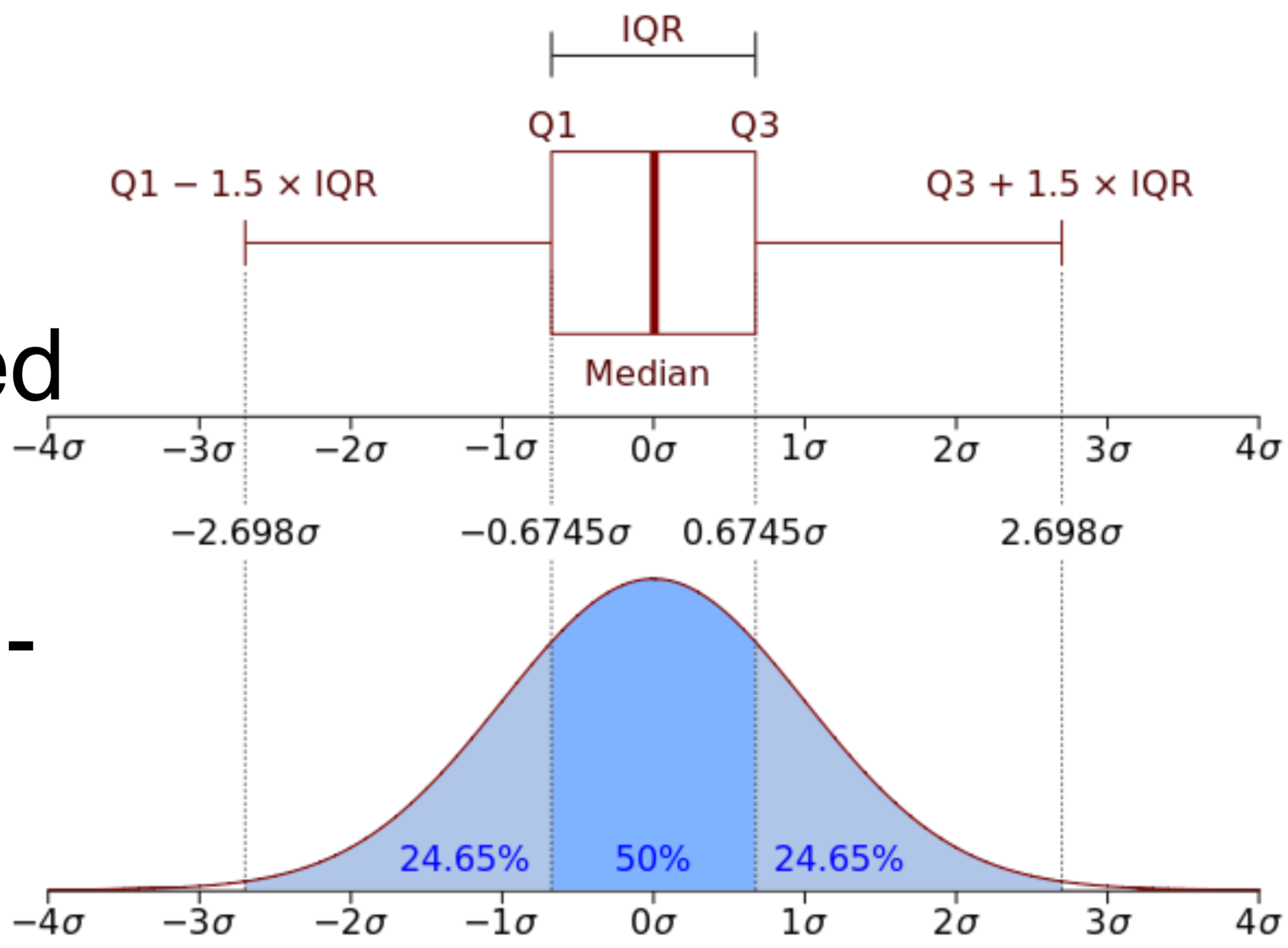
Box Plots

aka Box-and-Whisker Plot

Show outliers as points!

Bad for non-normal distributed data

Especially bad for bi- or multi-modal distributions



Wikipedia

One Boxplot, Four Distributions

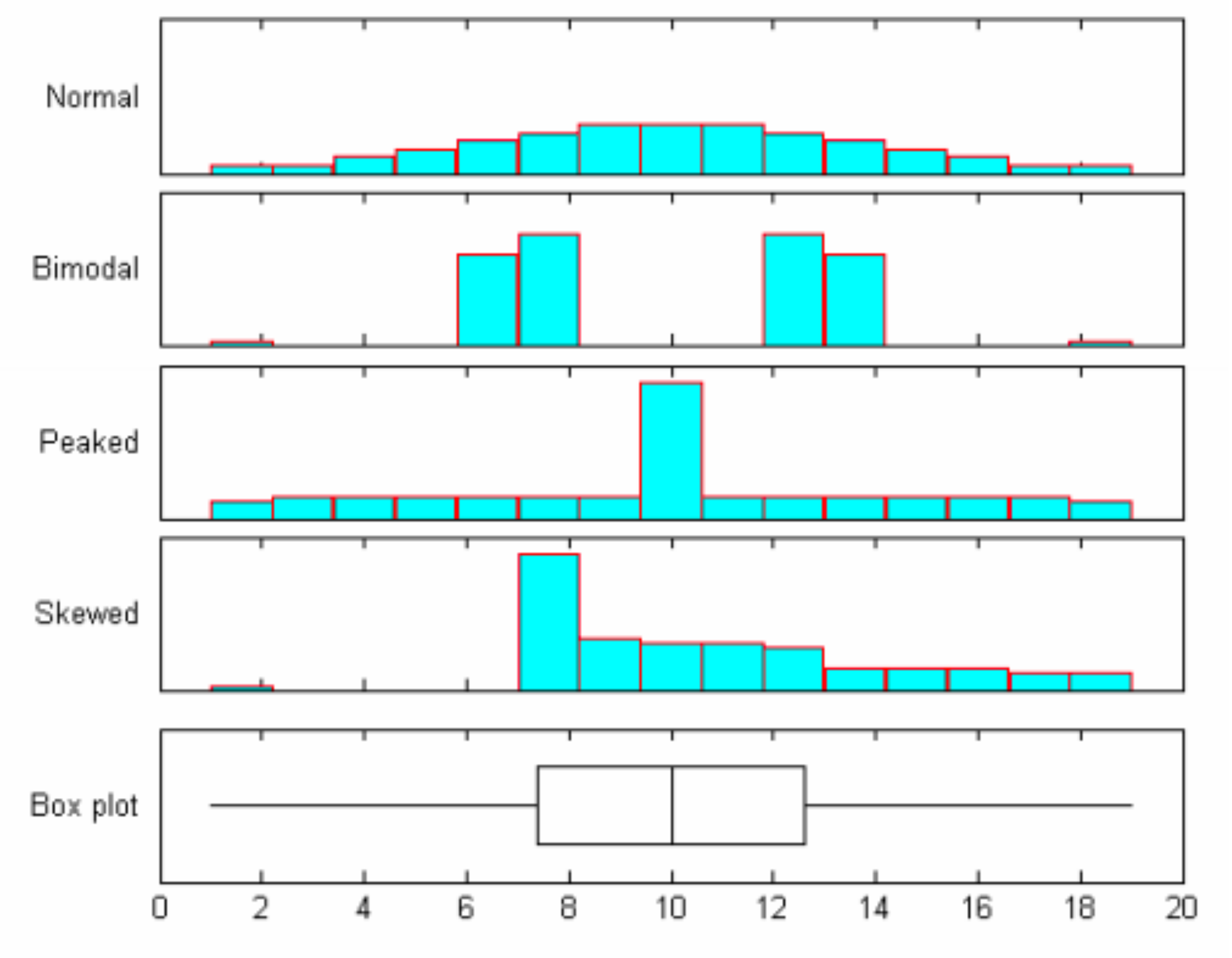


Figure 1: Histograms and box plot: four samples each of size 100

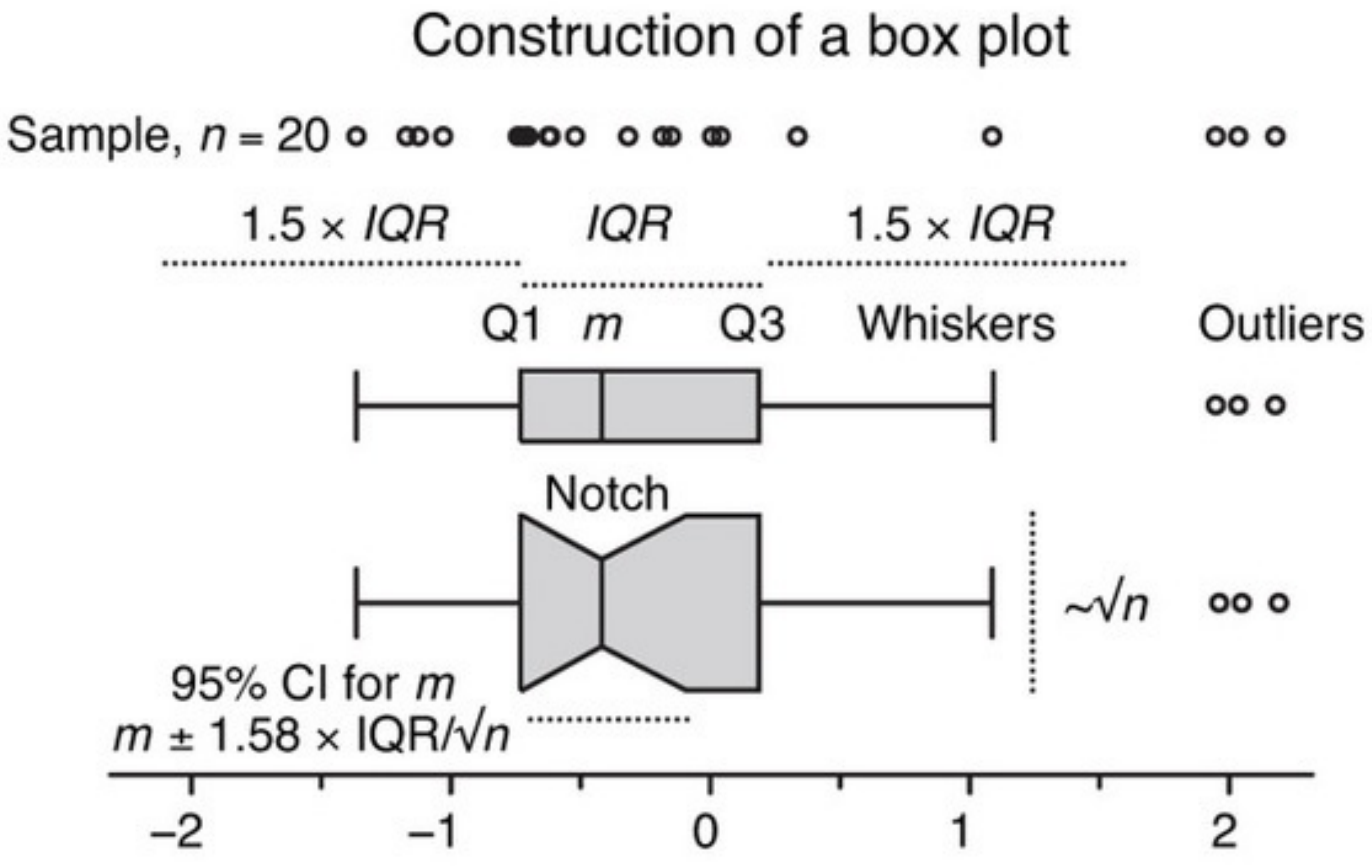
http://stat.mq.edu.au/wp-content/uploads/2014/05/Can_the_Box_Plot_be_Improved.pdf

Notched Box Plots

Notch shows
m +/- 1.5i x IQR/sqrt(n)

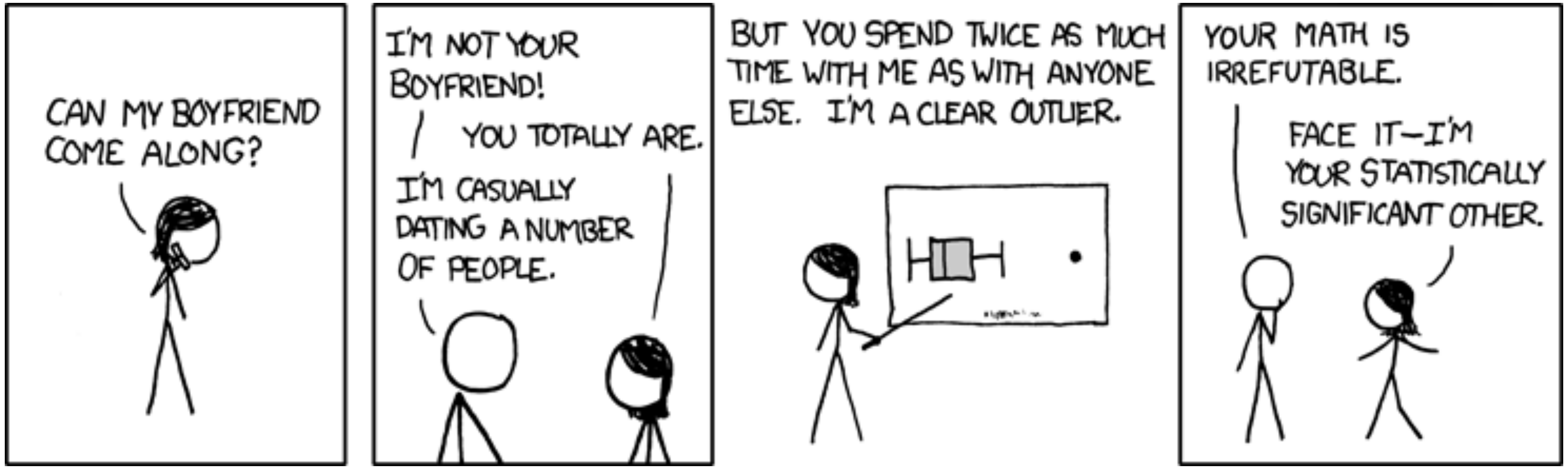
-> 95% Confidence Intervall

A guide to statistical
significance.

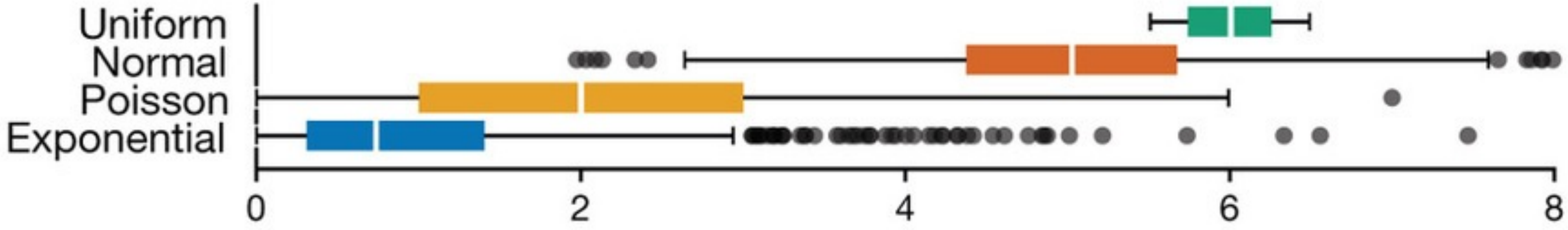


Kryzwinski & Altman, PoS, Nature Methods, 2014

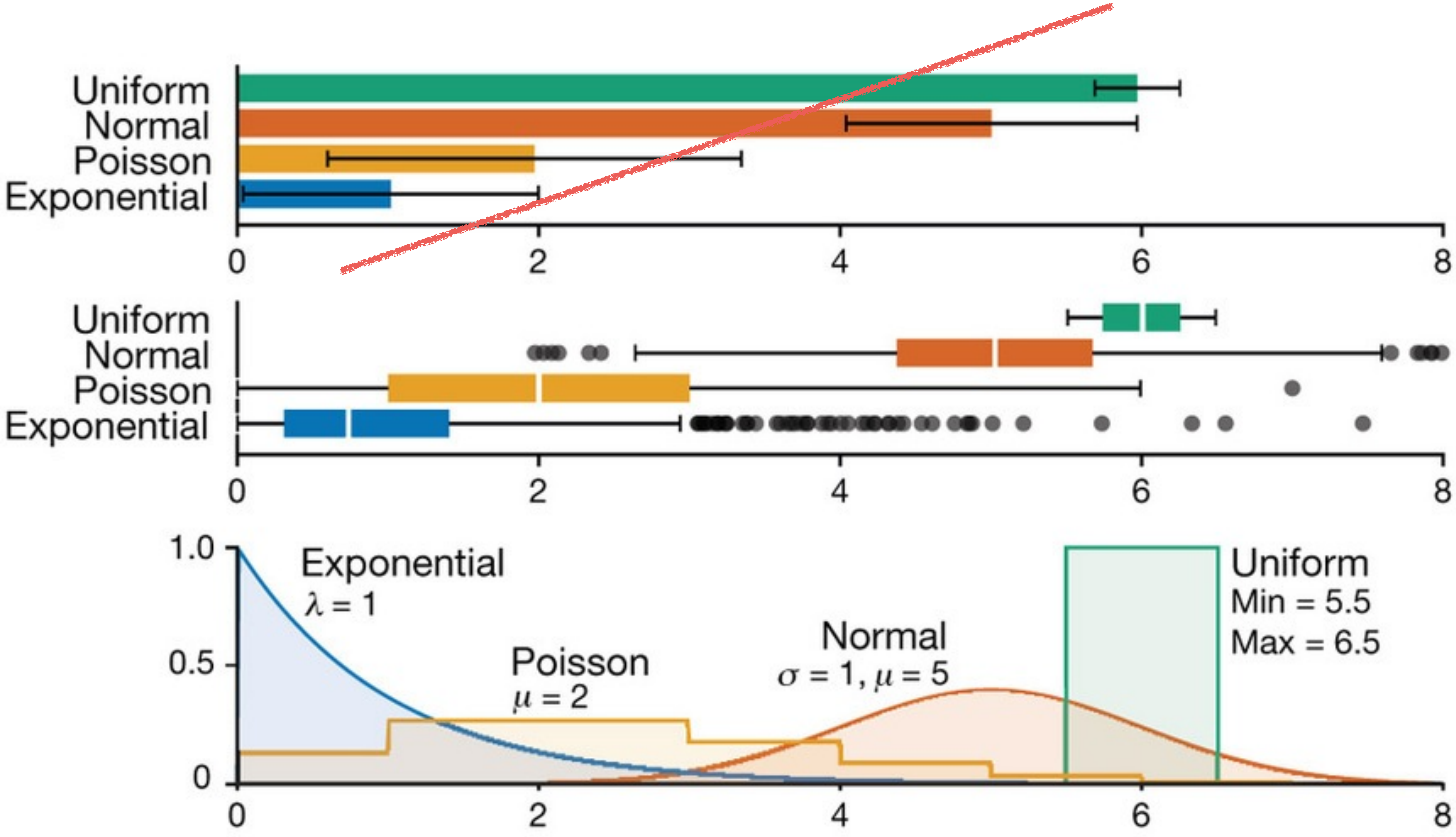
Box(and Whisker) Plots



http://xkcd.com/539/

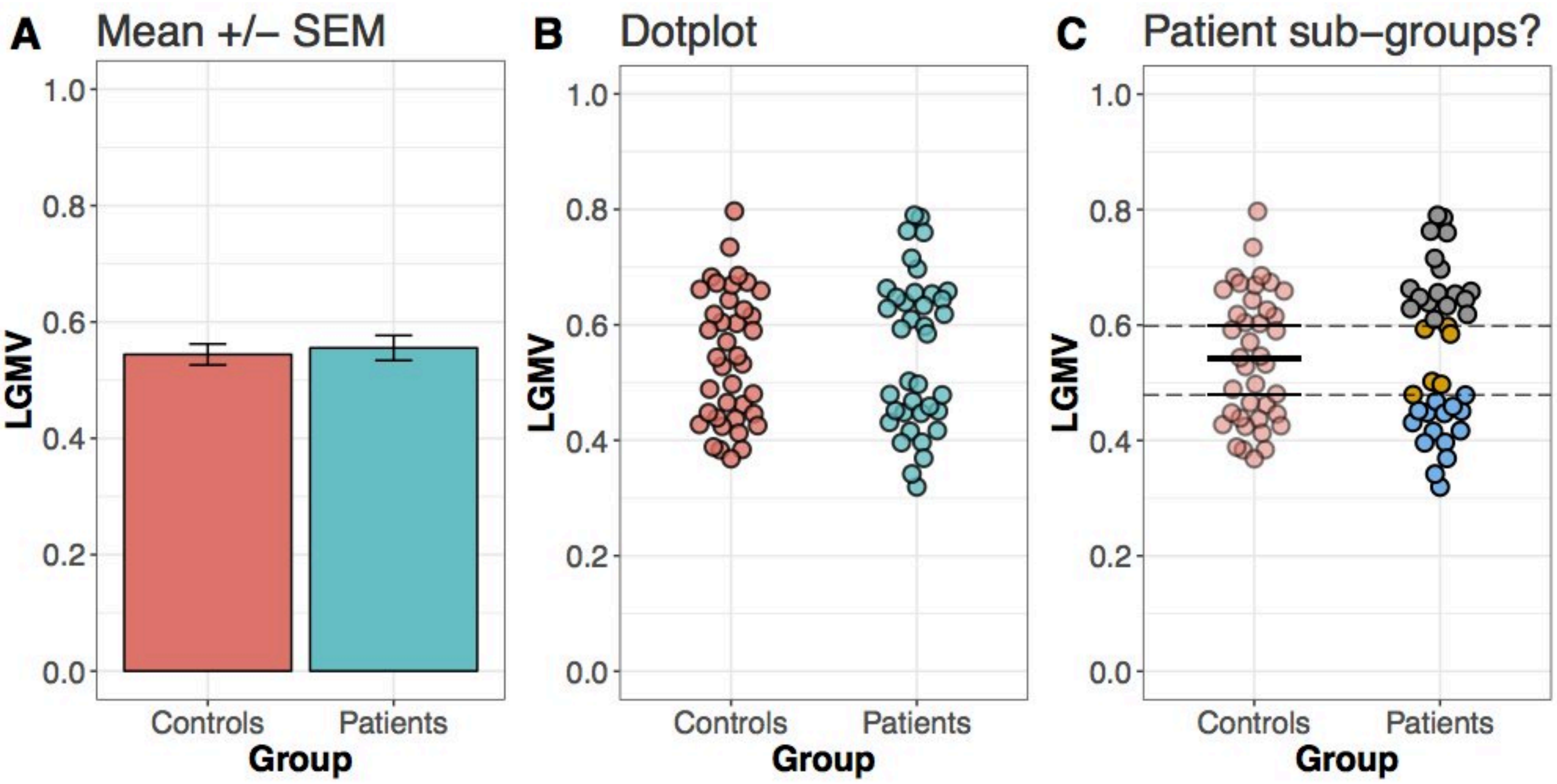


Comparison



Streit & Gehlenborg, PoV, Nature Methods, 2014

Bar Charts vs Dot Plots

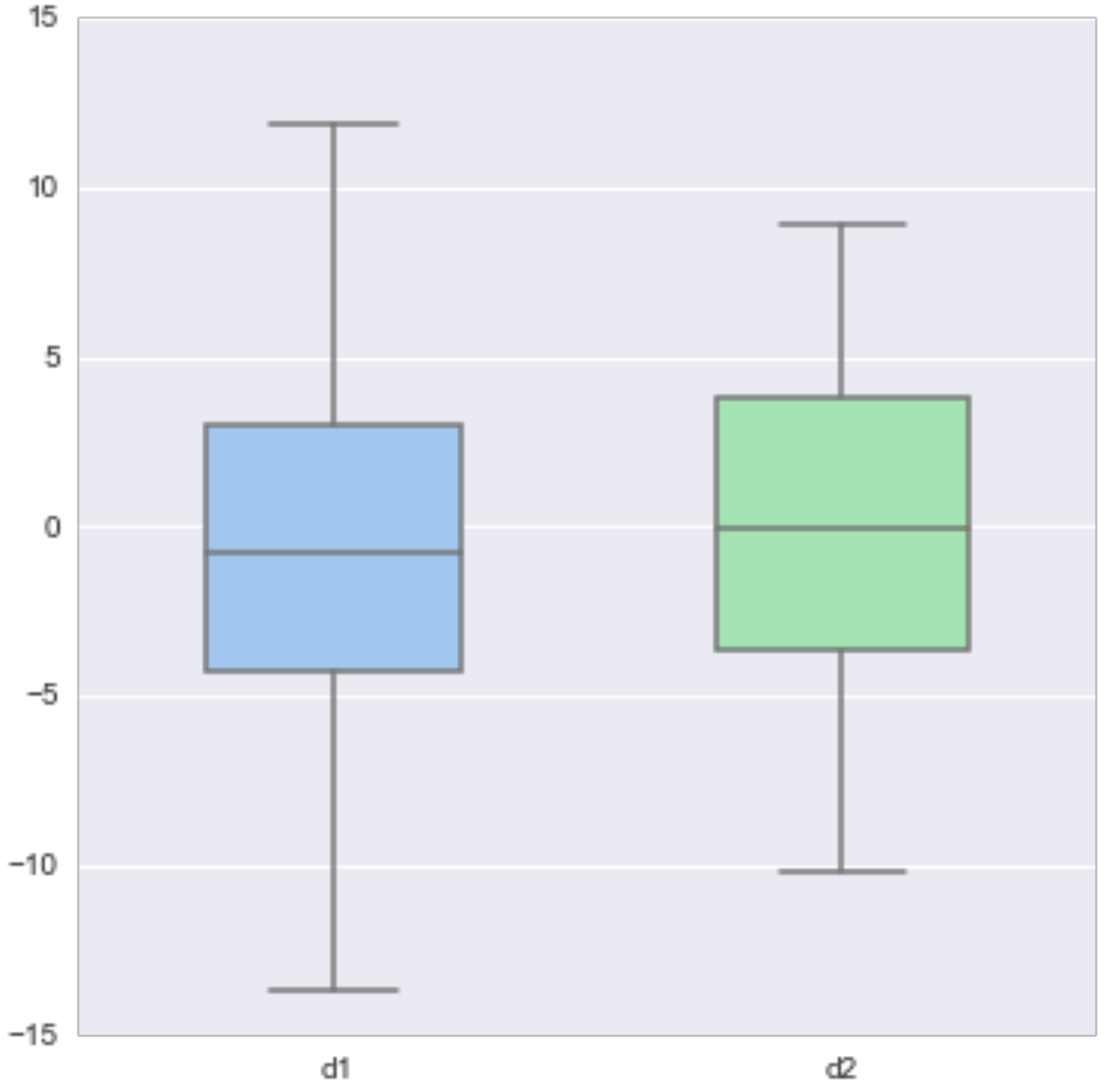


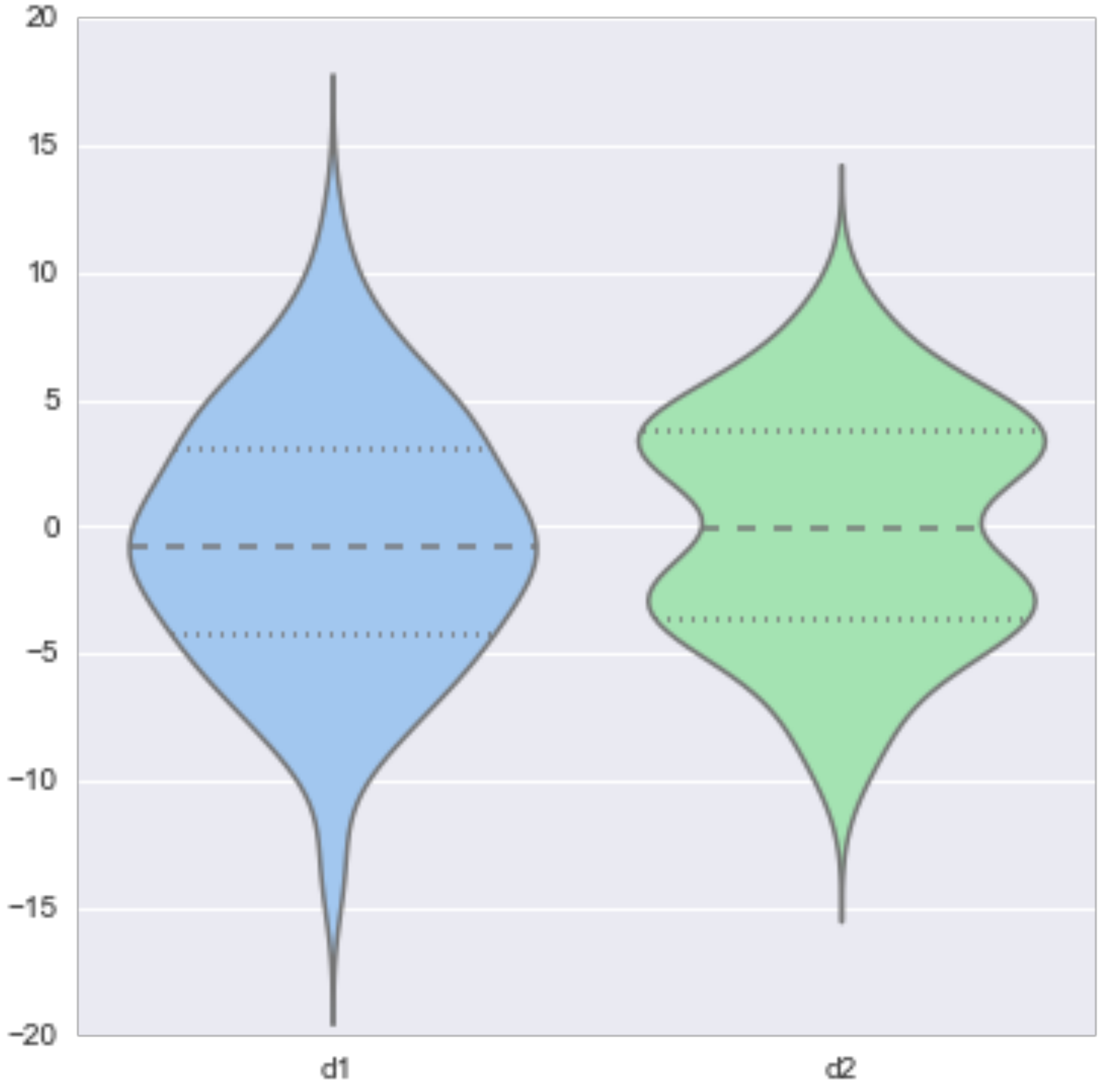
Data Source https://bmcneurosci.biomedcentral.com/articles/10.1186/1471-2202-10-67

https://twitter.com/robustgar/status/859318971920769024

Violin Plot

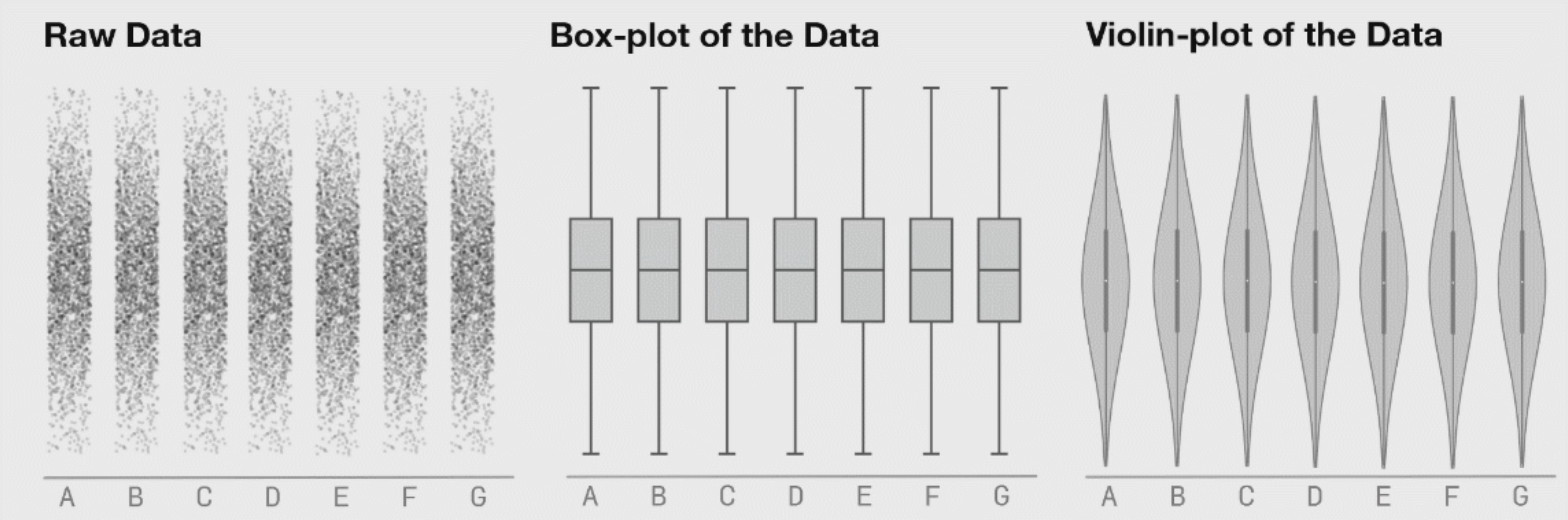
= Box Plot + Probability Density Function





http://web.stanford.edu/~mwaskom/software/seaborn/tutorial/plotting_distributions.html

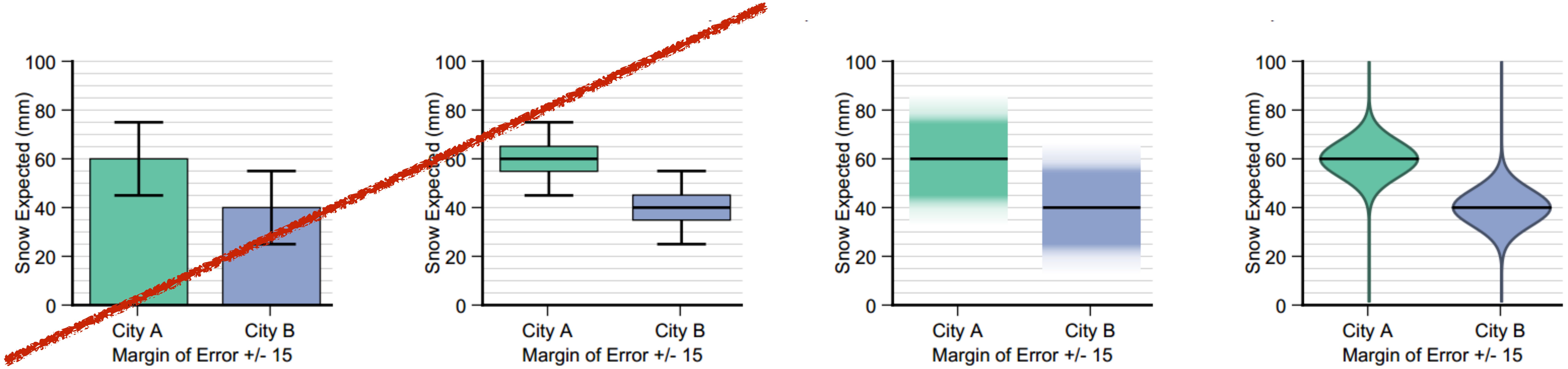
Different Distributions



https://blog.bioturing.com/2018/05/16/5-reasons-you-should-use-a-violin-graph/

Showing Expected Values & Uncertainty

NOT a distribution!



Error Bars Considered Harmful:
Exploring Alternate Encodings for Mean and Error
Michael Correll, and Michael Gleicher

One of these things is not like the other...

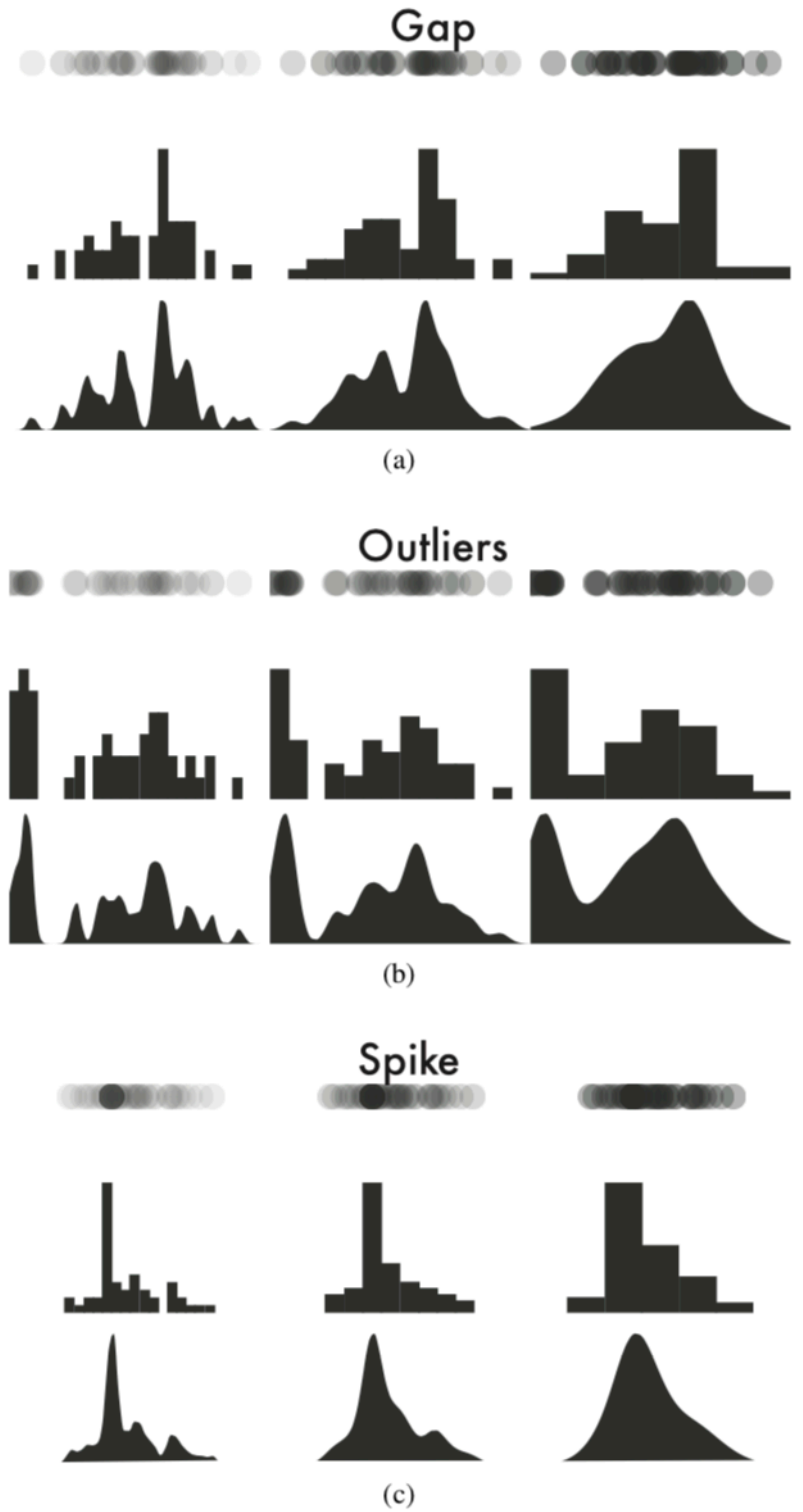
19 charts are random samples from a gaussian.
1 chart has 20% of samples with identical value

[Corell et al, InfoVis 2019]

Detecting Data Flaws

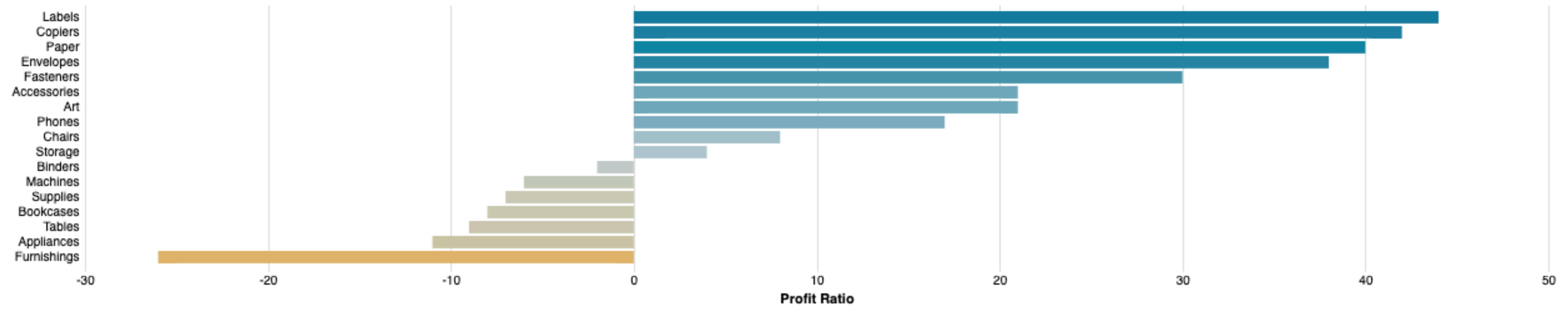
Tricky with aggregate visualization

Bin size / kernel type / bandwidth / visualization choice all affect different situations

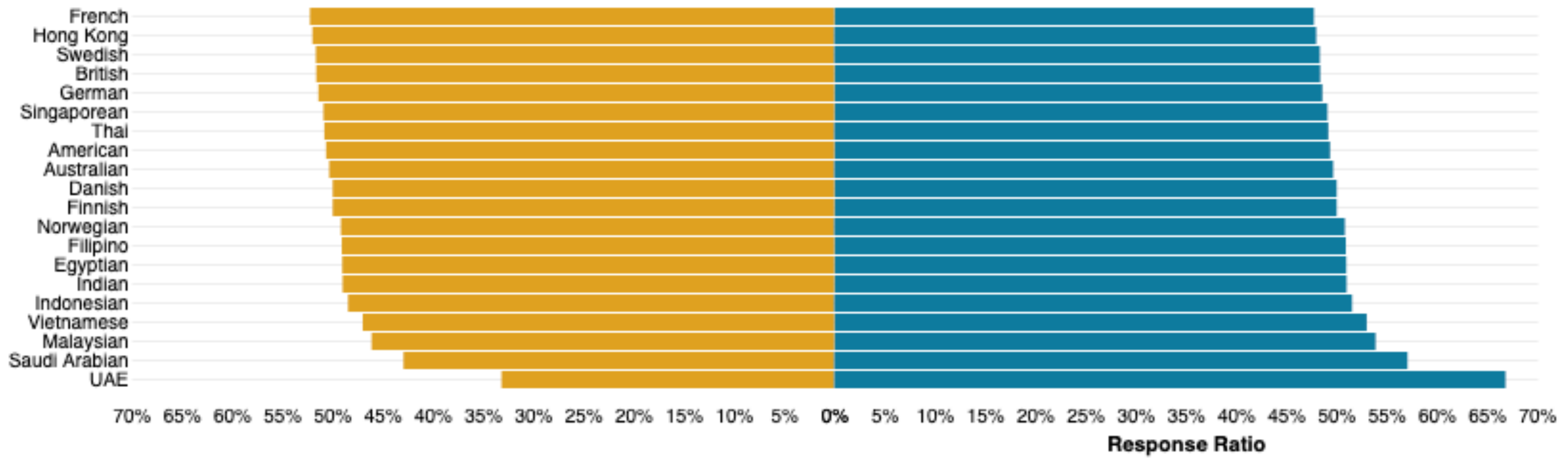


Deviation

Comparison to Reference Point



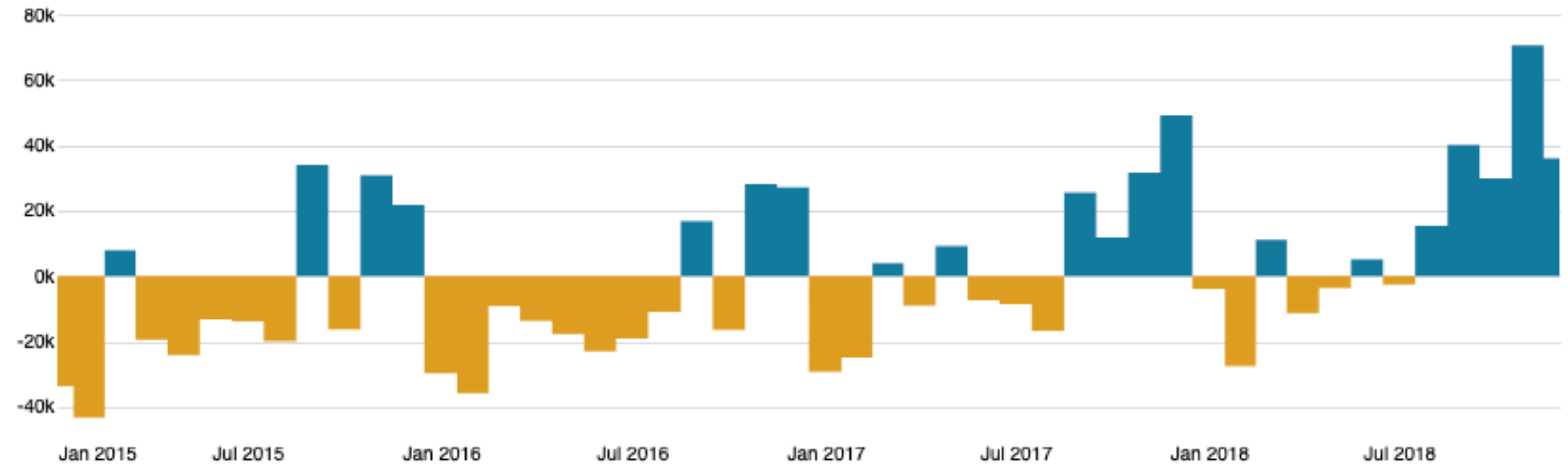
Diverging Bar Chart



Juxtaposing Two Variables (male/female)

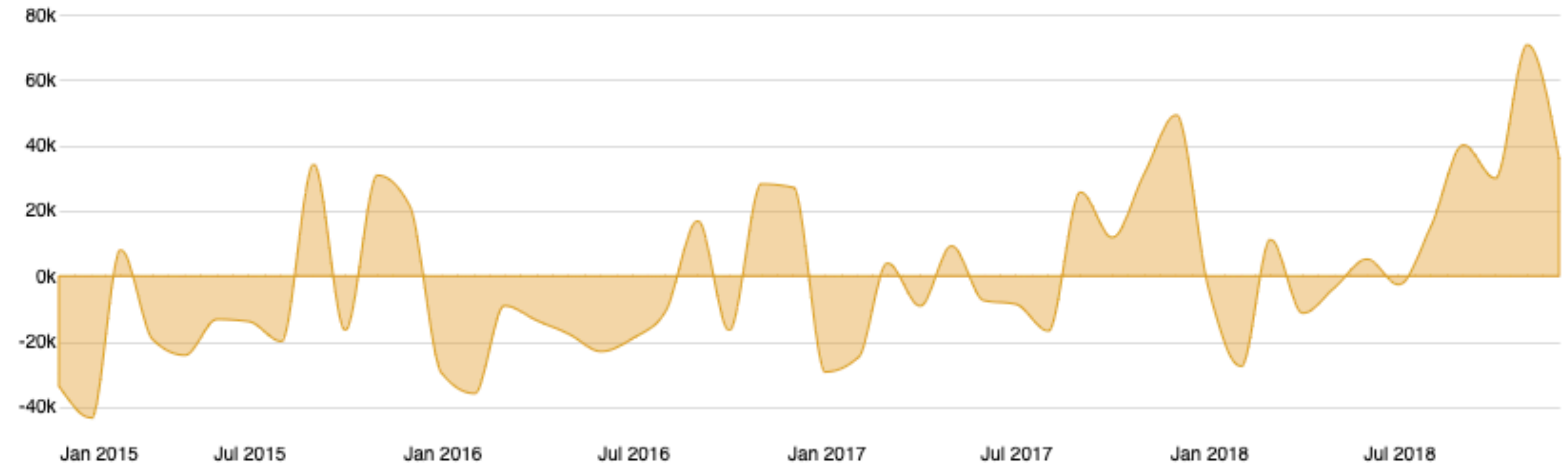
Surplus/deficit filled line

The shaded area of these charts allows a balance to be shown; either against a baseline or between two serie



Surplus/deficit filled area

Same as before.



Change over Time

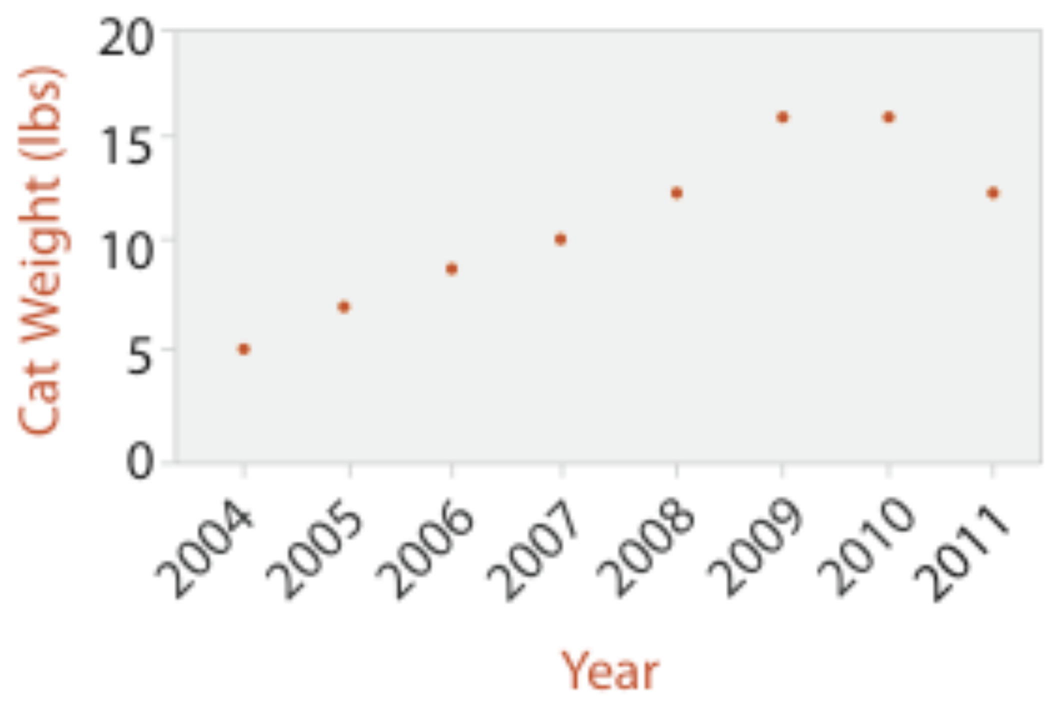
Line Chart

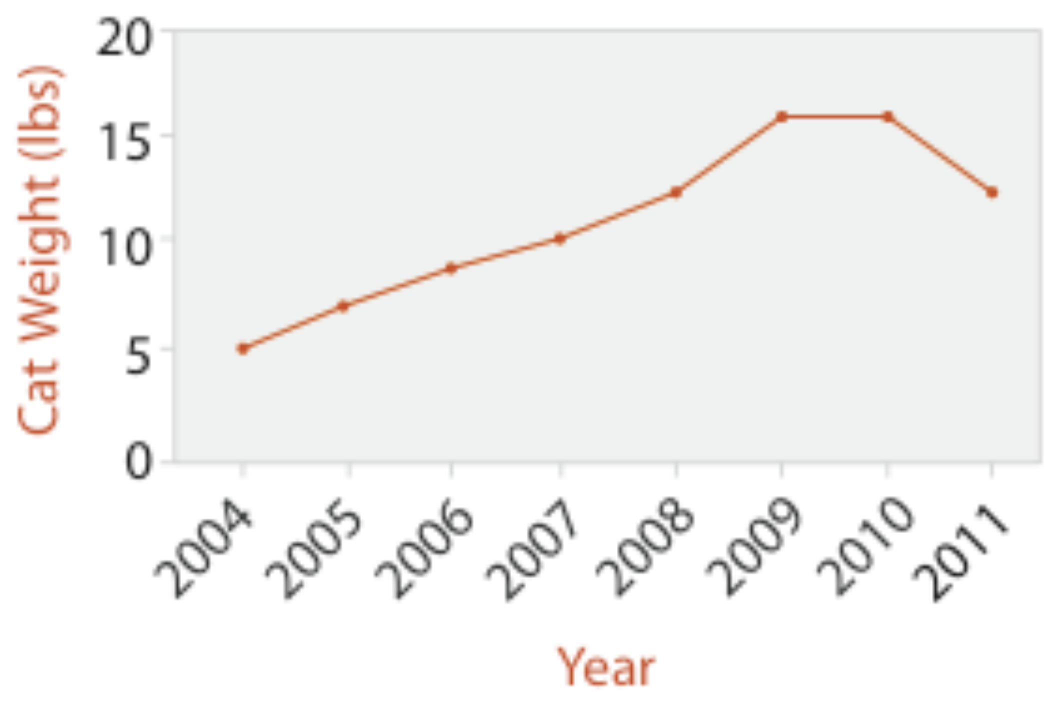
Simple

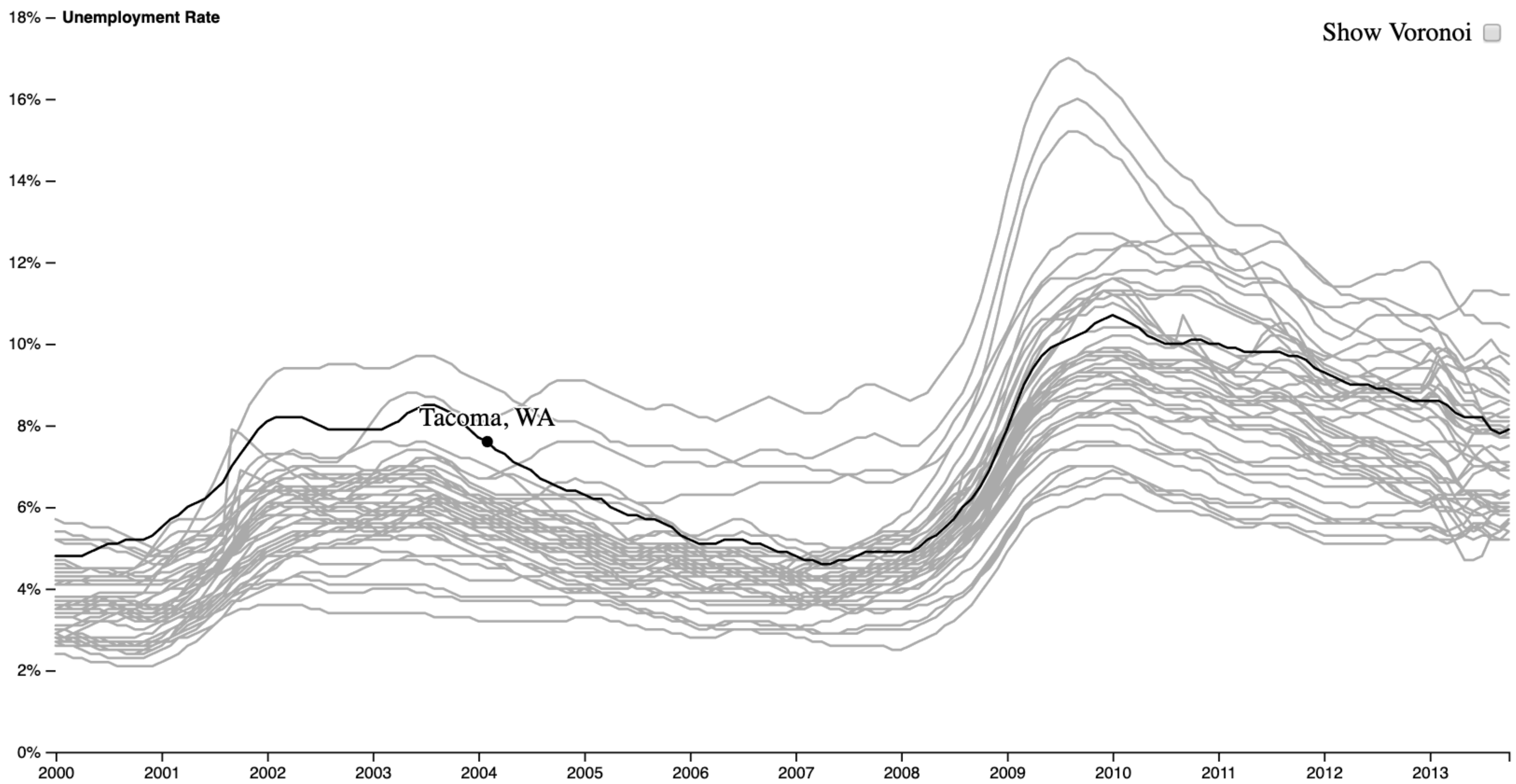
Familiar

Accurate

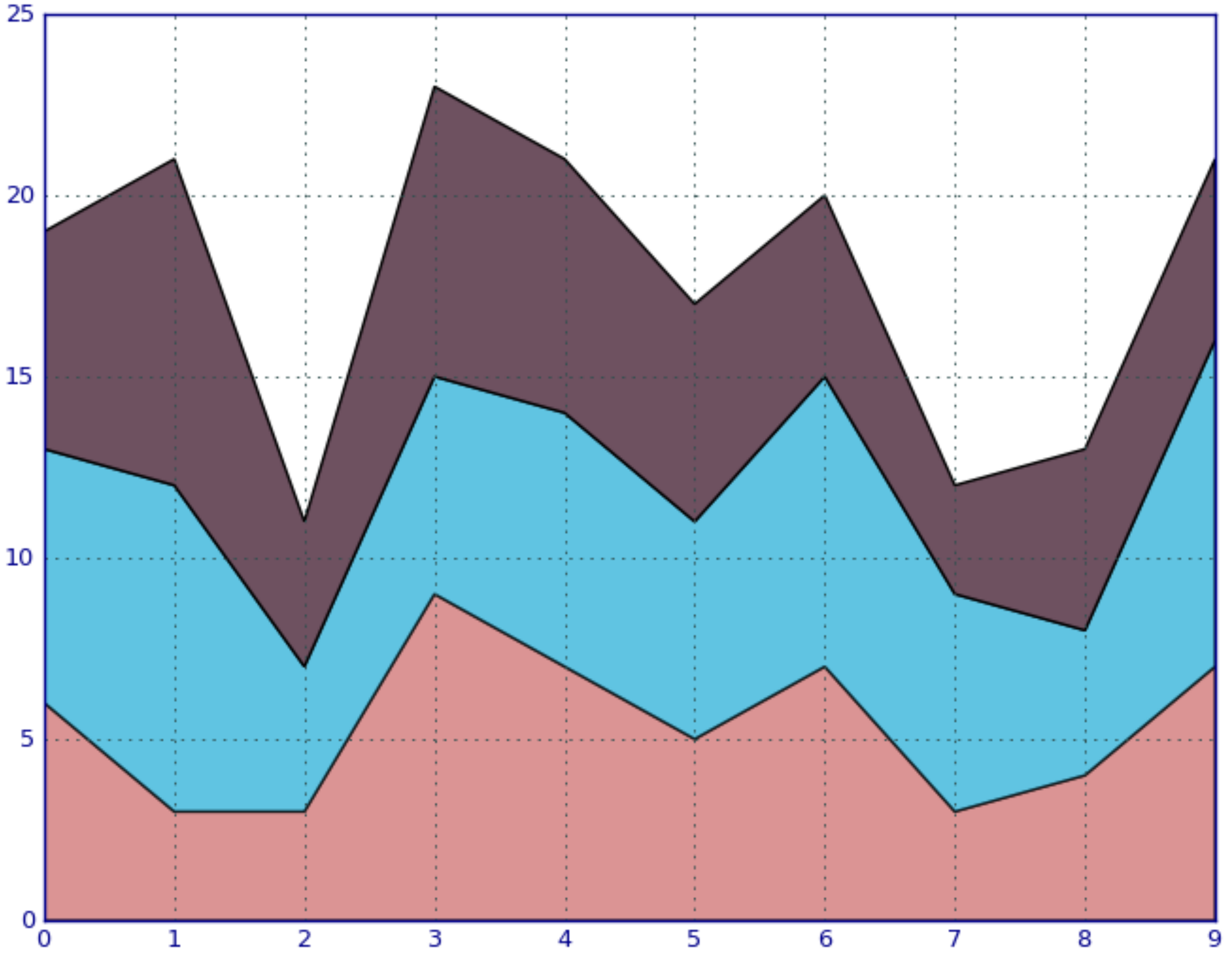
Fairly Scalable



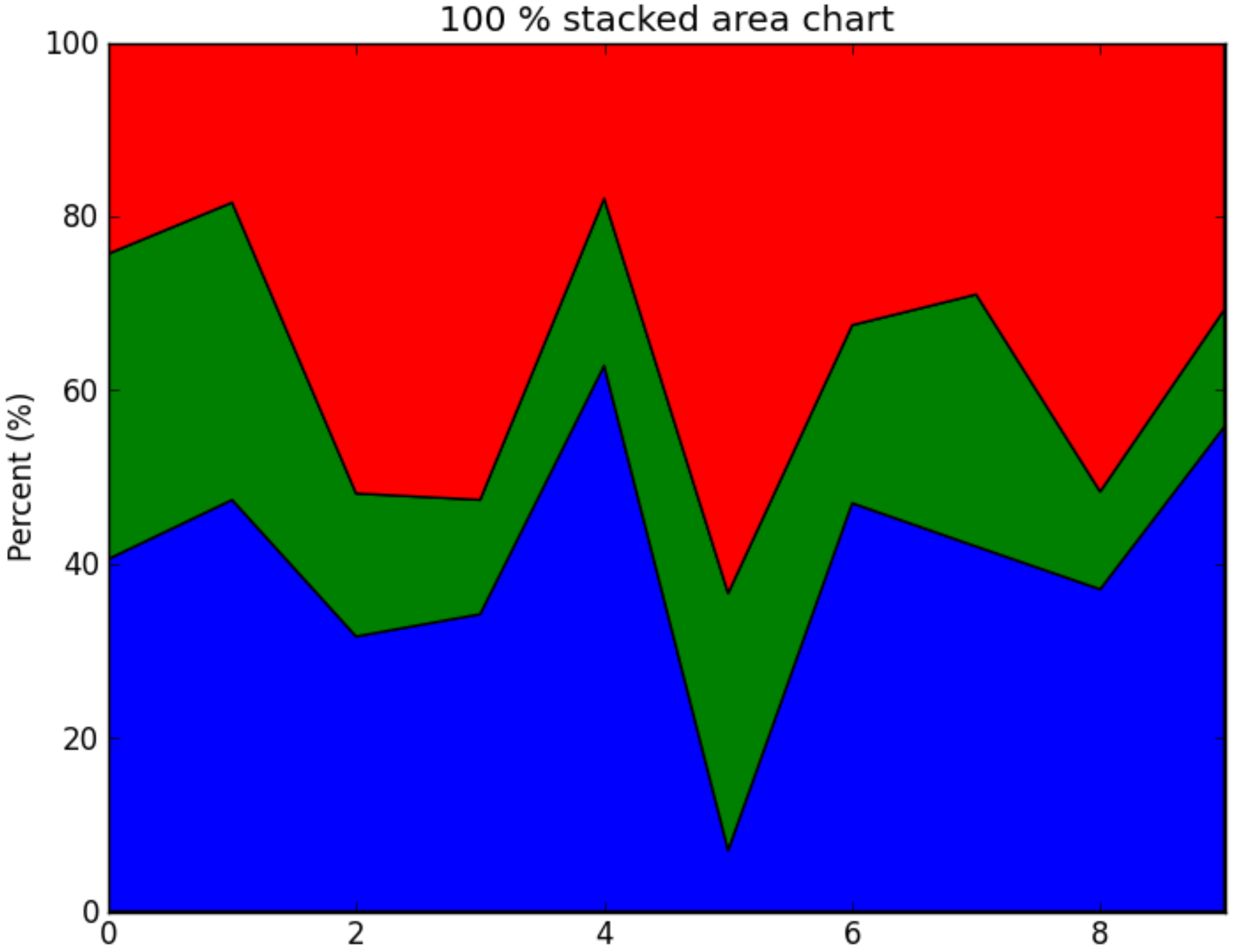




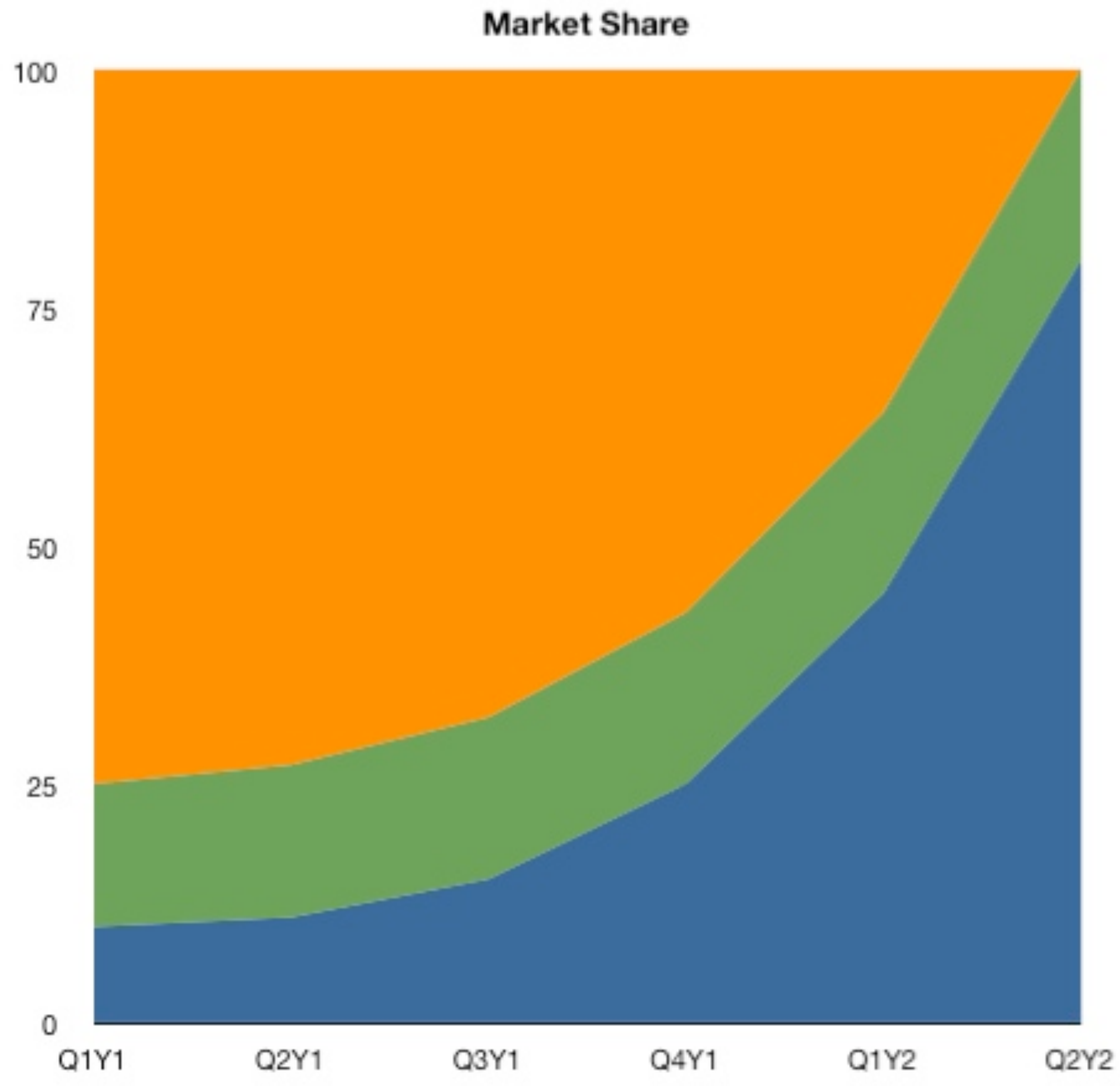
Stacked Area Chart

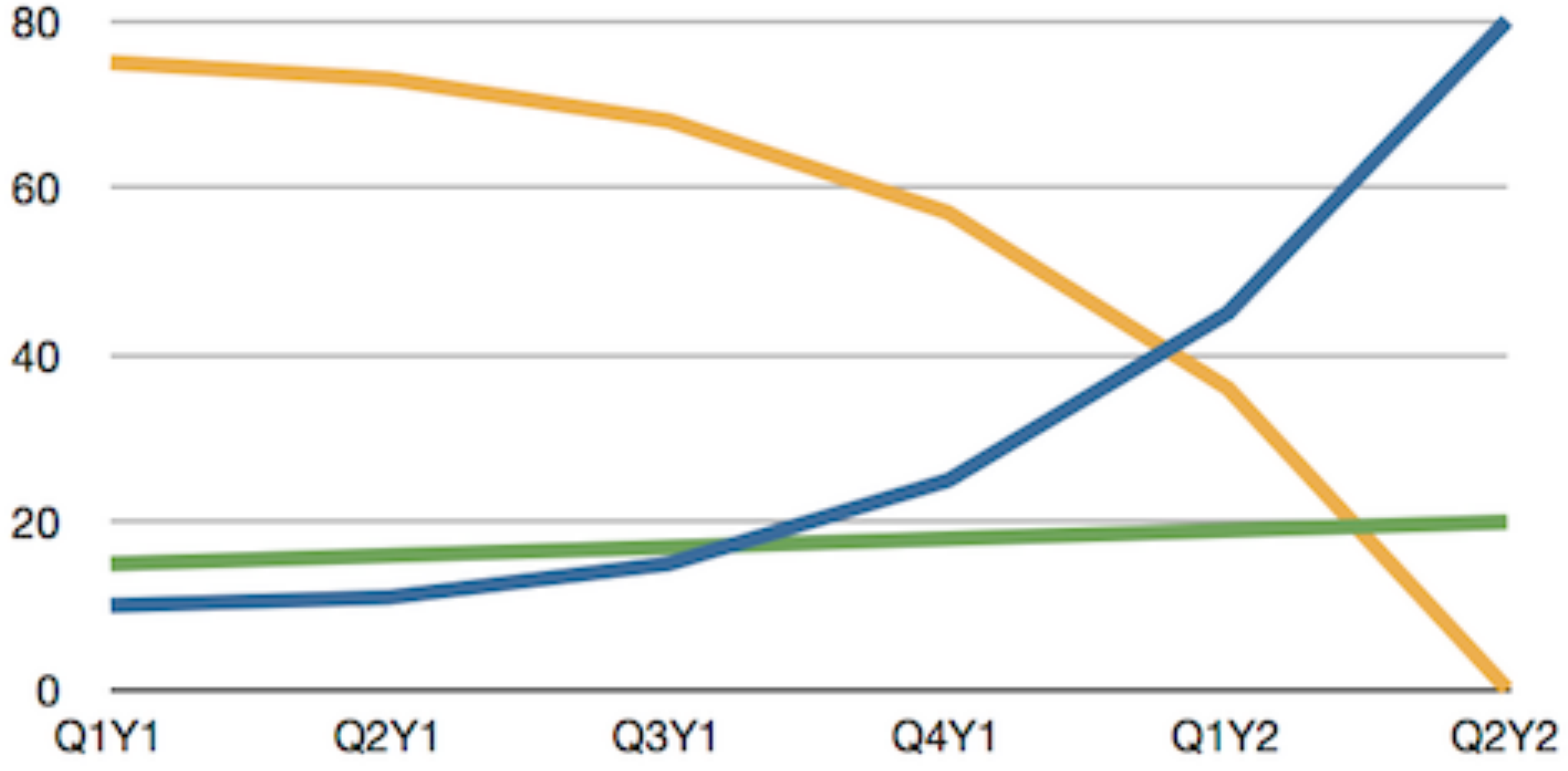


100% Stacked Area Chart



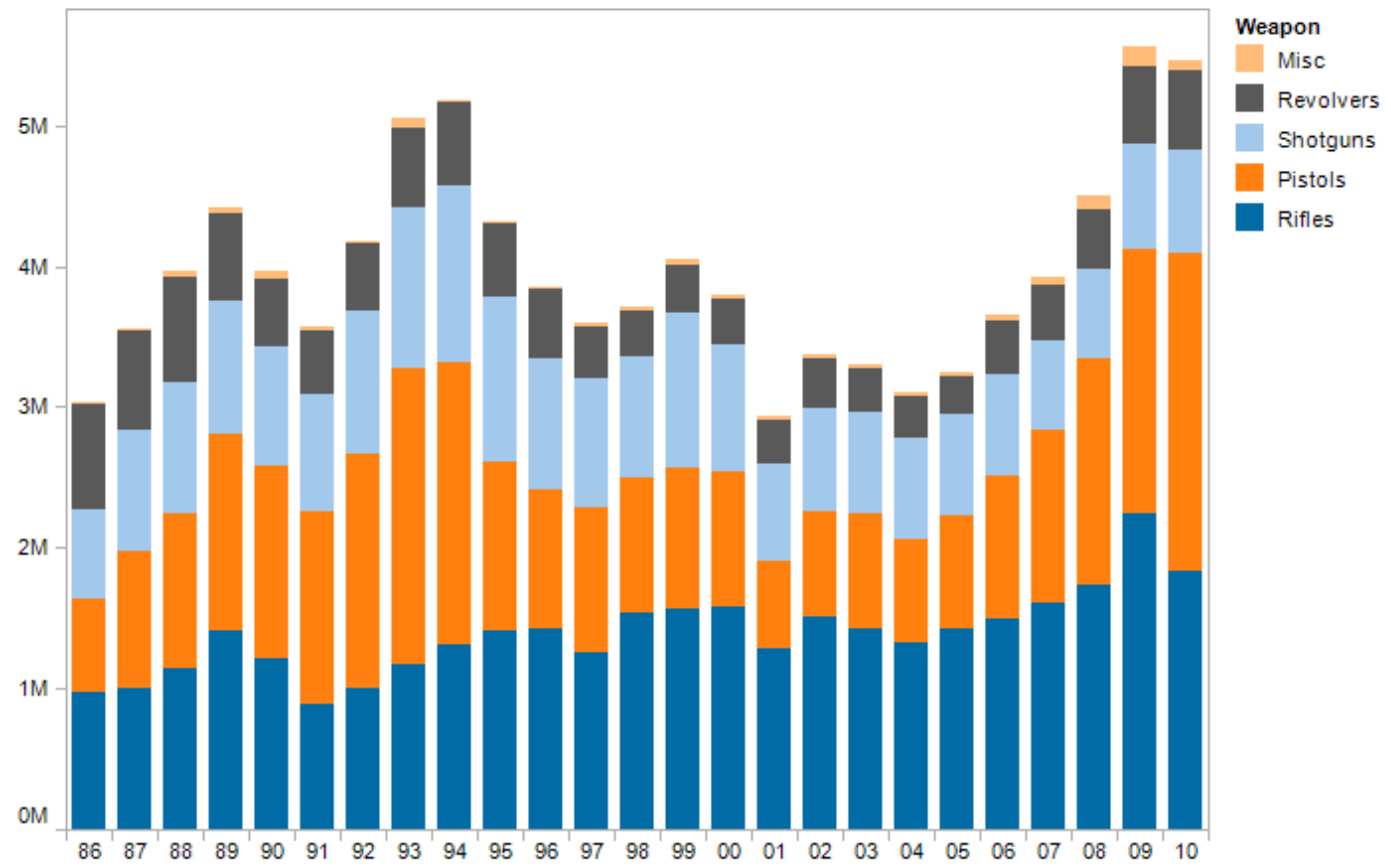
Stacked Area vs. Line Graphs

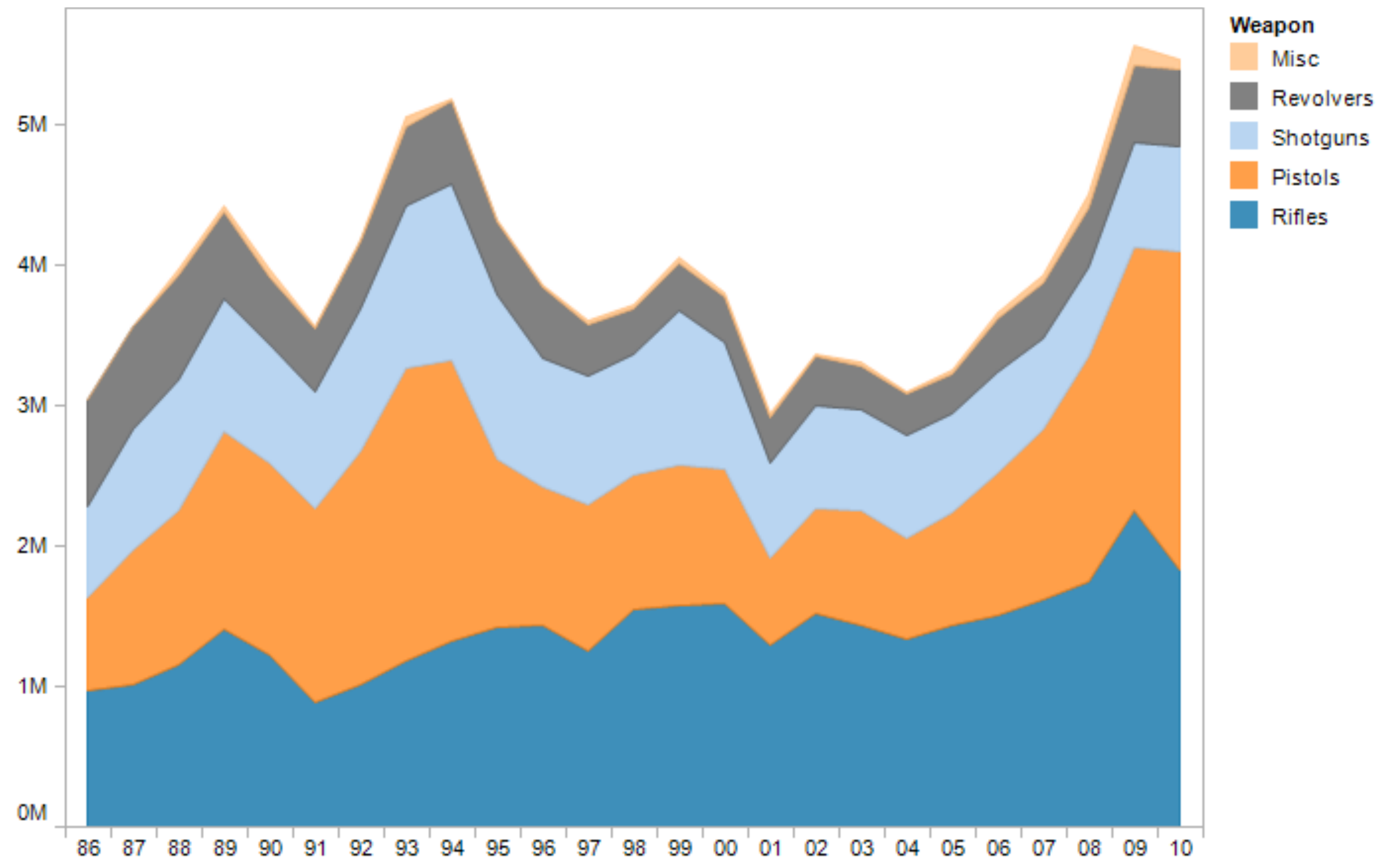


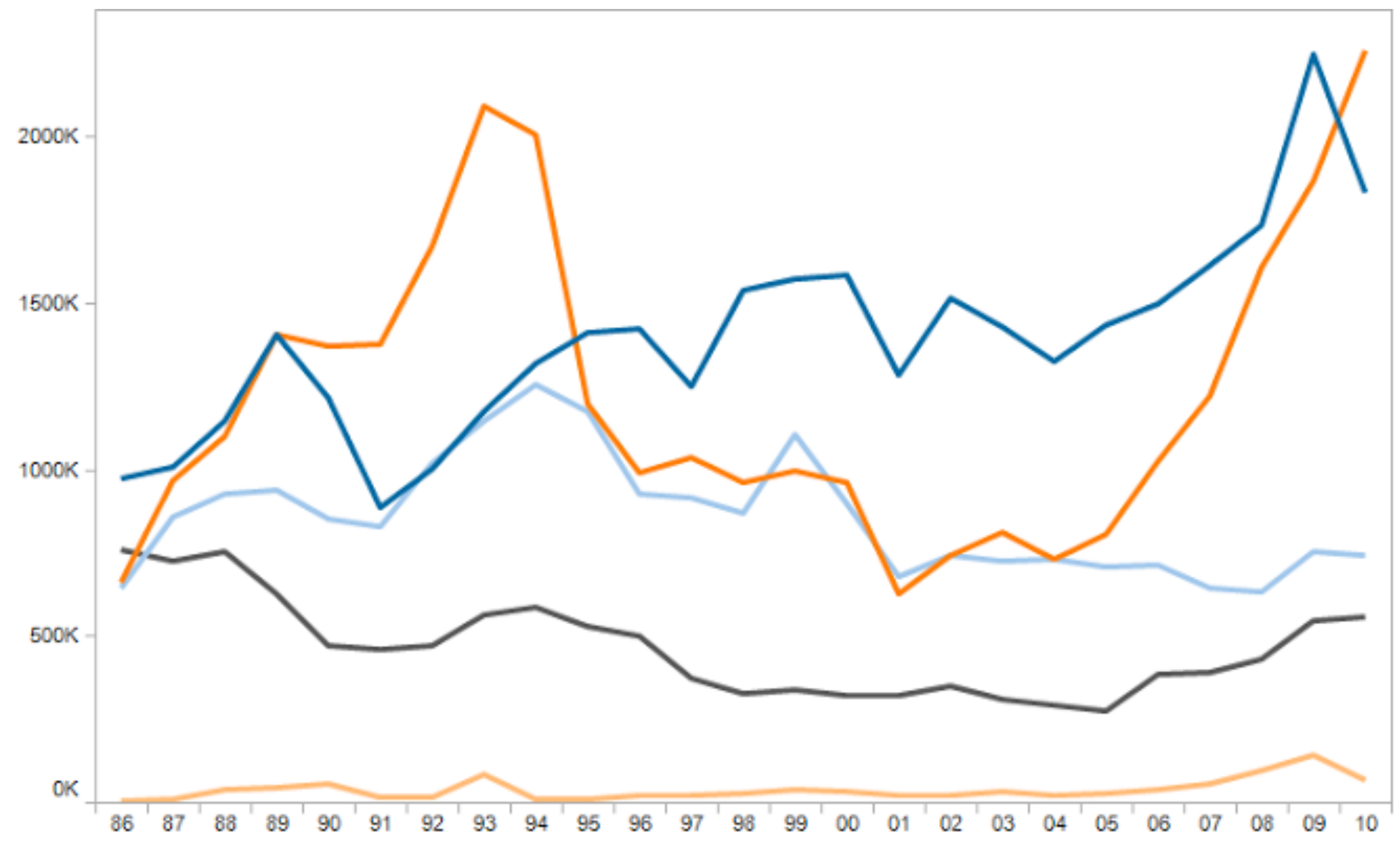


leancrew.com &
Practically Efficient

Can you spot the trends?

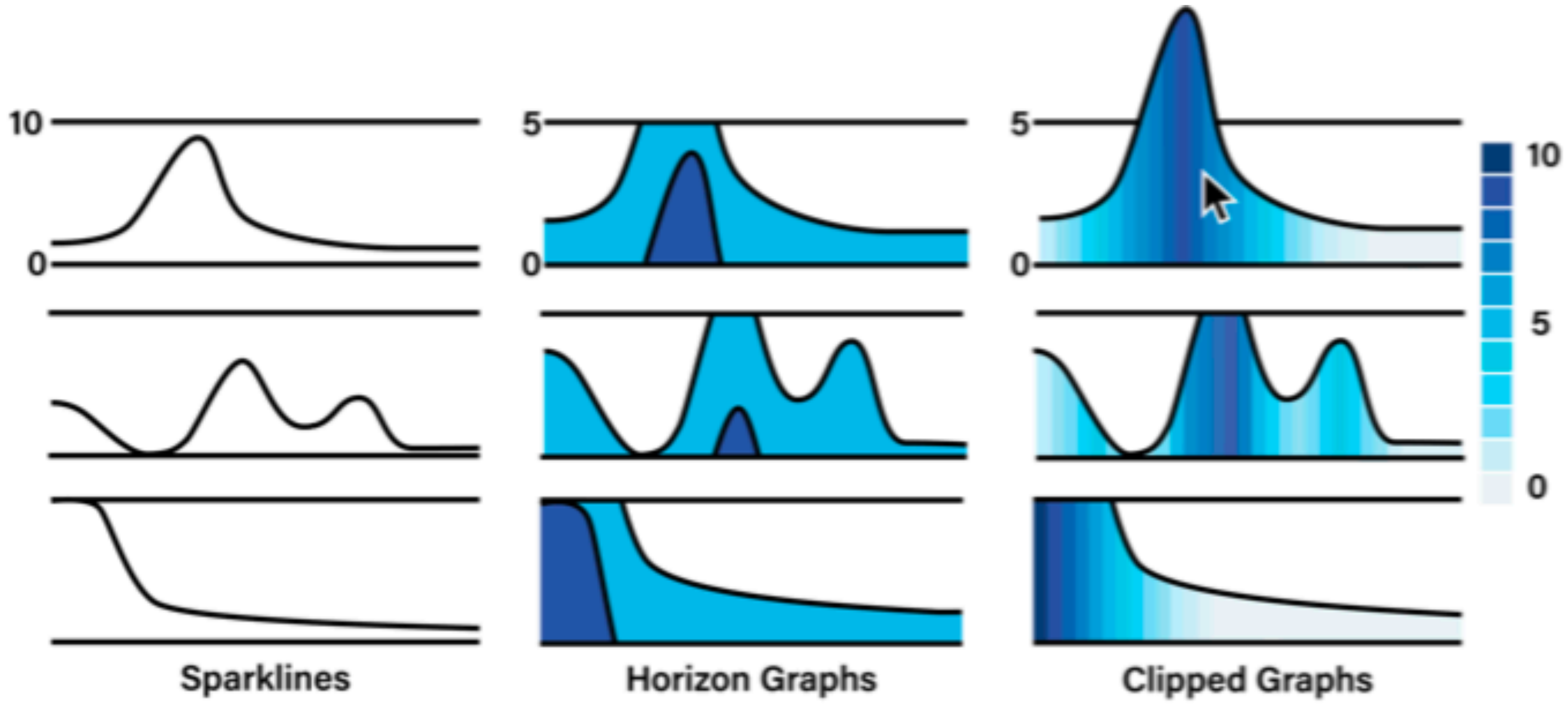






VizWiz, A. Kriebel

Multiple Line Charts

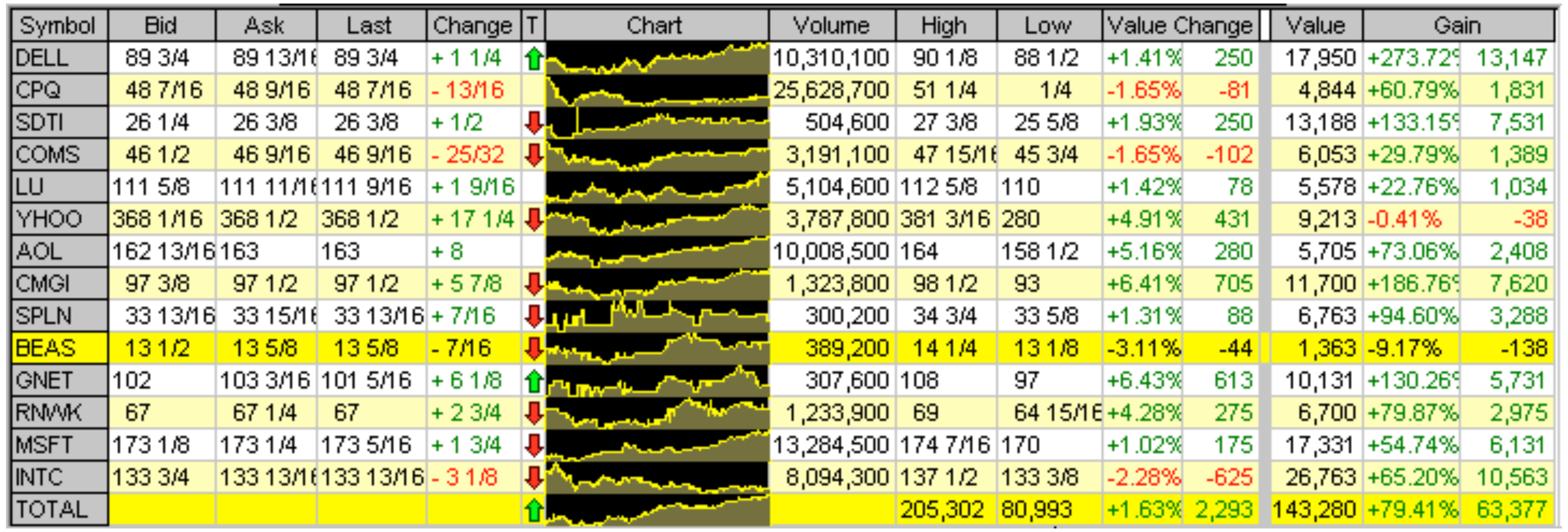


Sparklines

Small line charts

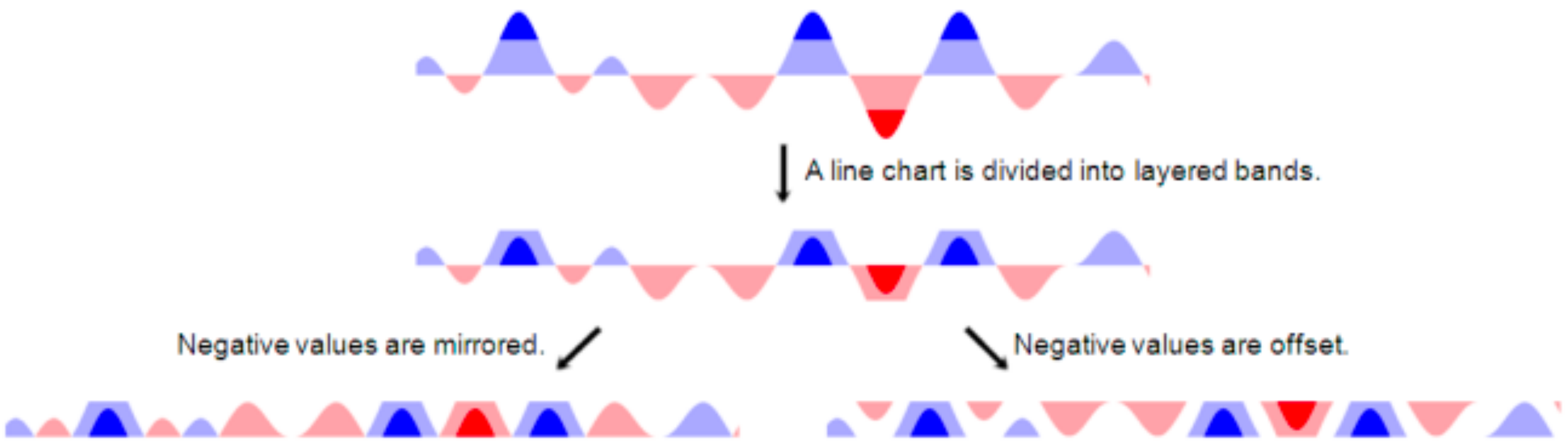
can be embedded in text

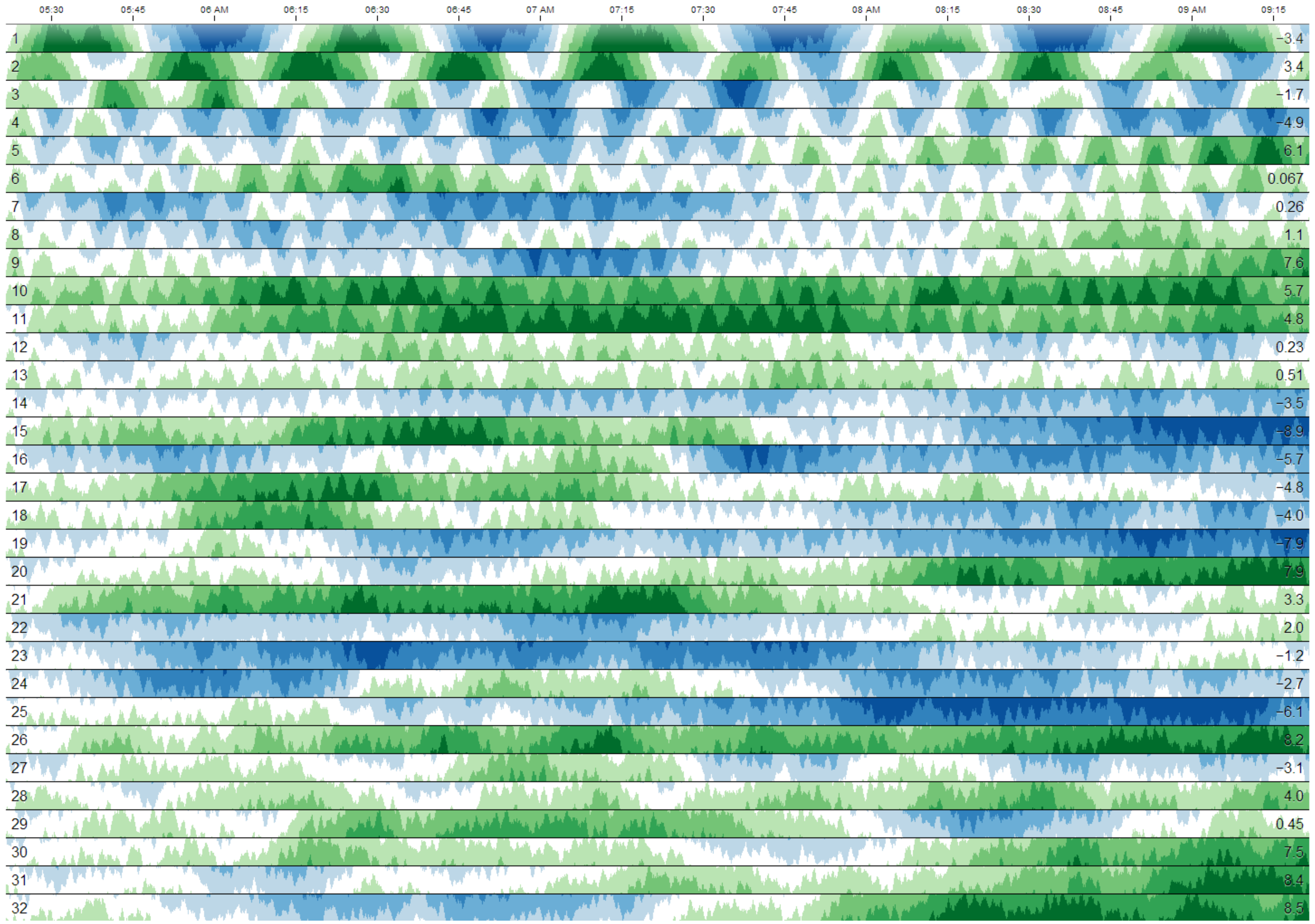
or part of a table



Symbol	Bid	Ask	Last	Change	T	Chart	Volume	High	Low	Value Change		Value	Gain	
DELL	89 3/4	89 13/1	89 3/4	+ 1 1/4	↑		10,310,100	90 1/8	88 1/2	+1.41%	250	17,950	+273.72	13,147
CPQ	48 7/16	48 9/16	48 7/16	- 13/16			25,628,700	51 1/4	1/4	-1.65%	-81	4,844	+60.79%	1,831
SDTI	26 1/4	26 3/8	26 3/8	+ 1/2	↓		504,600	27 3/8	25 5/8	+1.93%	250	13,188	+133.15	7,531
COMS	46 1/2	46 9/16	46 9/16	- 25/32	↓		3,191,100	47 15/1	45 3/4	-1.65%	-102	6,053	+29.79%	1,389
LU	111 5/8	111 11/1	111 9/16	+ 1 9/16			5,104,600	112 5/8	110	+1.42%	78	5,578	+22.76%	1,034
YHOO	368 1/16	368 1/2	368 1/2	+ 17 1/4	↓		3,787,800	381 3/16	280	+4.91%	431	9,213	-0.41%	-38
AOL	162 13/16	163	163	+ 8			10,008,500	164	158 1/2	+5.16%	280	5,705	+73.06%	2,408
CMGI	97 3/8	97 1/2	97 1/2	+ 5 7/8	↓		1,323,800	98 1/2	93	+6.41%	705	11,700	+186.76	7,620
SPLN	33 13/16	33 15/1	33 13/16	+ 7/16	↓		300,200	34 3/4	33 5/8	+1.31%	88	6,763	+94.60%	3,288
BEAS	13 1/2	13 5/8	13 5/8	- 7/16	↓		389,200	14 1/4	13 1/8	-3.11%	-44	1,363	-9.17%	-138
GNET	102	103 3/16	101 5/16	+ 6 1/8	↑		307,600	108	97	+6.43%	613	10,131	+130.26	5,731
RNWK	67	67 1/4	67	+ 2 3/4	↓		1,233,900	69	64 15/1	+4.28%	275	6,700	+79.87%	2,975
MSFT	173 1/8	173 1/4	173 5/16	+ 1 3/4	↓		13,284,500	174 7/16	170	+1.02%	175	17,331	+54.74%	6,131
INTC	133 3/4	133 13/1	133 13/16	- 3 1/8	↓		8,094,300	137 1/2	133 3/8	-2.28%	-625	26,763	+65.20%	10,563
TOTAL					↑			205,302	80,993	+1.63%	2,293	143,280	+79.41%	63,377

Horizon Graphs

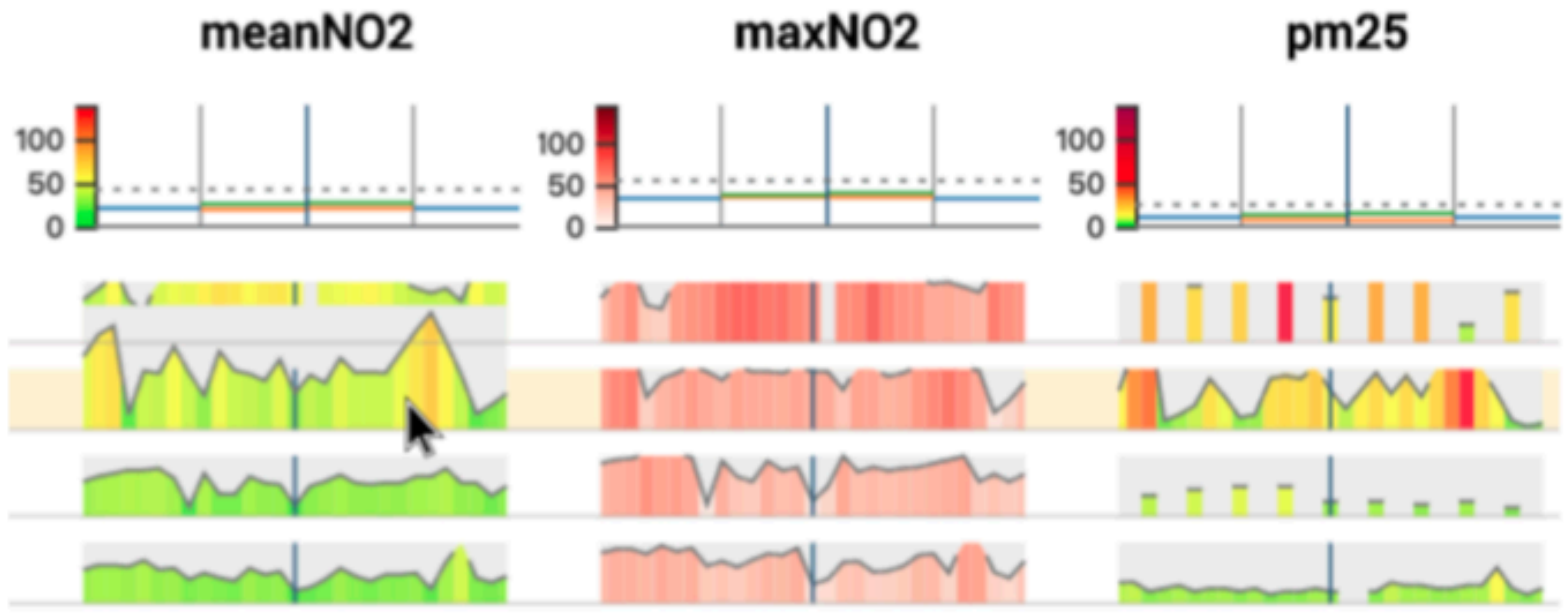




[Heer, Sizing the Horizon, 2009]

http://square.github.io/cubism/

Clipped Graphs

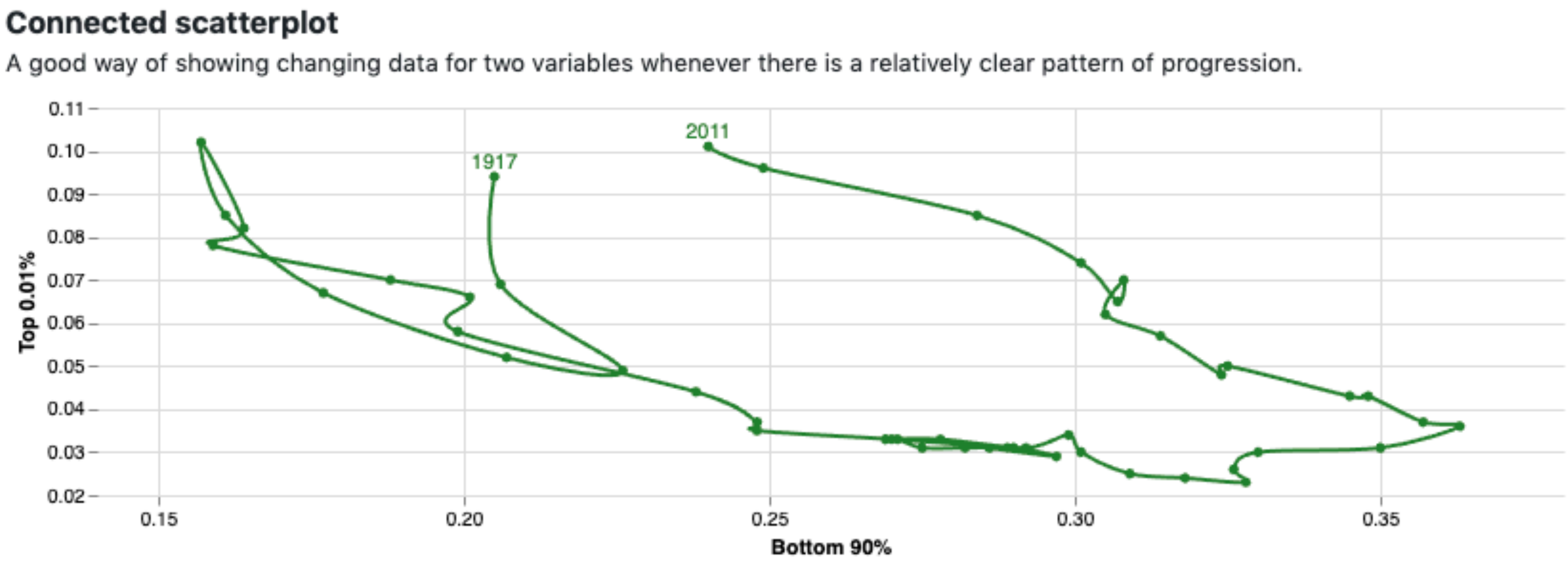


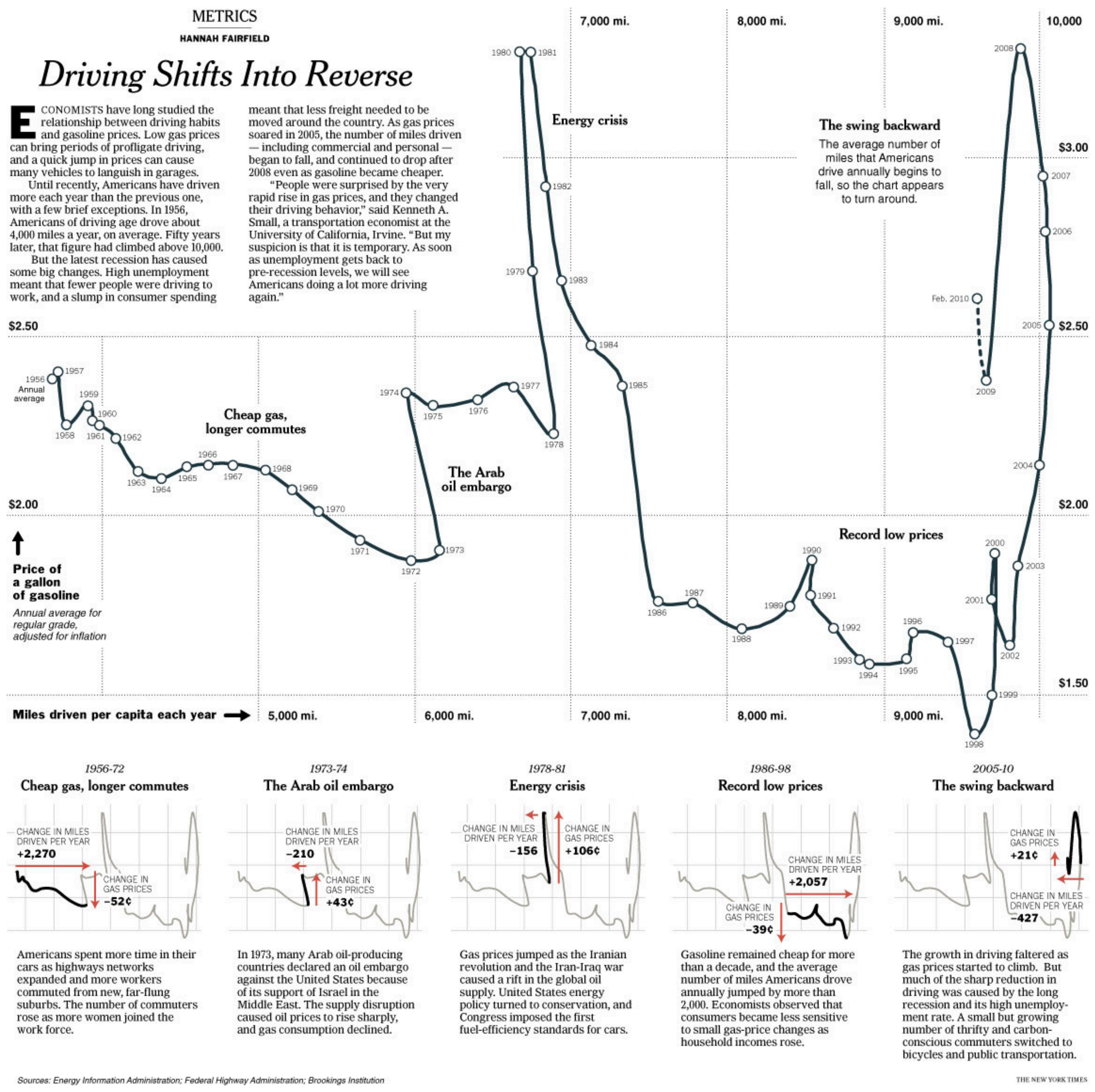
Connected Scatterplot

Two Variables + Time

Only one per Chart!

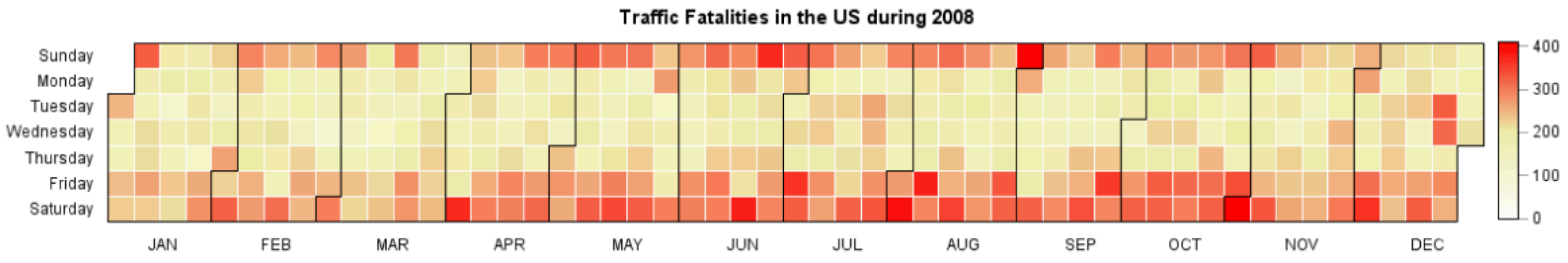
Labels important





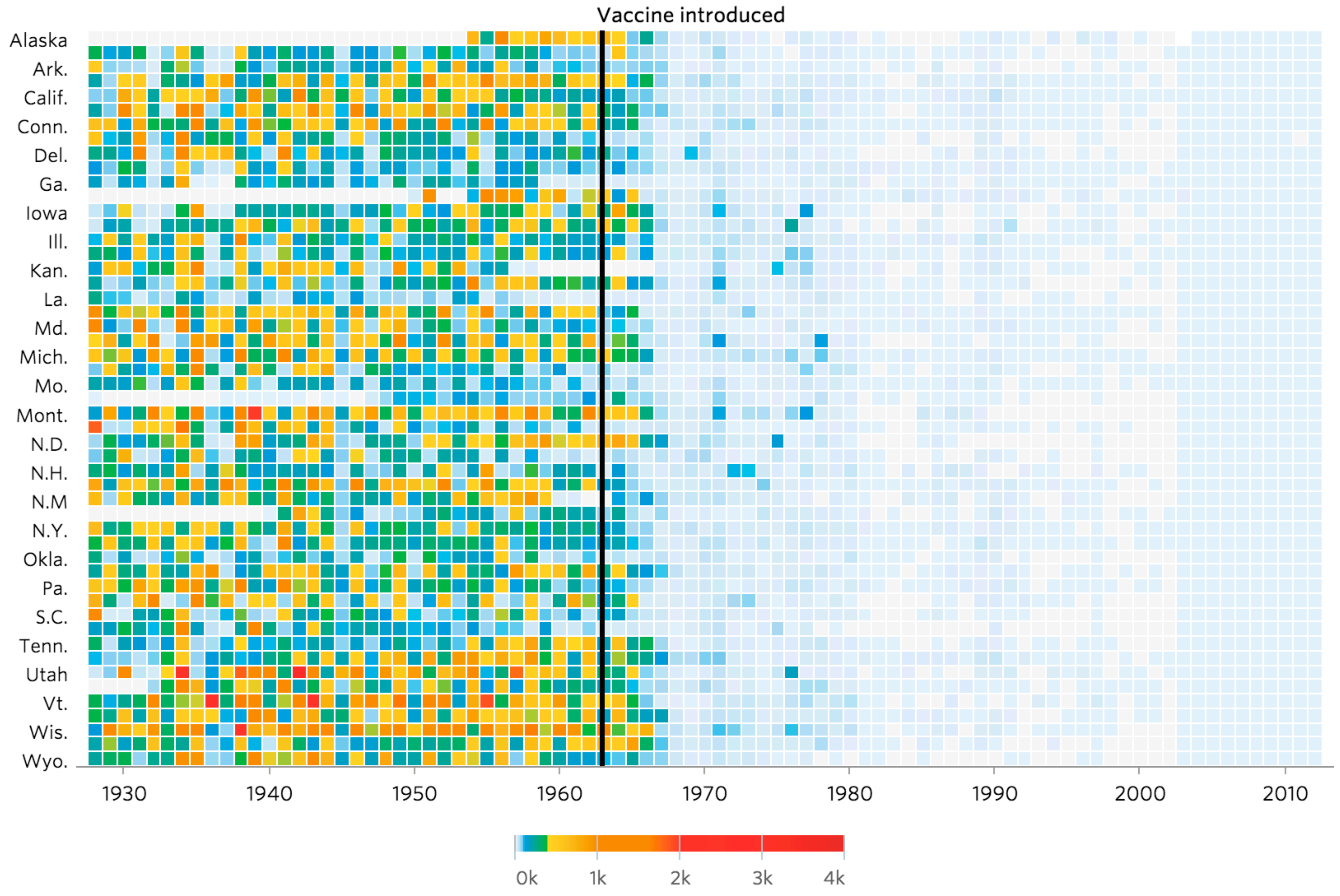
http://www.thefunctionalart.com/2012/09/in-praise-of-connected-scatter-plots.html

Heat Map and Calendar Heat Map



The heat maps below show number of cases per 100,000 people.

Measles

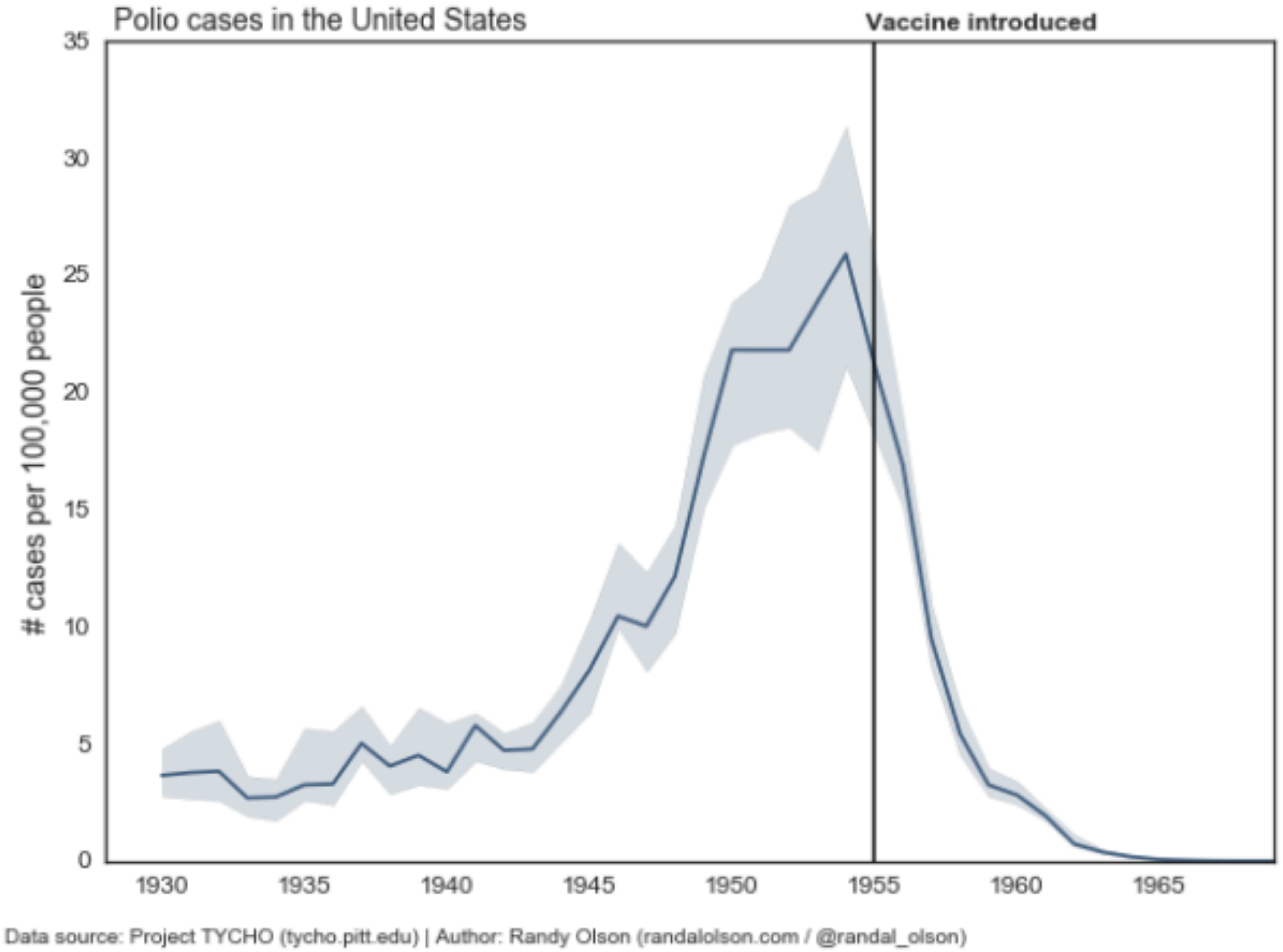


Note: CDC data from 2003-2012 comes from its Summary of Notifiable Diseases, which publishes yearly rather than weekly and counts confirmed cases as opposed to provisional ones.

https://blogs.sas.com/content/graphicallyspeaking/2011/12/08/calendar-heatmaps-in-gtl/

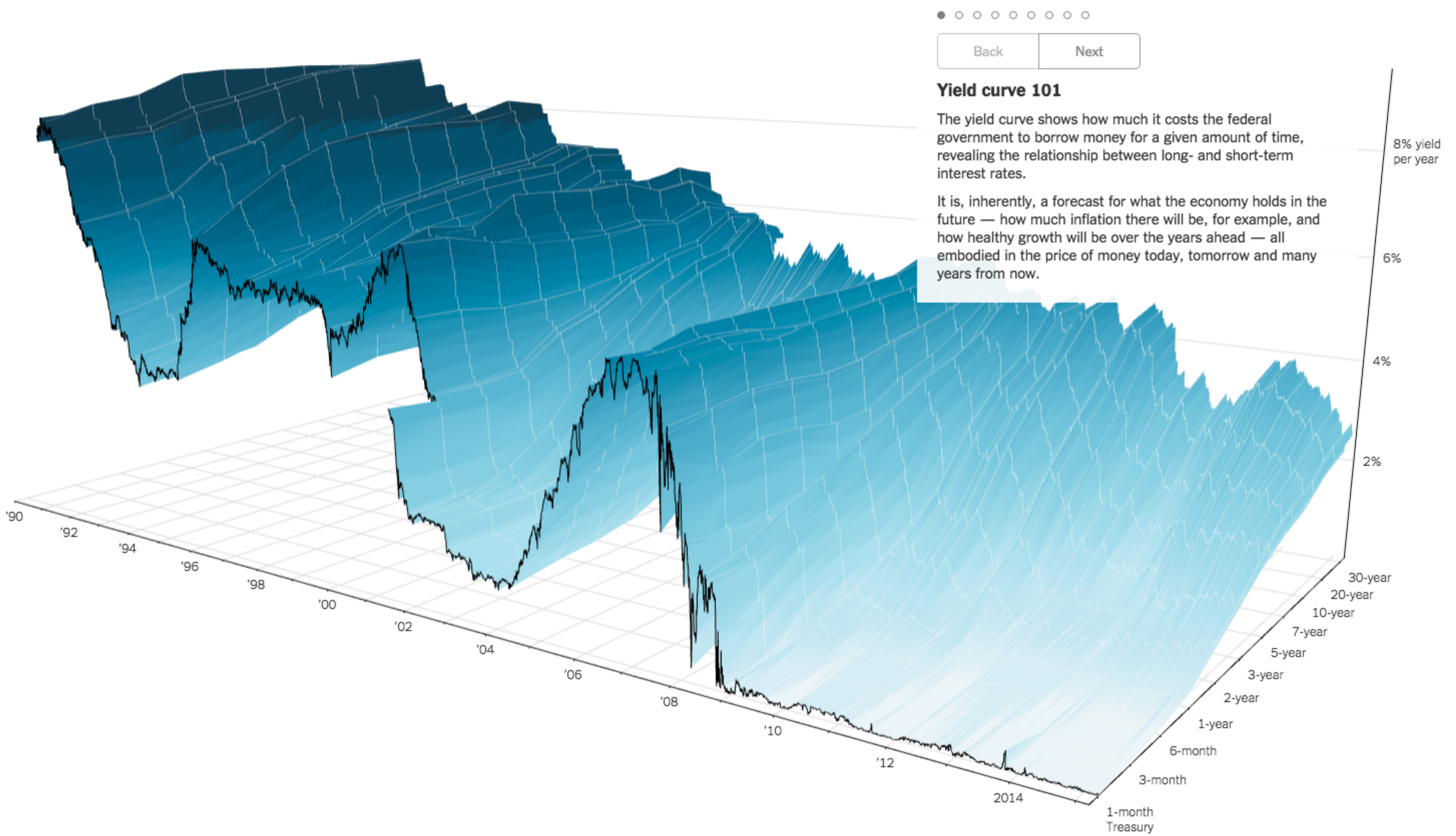
https://www.informationisbeautifulawards.com/showcase/660-vaccines-and-infectious-diseases

Sometimes you can Show Too Much Data



http://www.randalolson.com/2016/03/04/revisiting-the-vaccine-visualizations/

Design Critique



Document: https://goo.gl/W6w0iI
Website: http://goo.gl/D3mIsy

Context / Critiques

https://vimeo.com/127205447

https://community.jmp.com/t5/JMP-Blog/Graph-makeover-3-D-yield-curve-surface/ba-p/30573

http://www.visualisingdata.com/2015/03/when-3d-works/

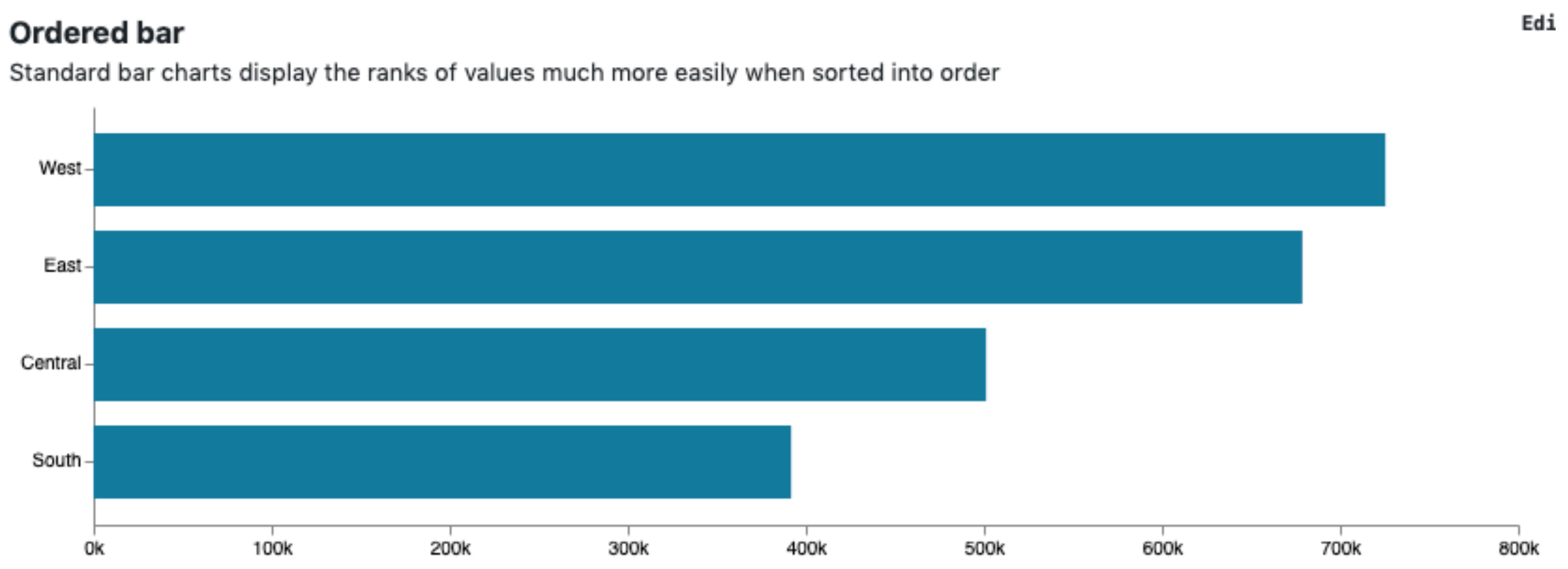
Ranking

Ranking Exercise

	1	2	3	4	5	6	7
Bavaria	8	6	2	4	2	**1**	3
Dortmund	**1**	**1**	5	2	3	8	8
Leipzig	2	2	**1**	**1**	**1**	2	4
Leverkusen	5	5	4	8	7	6	7
Moenchengladbach	10	7	8	7	6	5	**1**
Wolfsburg	6	4	3	5	8	7	2

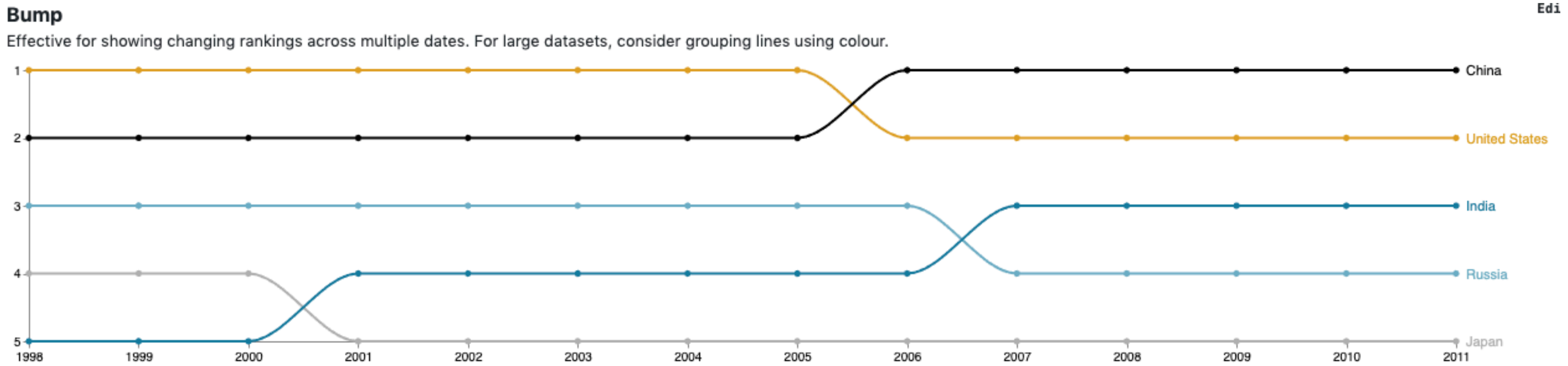
Design a visualization showing the ranking of these football clubs over time.

Ranking



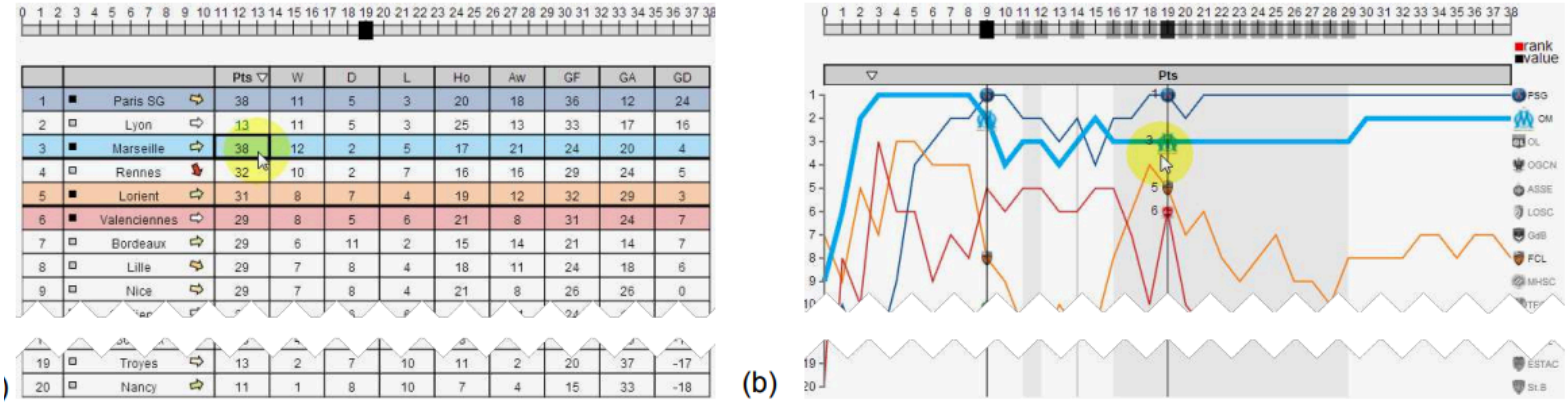
Magnitude Visualization + Sorting

Bump Charts for Rankings over Time



https://gramener.github.io/visual-vocabulary-vega/#/Ranking/

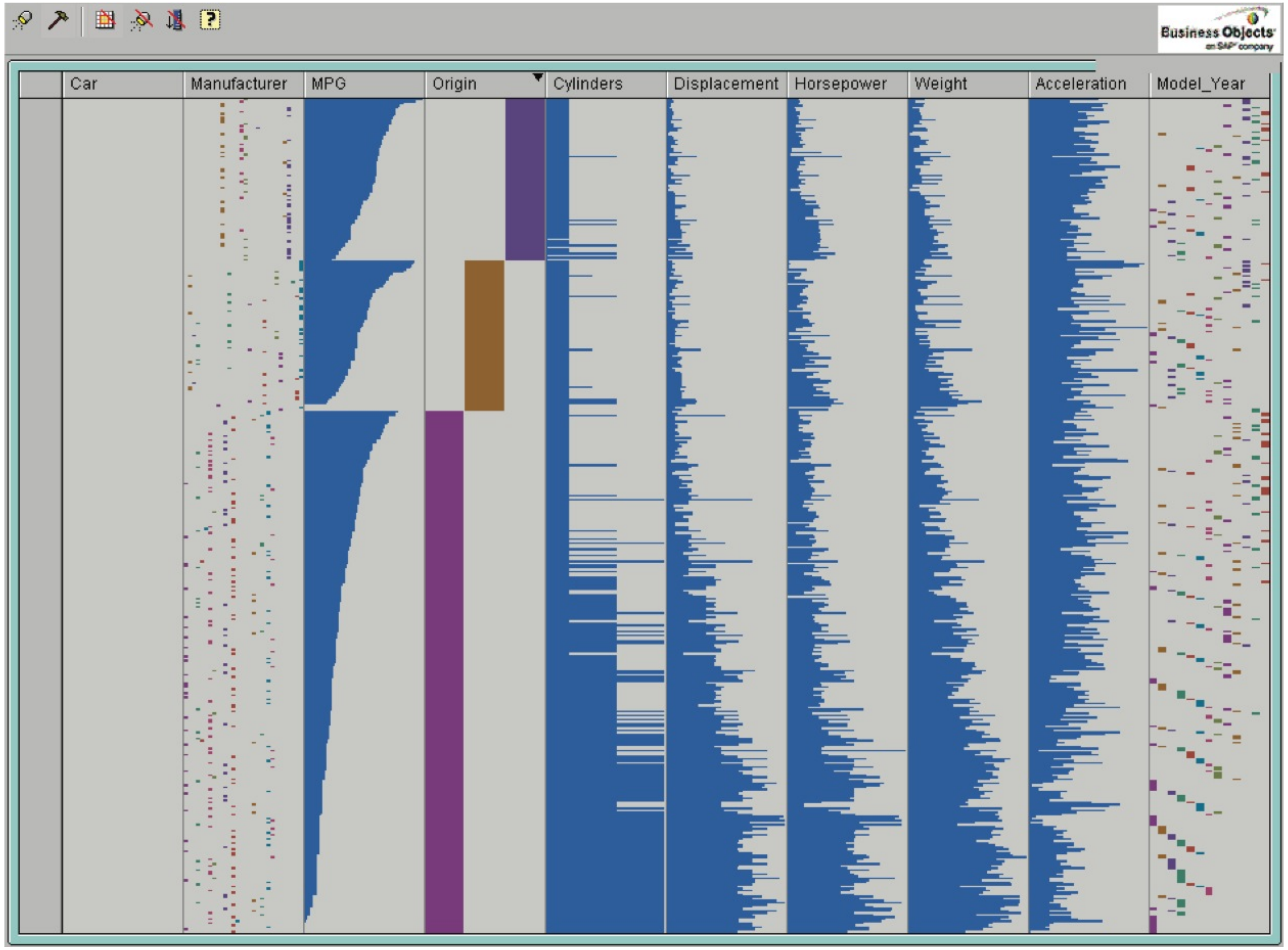
Temporal Rankings



[Perin, Vuillemot, Fekete, CHI 2014]

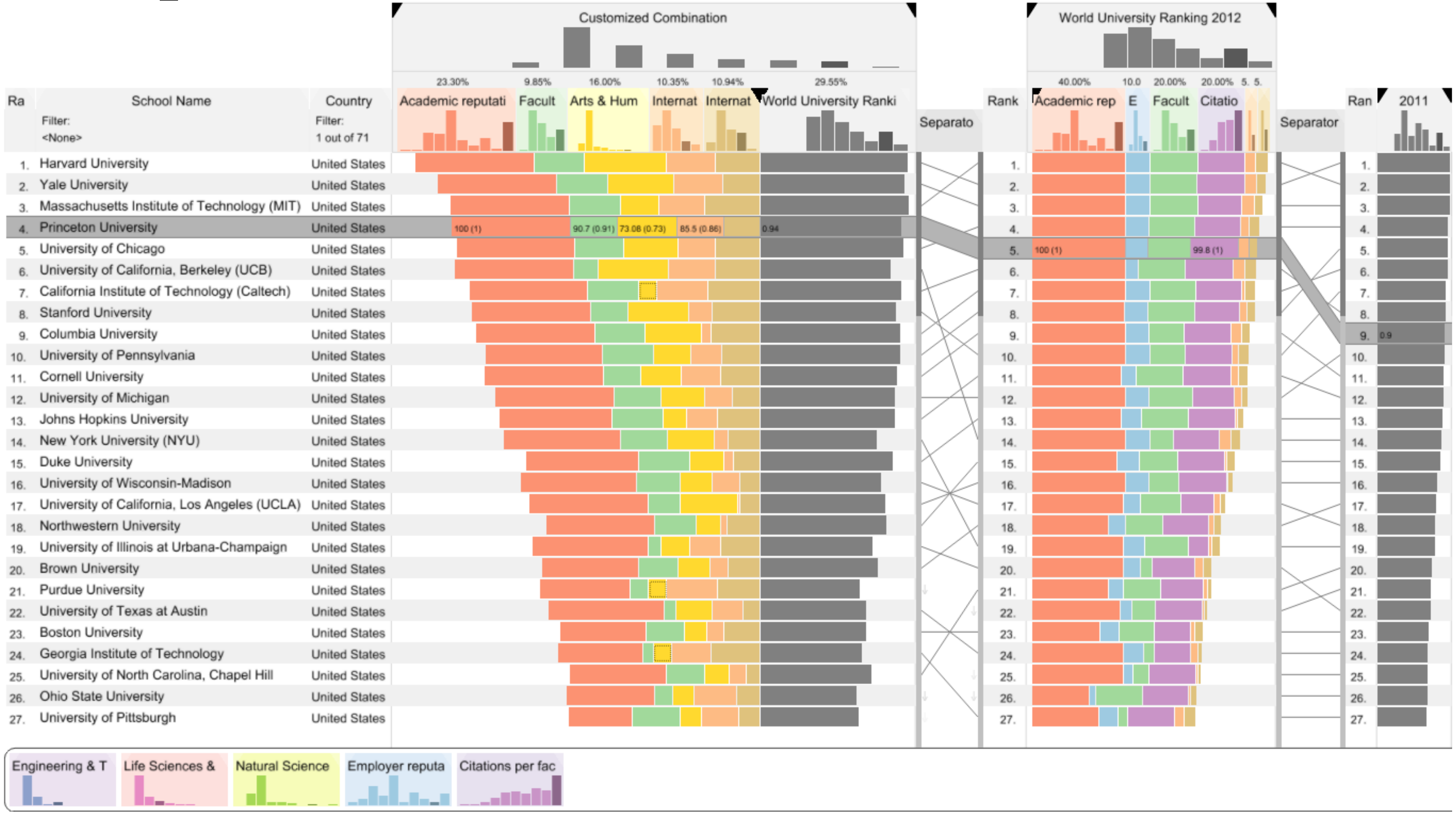
Table Lens

Interactive table-based representation



Rao & Card 1994

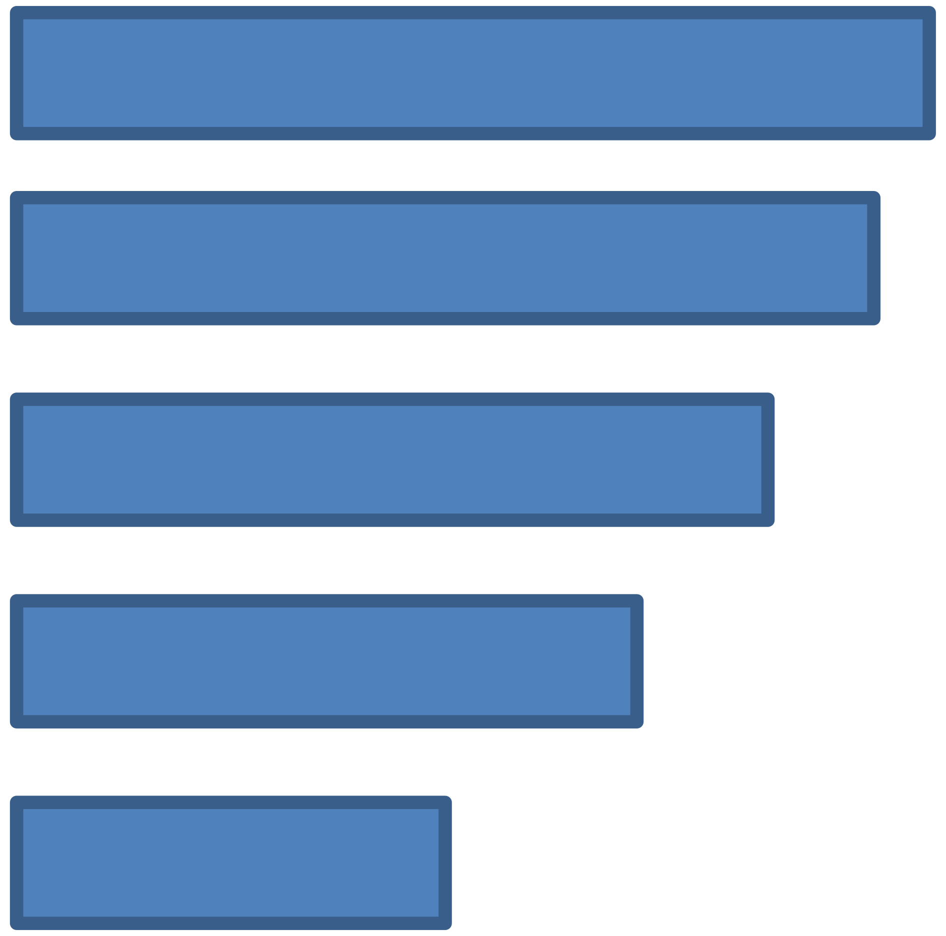
LineUp



Video at http://lineup.caleydo.org

Rankings are Popular

Rank	University	Score
1.	MIT	
2.	Harvard	
3.	Princeton	
4.	Cambridge	
5.	Oxford	



Support Multiple Attributes

Combiner functions: f(A,B,C)

(Weighted) sum

$Score = w_a A + w_b B + w_c C$

Maximum

$Score = max(A, B, C)$

Product

Nesting

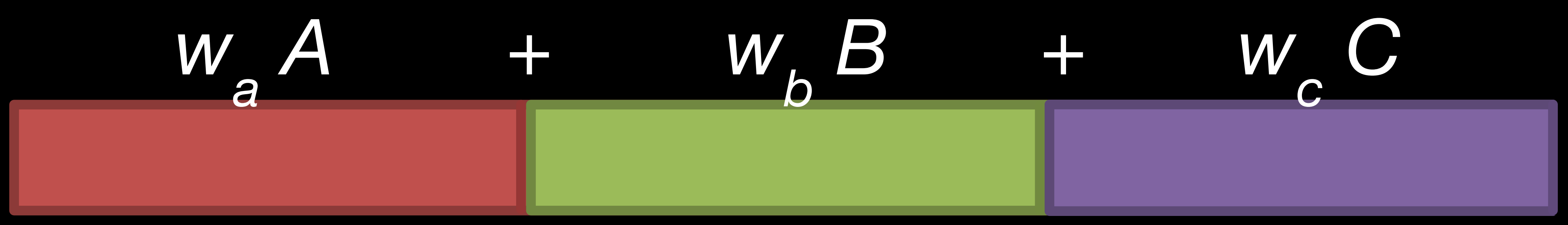
…

→Serial

→Parallel

→Complex Combiners

Serial Combiner (as Stacked Bar)

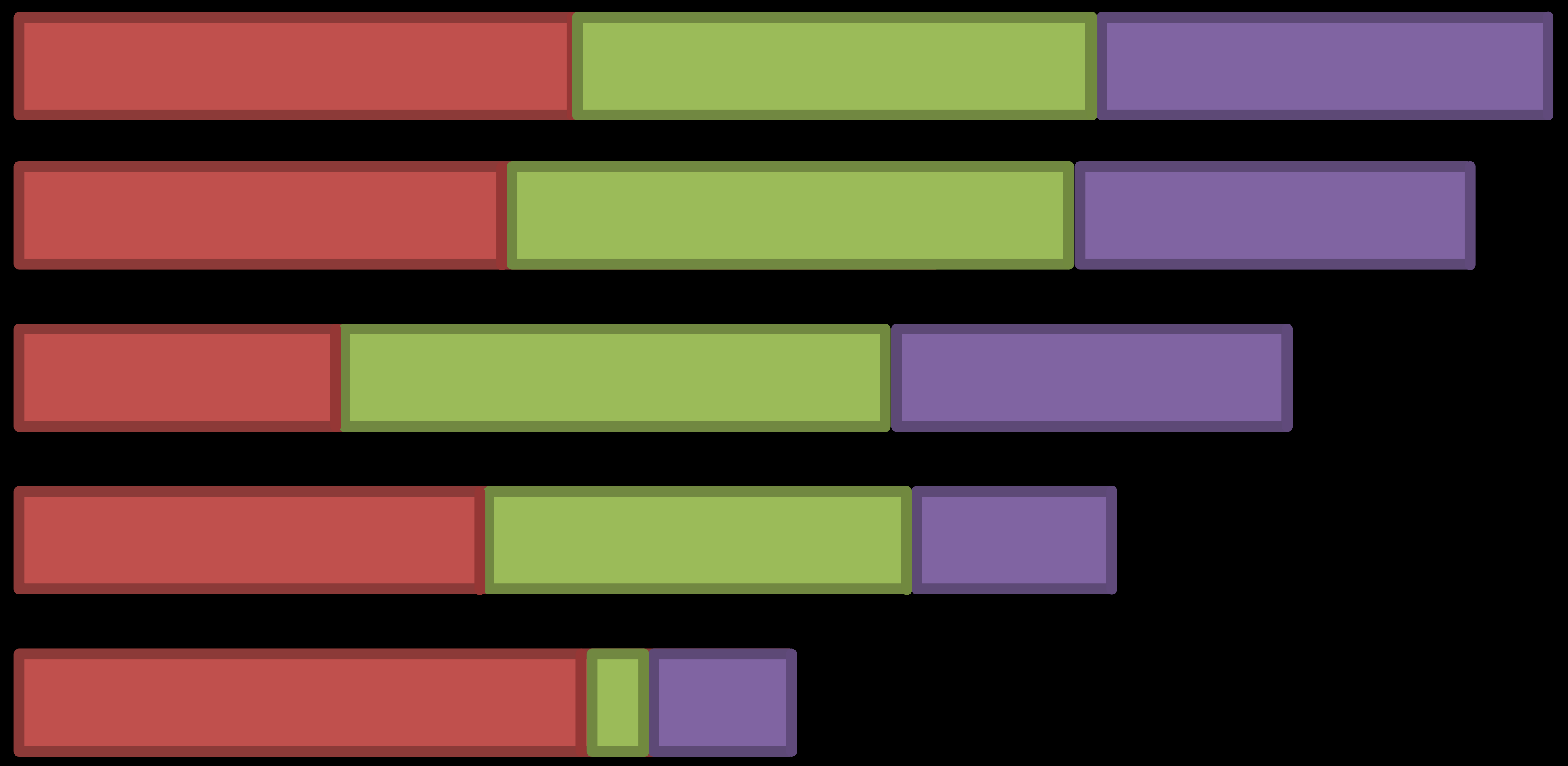


Rank	University	A	B	C
1.	MIT			
2.	Harvard			
3.	Princeton			
4.	Cambridge			
5.	Oxford			

Serial Combiner (as Stacked Bar)

$$w_a A \quad + \quad w_b B \quad + \quad w_c C$$

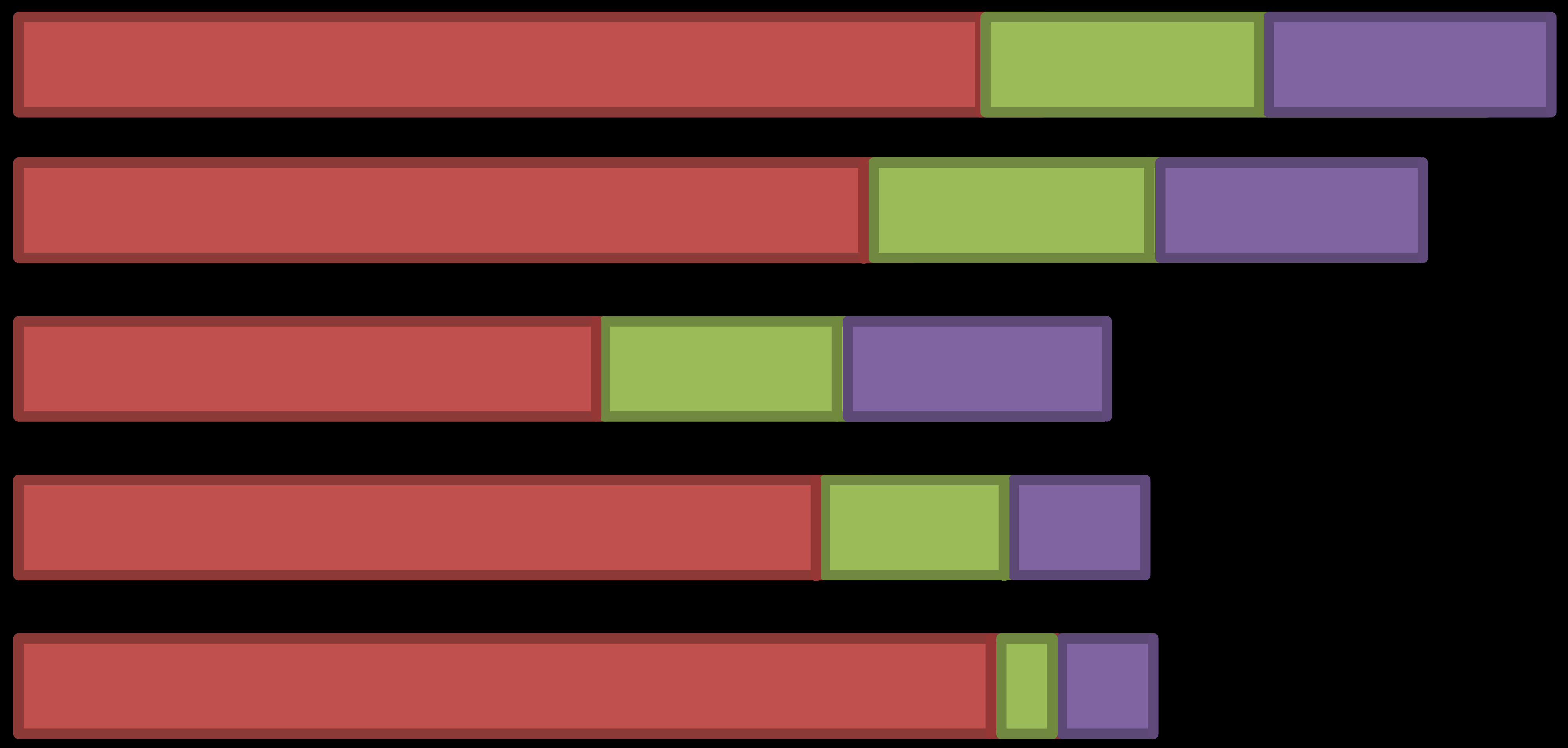
Rank	University	A	B	C
1.	MIT			
2.	Harvard			
3.	Princeton			
4.	Cambridge			
5.	Oxford			



Serial Combiner (as Stacked Bar)

$w_a A + w_b B + w_c C$

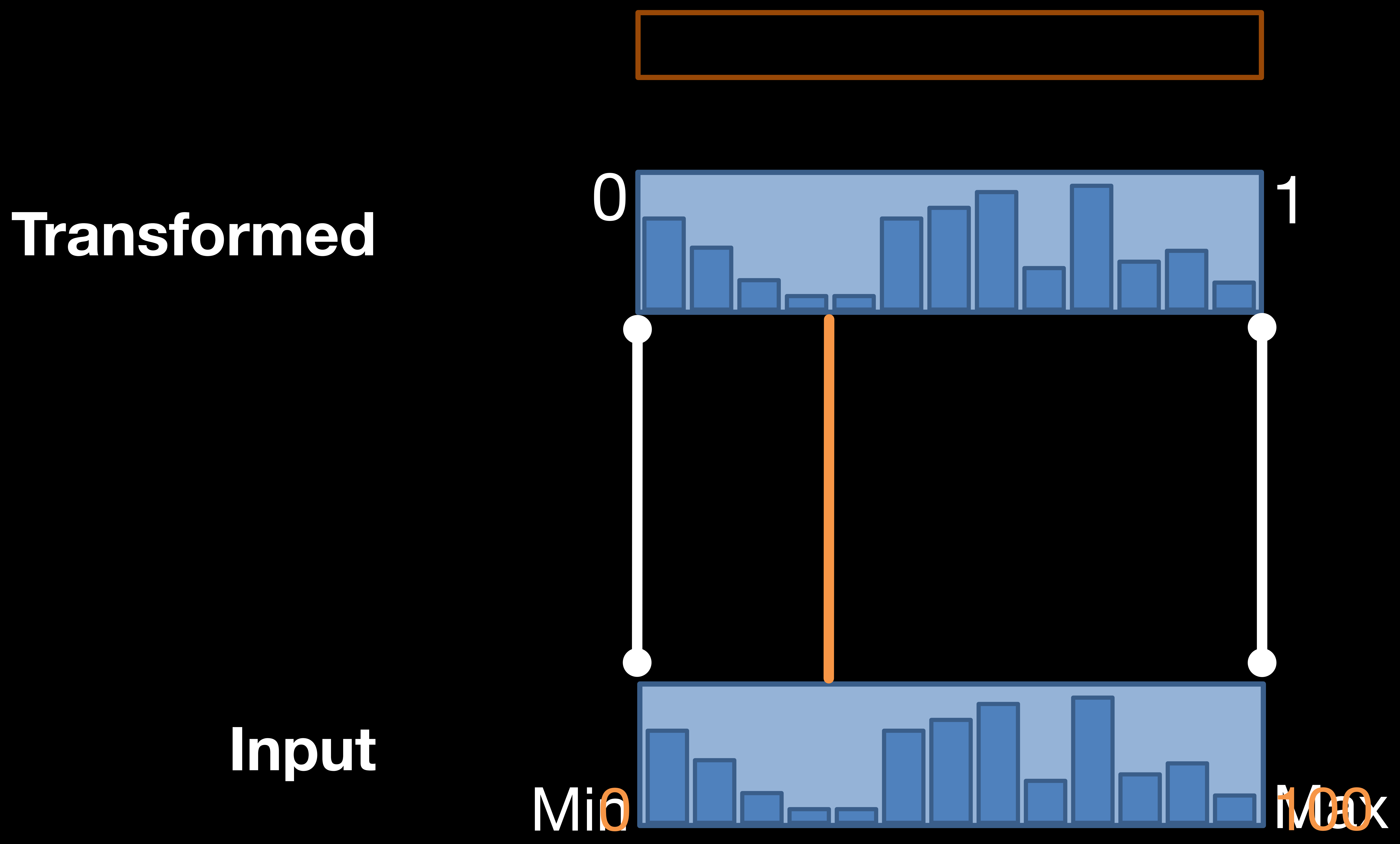
Rank	University	A	B	C
1.	MIT			
2.	Harvard			
3.	Princeton			
4.	Cambridge			
5.	Oxford			

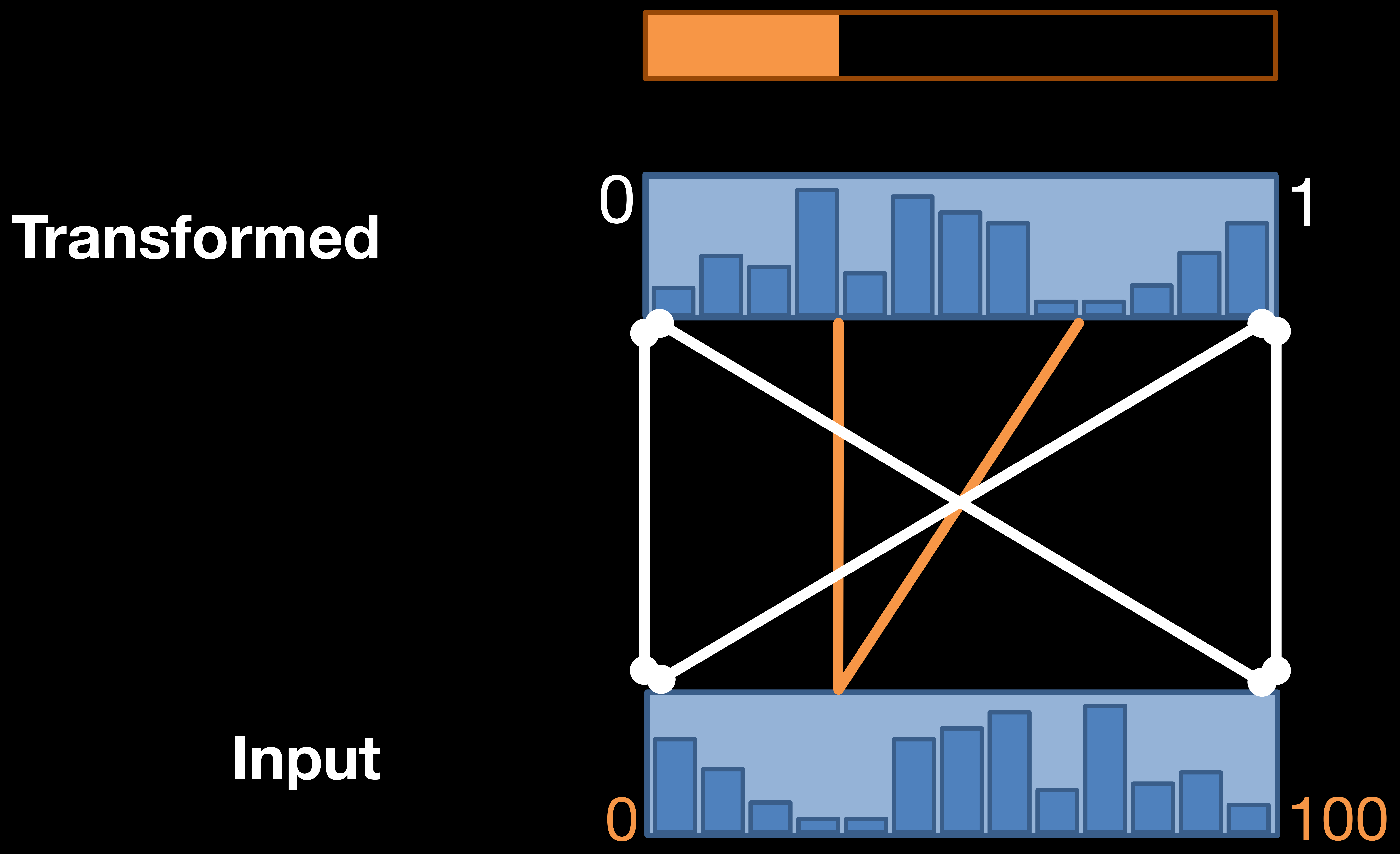


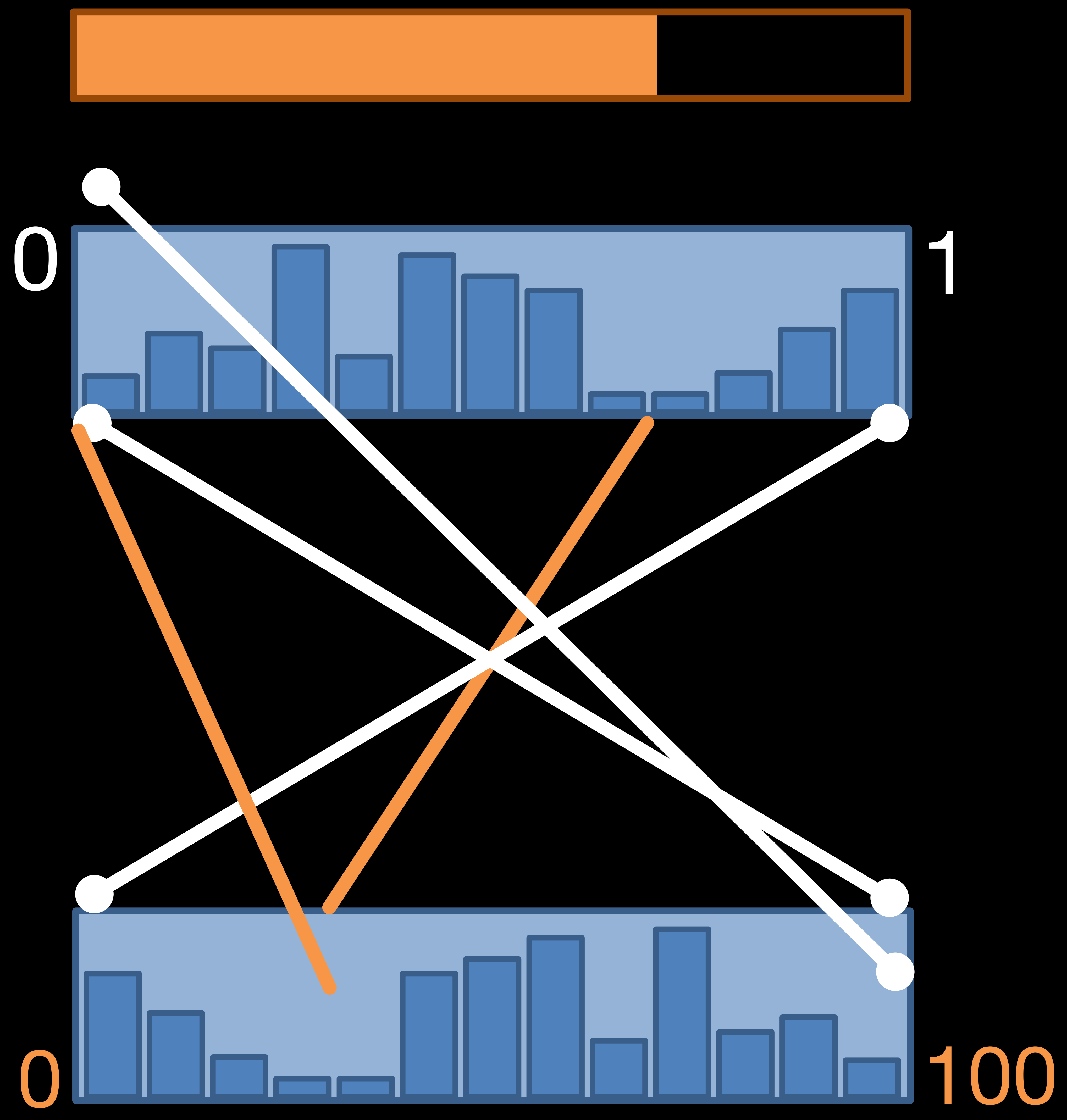
128 visible of 906 (14.13%)

Ran	School Name	Country	Faculty/student ratio	Employer reputation	Citations per faculty
	Filter: <None>	Filter: 2 out of 72			
1.	American University	United States			
2.	Arizona State University	United States			
3.	Aston University	United Kingdom			
4.	Birkbeck College, University of L	United Kingdom			
5.	Boston College	United States			
6.	Boston University	United States			
7.	Brandeis University	United States			
8.	Brown University	United States			
9.	Brunel University	United Kingdom			
10.	California Institute of Technology	United States			
11.	Cardiff University	United Kingdom			
12.	Case Western Reserve University	United States			
13.	City University London	United Kingdom			
14.	College of William & Mary	United States			
15.	Colorado State University	United States			
16.	Columbia University	United States			
17.	Cornell University	United States			
18.	Cranfield University	United Kingdom			
19.	Dartmouth College	United States			
20.	Drexel University	United States			
21.	Duke University	United States			
22.	Durham University	United Kingdom			

Flexible Mapping of Attributes to Scores


Transformed
0
1
Input
Min
0
Max
100

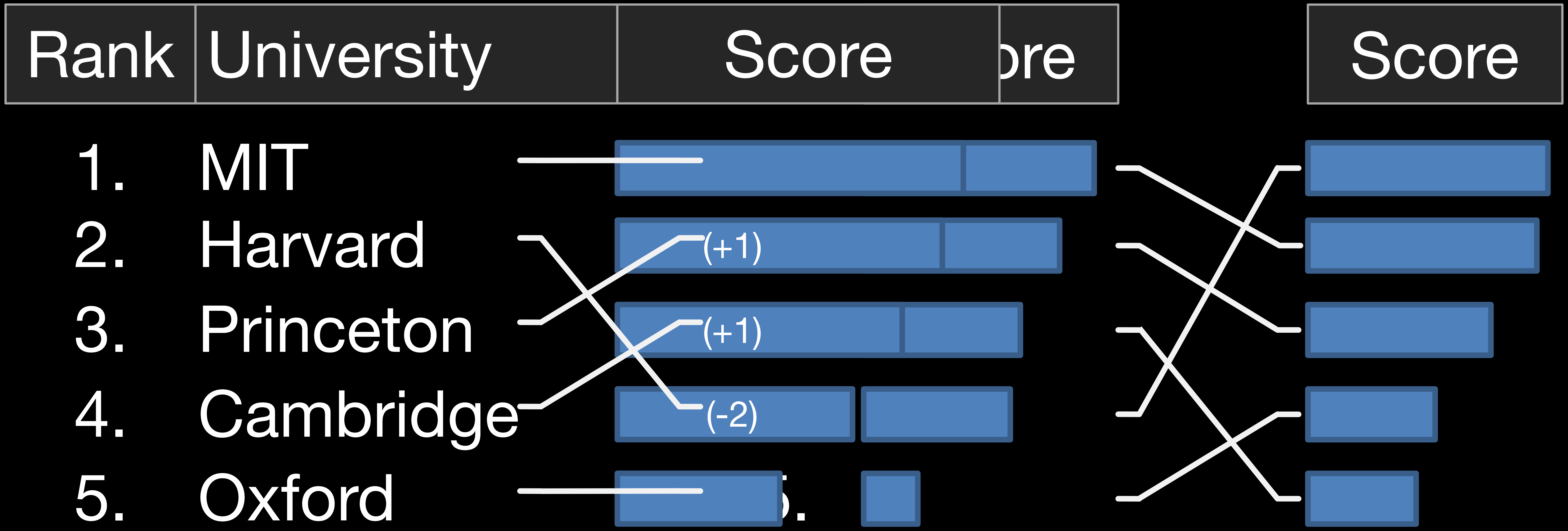

Transformed
0
1
Input
0
100


0
1
0
100

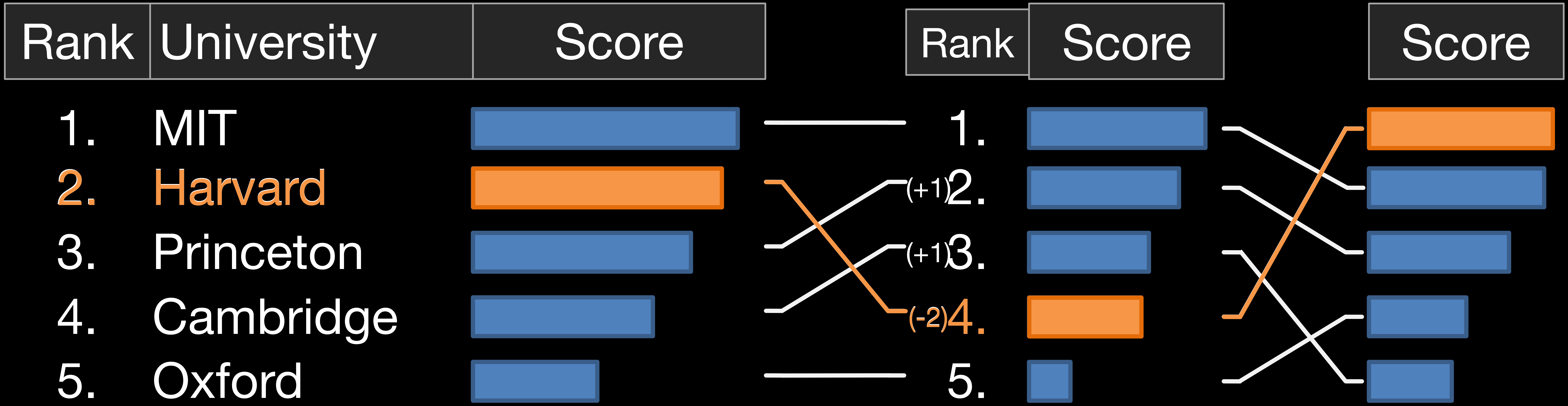

93 visible of 399 (23.31%)
SUM (Engineering & Technology, Arts & Humanities, Life Sciences & Medicine)
33.33%
33.33%
33.33%
Ran
School Name
Country
Engineering & Technology
Arts & Humanities
Life Sciences & Medicine
Filter: <None>
Filter: 2 out of 43
1. University of Oxford United Kingdom
2. University of Cambridge United Kingdom
3. Harvard University United States
4. Stanford University United States
5. Massachusetts Institute of Technology (MIT United States
6. University of California, Berkeley (UCB) United States
7. University of California, Los Angeles (UCL United States
8. Yale University United States
9. UCL (University College London) United Kingdom
10. Columbia University United States
11. Princeton University United States
12. University of Edinburgh United Kingdom
13. University of Michigan United States
14. Cornell University United States
15. University of Pennsylvania United States
16. The University of Manchester United Kingdom
17. Imperial College London United Kingdom
18. University of Chicago United States

Compare Rankings

Bump Charts


Rank
University
Score
Score
1. MIT
2. Harvard
3. Princeton
4. Cambridge
5. Oxford
(+1)
(+1)
(-2)

Bump Charts



Rank
University
Score
1. MIT
2. Harvard
3. Princeton
4. Cambridge
5. Oxford
Rank
Score
1.
(+1)2.
(+1)3.
(-2)4.
5.
Score

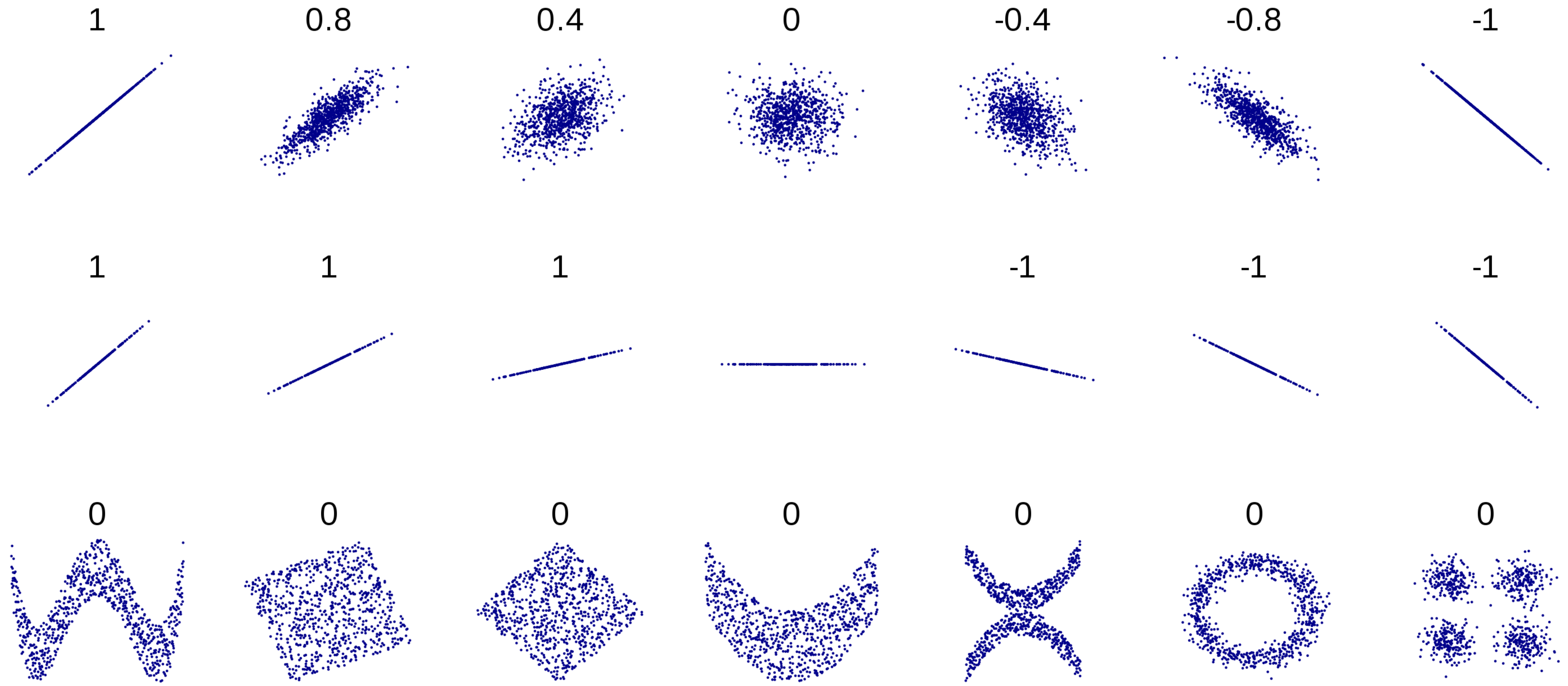

453 visible of 453 (100.00%)
World University Ranking
46.55%
32.72%
20.72%
Rank
School Name
Filter:
<None>
MAX (Academic re
Faculty/stud
Citatio
1. Massachusetts Institute of Te
2. California Institute of Technol
3. Harvard University
4. University of Cambridge
5. UCL (University College Lond
6. University of Oxford
7. Princeton University
8. Imperial College London
9. University of Chicago
10. Stanford University
11. Columbia University
12. Duke University
13. University of Pennsylvania
14. Johns Hopkins University
15. Yale University
16. University of Michigan
17. Ecole normale supérieure, Pa
18. Northwestern University

https://lineup.js.org/

Correlation

What is Correlation

How do two or more variables behave relative to each other?



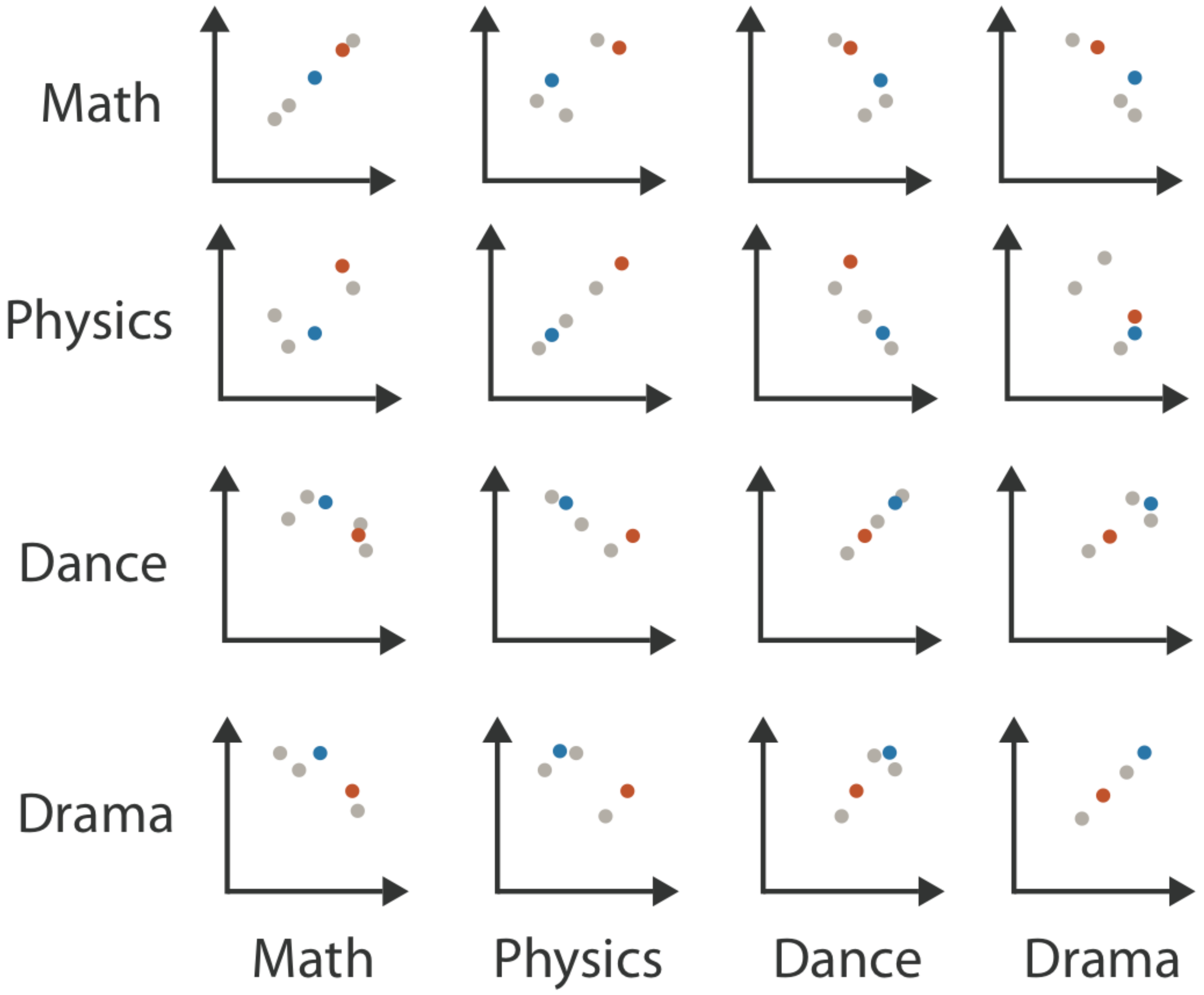
By DenisBoigelot, CC0, https://commons.wikimedia.org/w/index.php?curid=15165296

Axis-Based Techniques

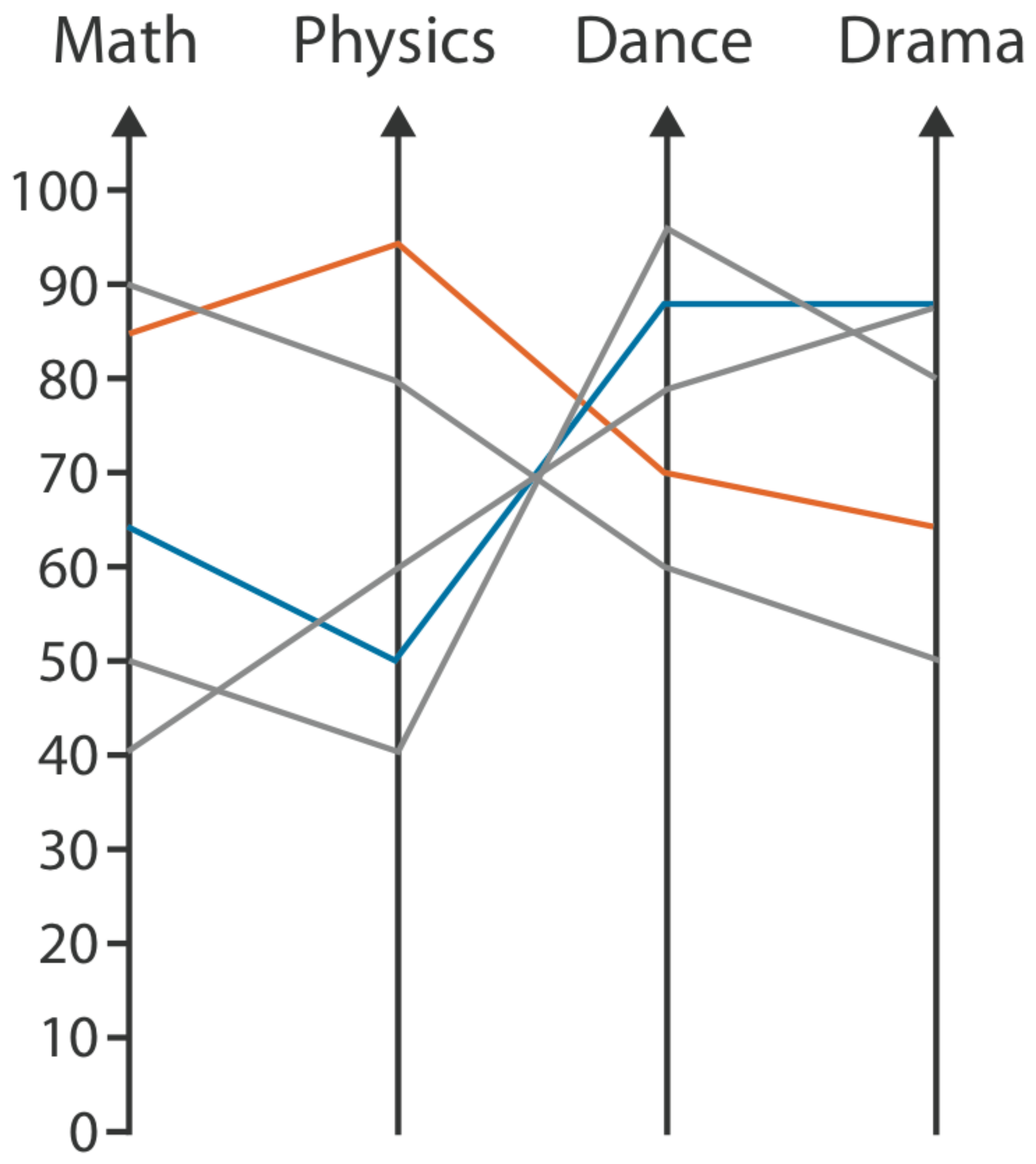
Table

Math	Physics	Dance	Drama
85	95	70	65
90	80	60	50
65	50	90	90
50	40	95	80
40	60	80	90

Scatterplot Matrix



Parallel Coordinates



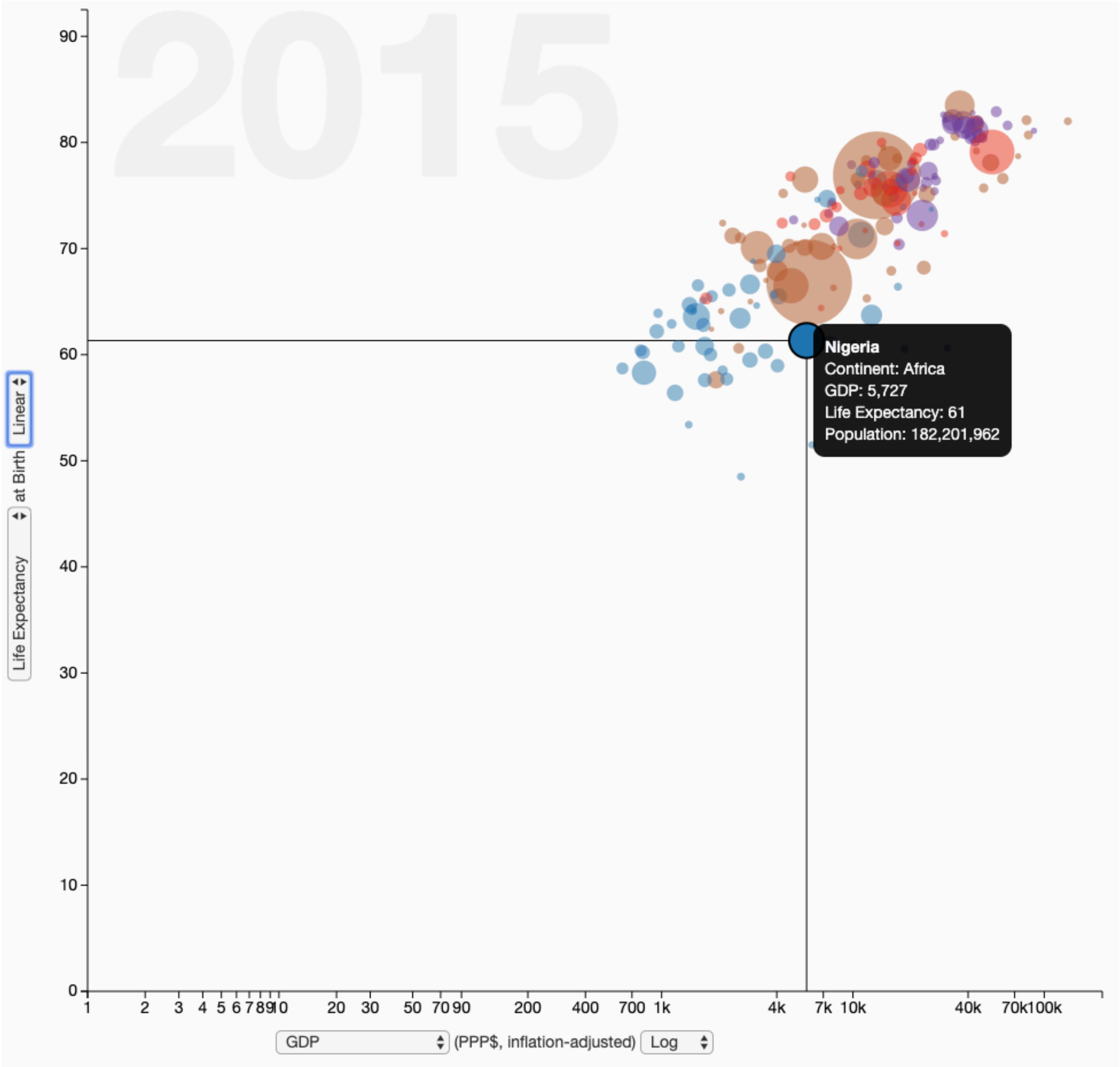
Scatterplots

Scatterplots

Two orthogonal axis visualizing one dimension each.

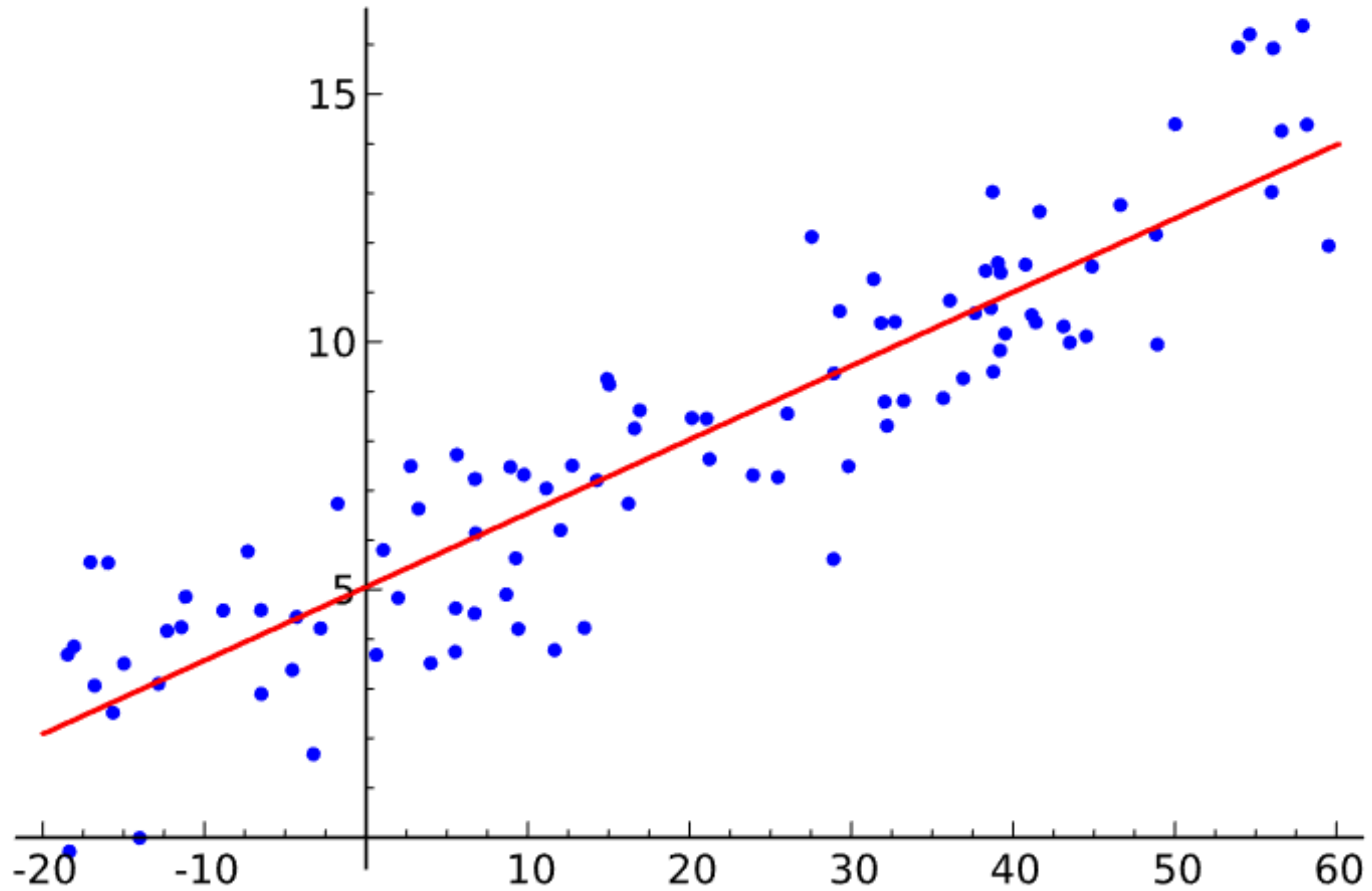
How to encode the mark?

How to deal with many points?



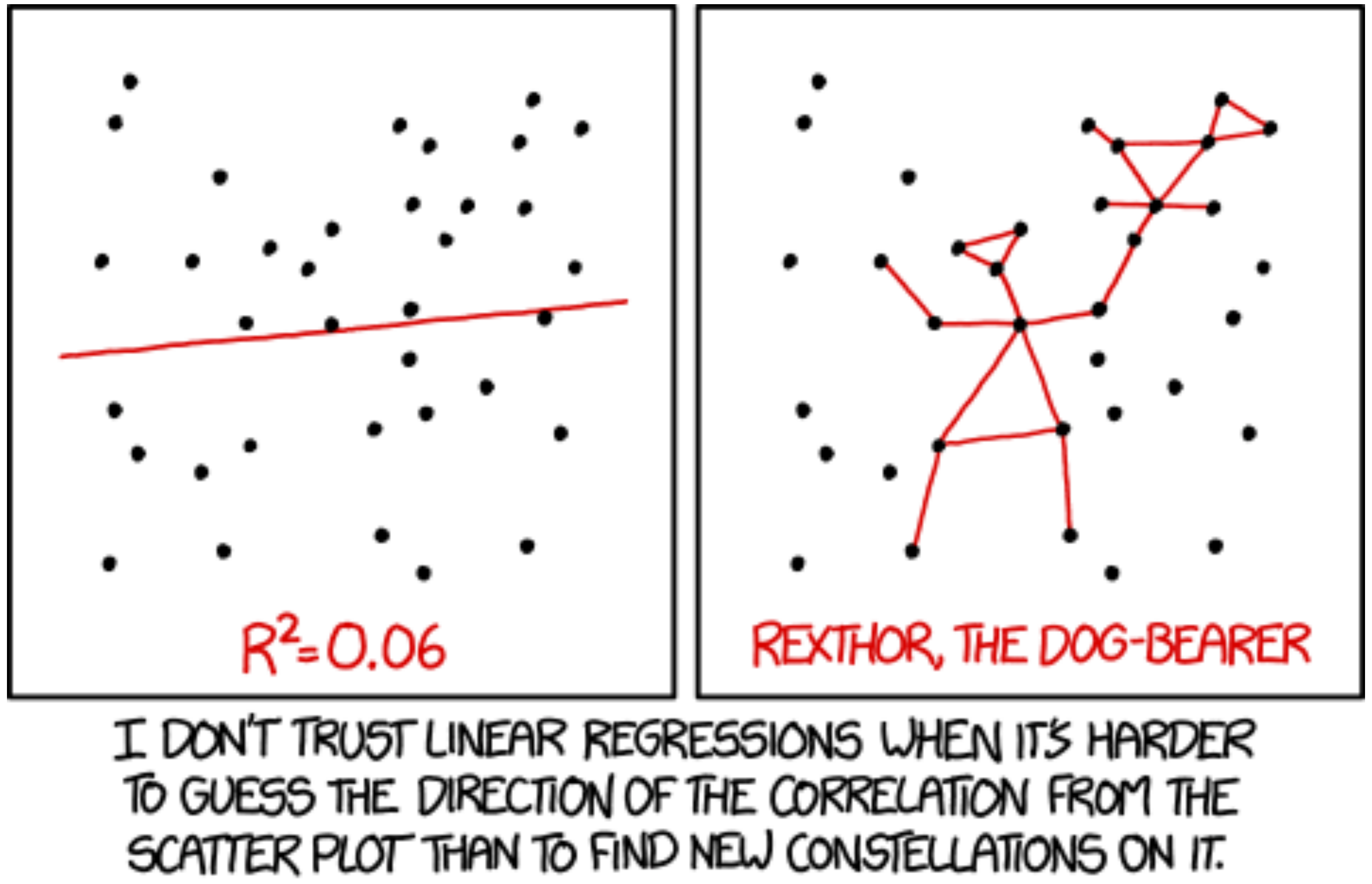
Regression Lines

$$y \sim \beta_0 + \beta_1 x$$

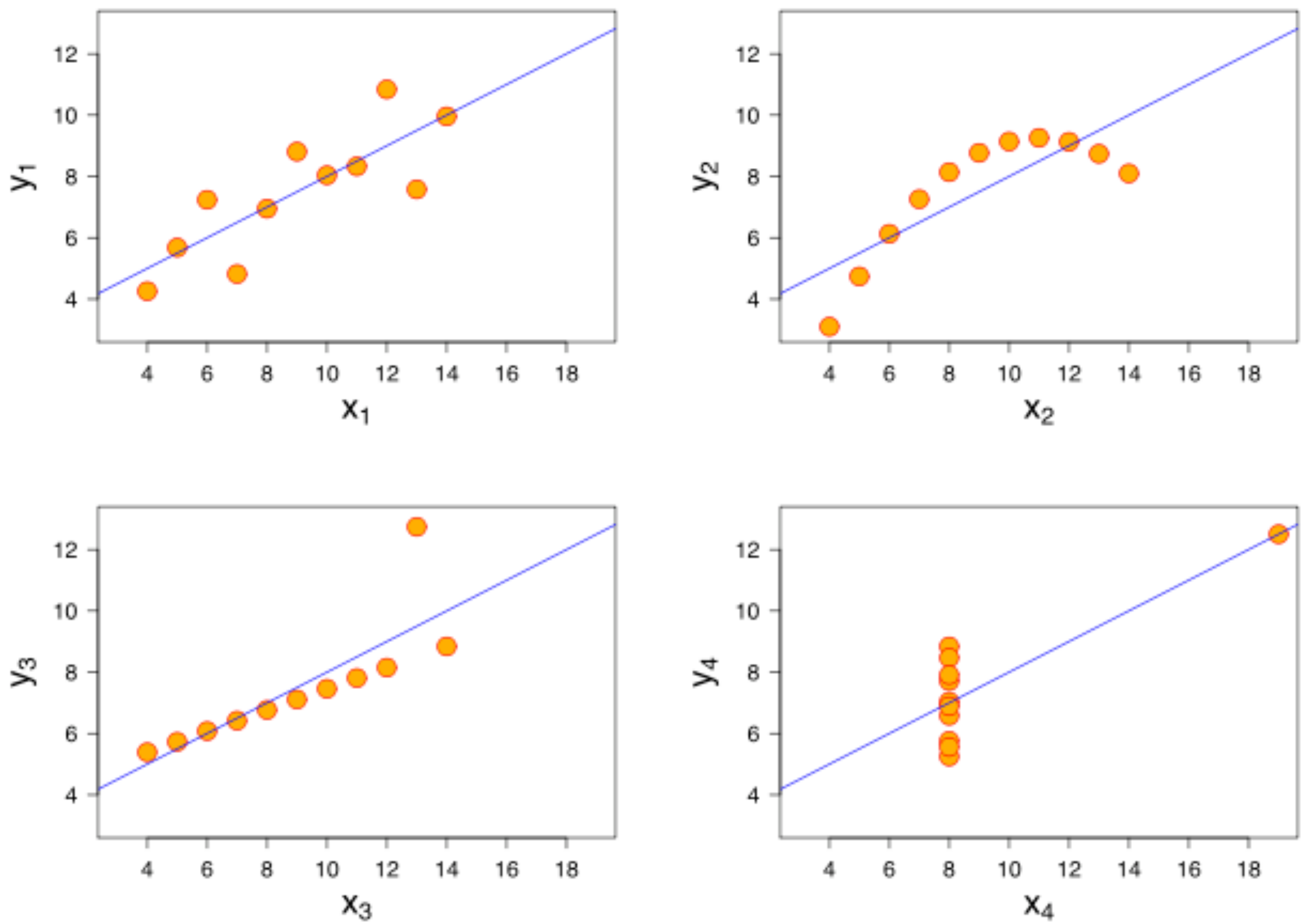


Goal: Find the best values of β_0 and β_1, denoted $\hat{\beta}_0$ and $\hat{\beta}_1$, so that the prediction $y = \hat{\beta}_0 + \hat{\beta}_1 x$ "best fits" the data.

Approach: use least squares to minimize the sum of the squares of the errors



Anscombe's Quartet

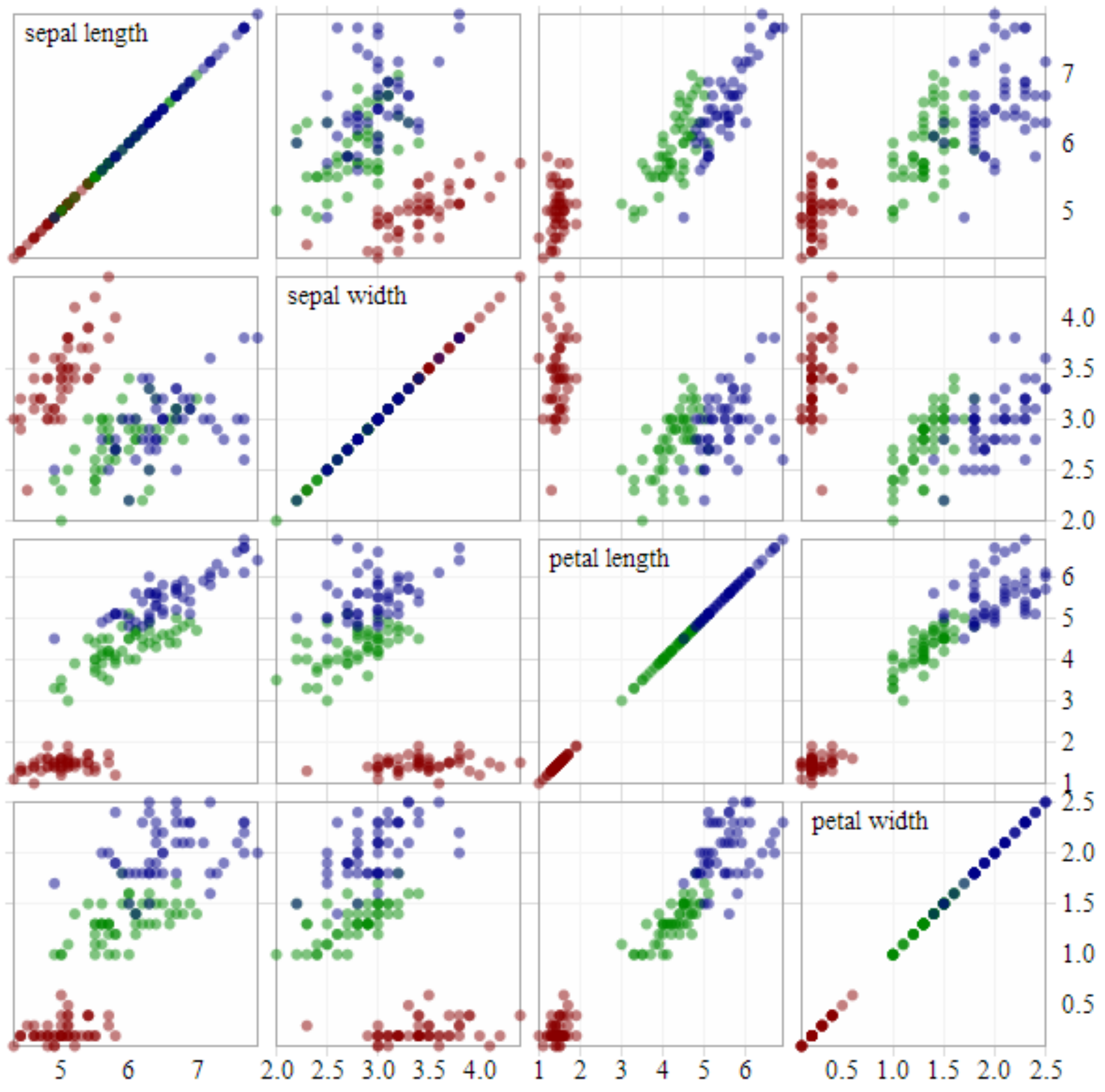


Scatterplot Matrices (SPLOM)

Matrix of size d*d

Each row/column is one dimension

Each cell plots a scatterplot of two dimensions



Scatterplot Matrices

Limited scalability (~20 dimensions, ~500-1k records)

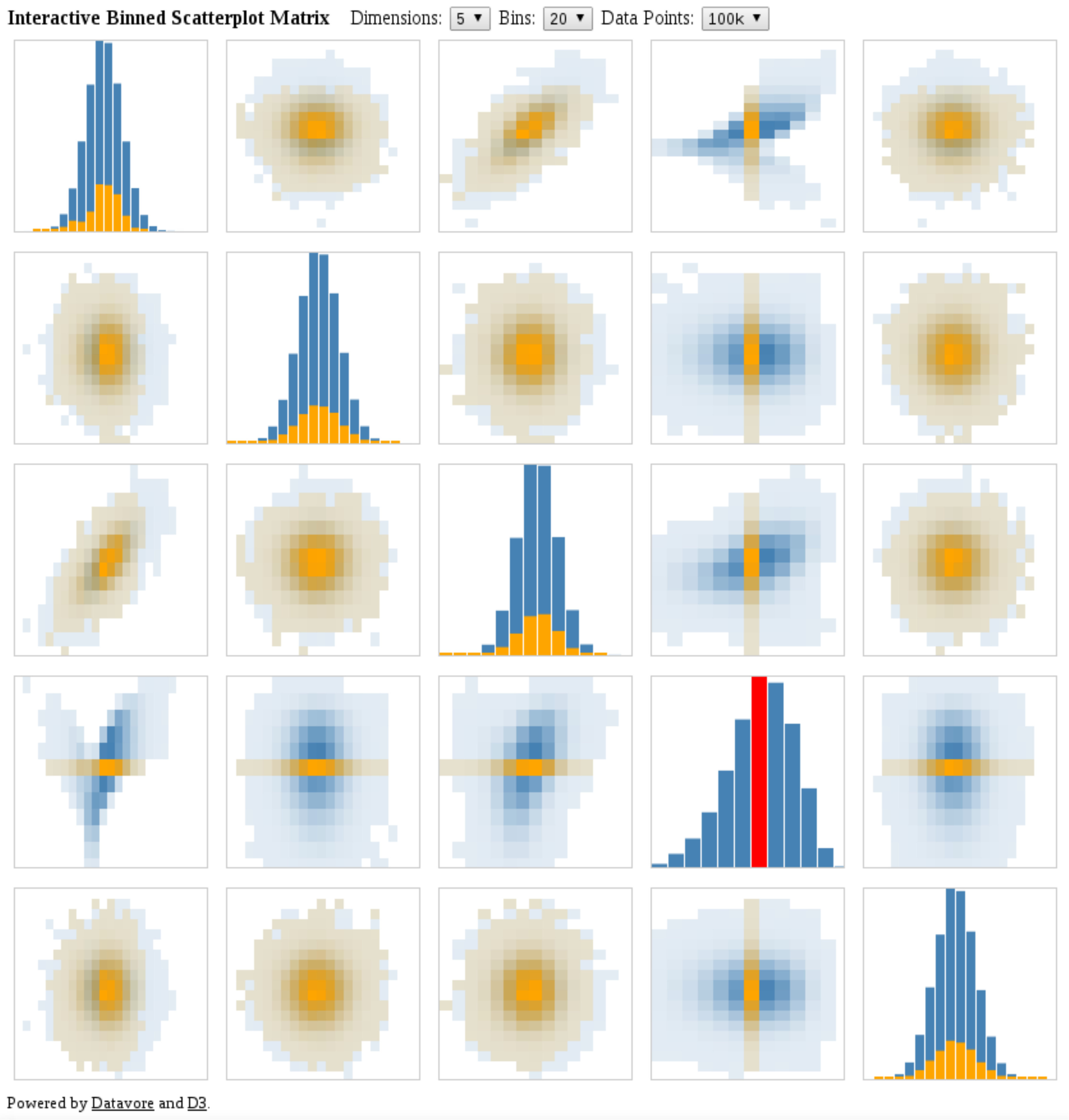
Brushing is important

Often combined with “Focus Scatterplot” as F+C technique

Algorithmic approaches:

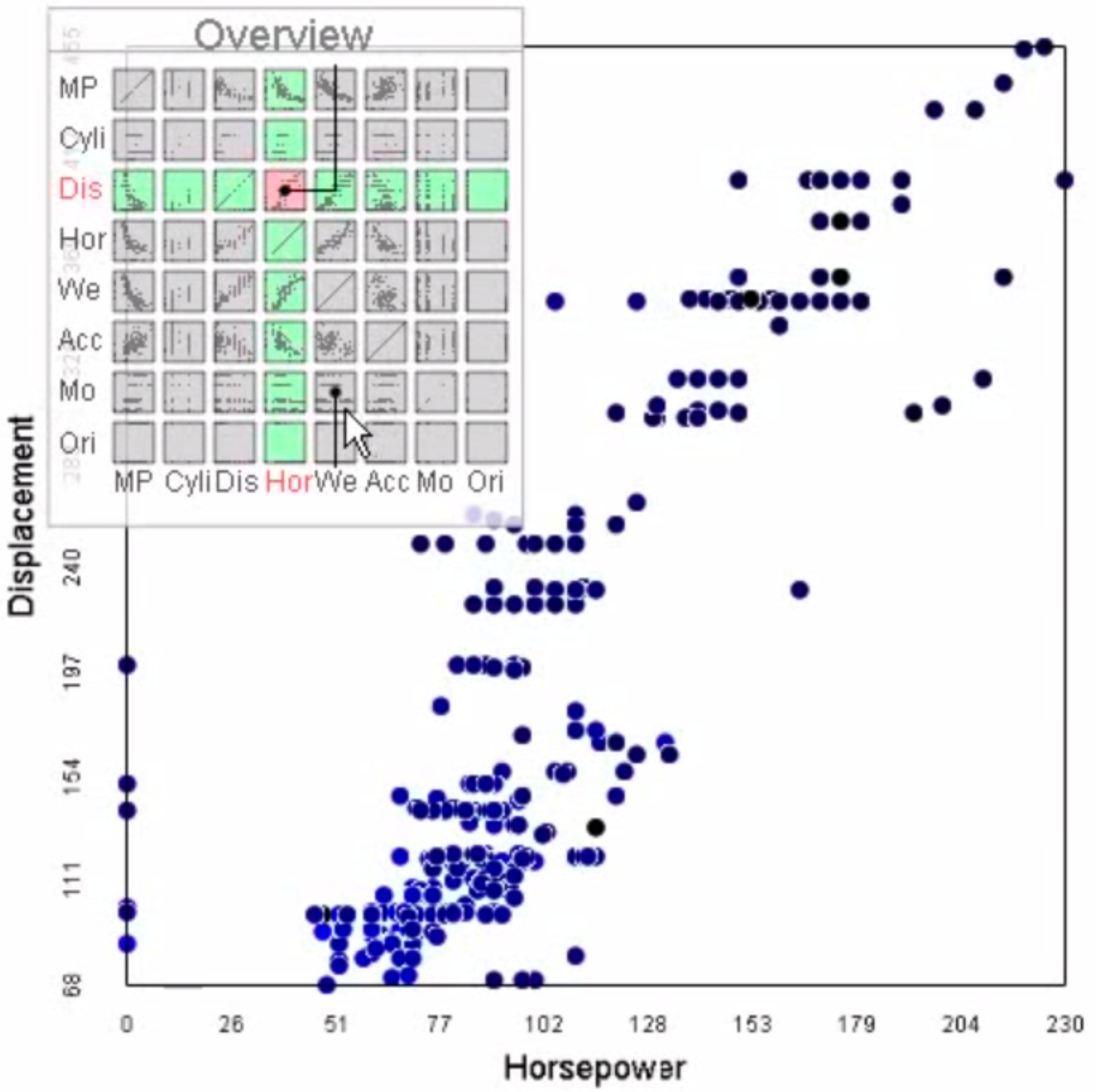
- Clustering & aggregating records
- Choosing dimensions
- Choosing order

SPLOM Aggregation - Heat Map



Datavore: http://vis.stanford.edu/projects/datavore/splom/

SPLOM F+C, Navigation



[Elmqvist]

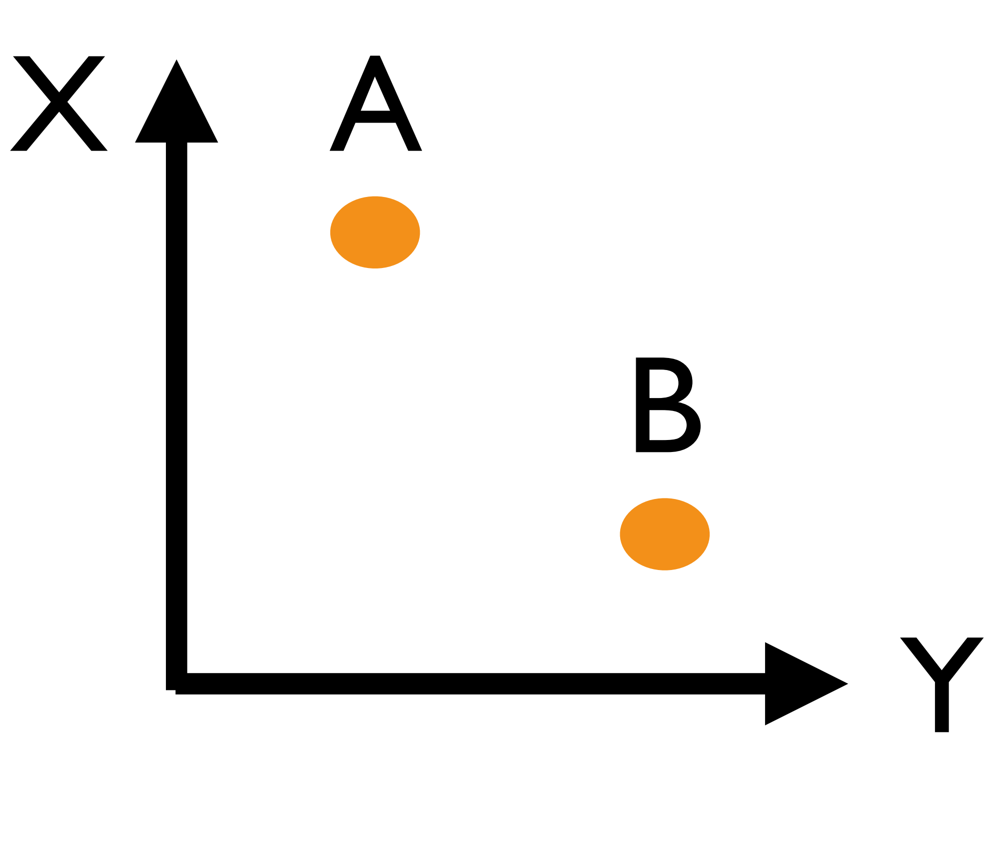
Parallel Coordinates

Parallel Coordinates (PC)

Inselberg 1985

Axes represent attributes

Lines connecting axes represent items



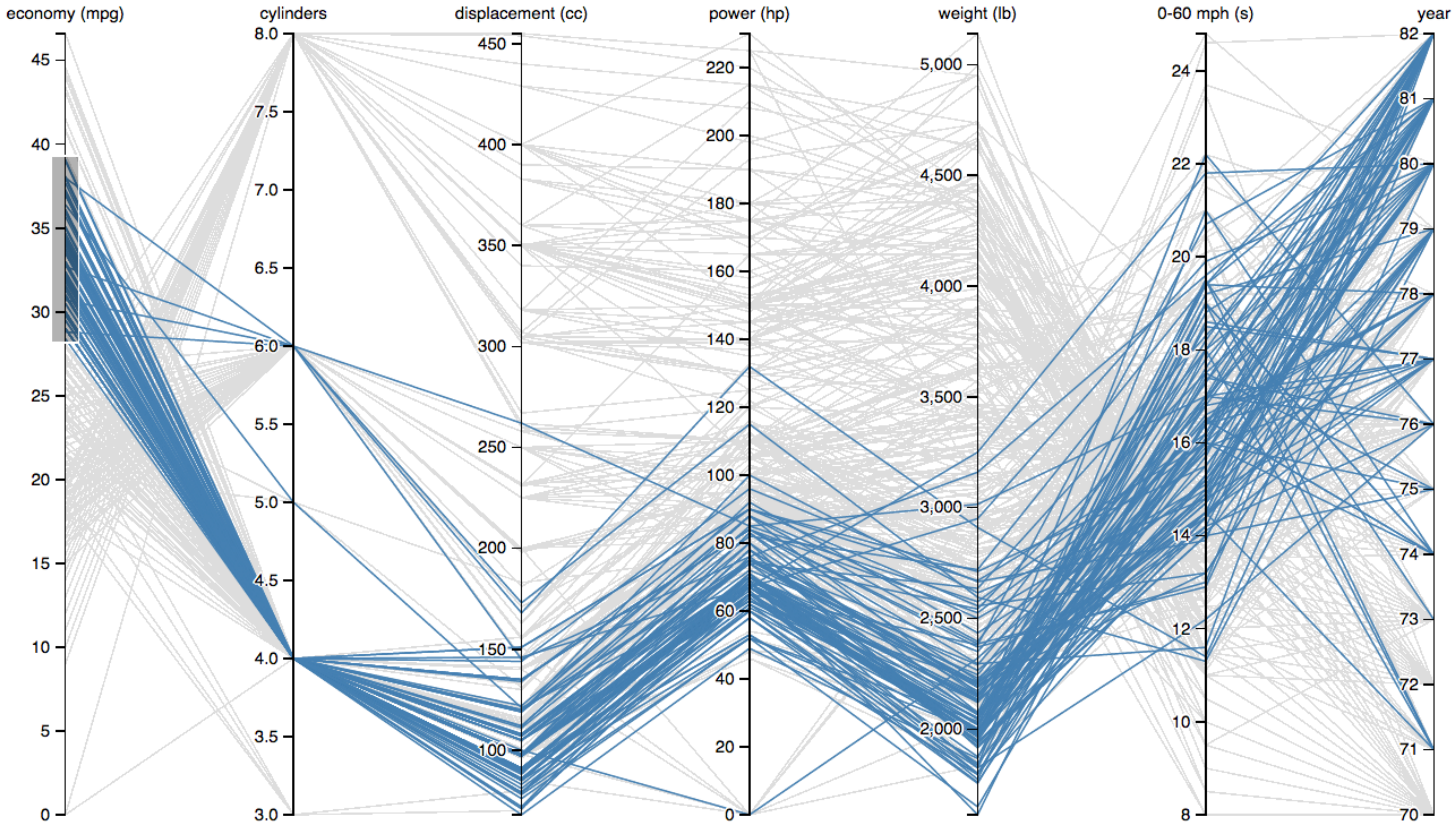
Parallel Coordinates

Each axis represents dimension

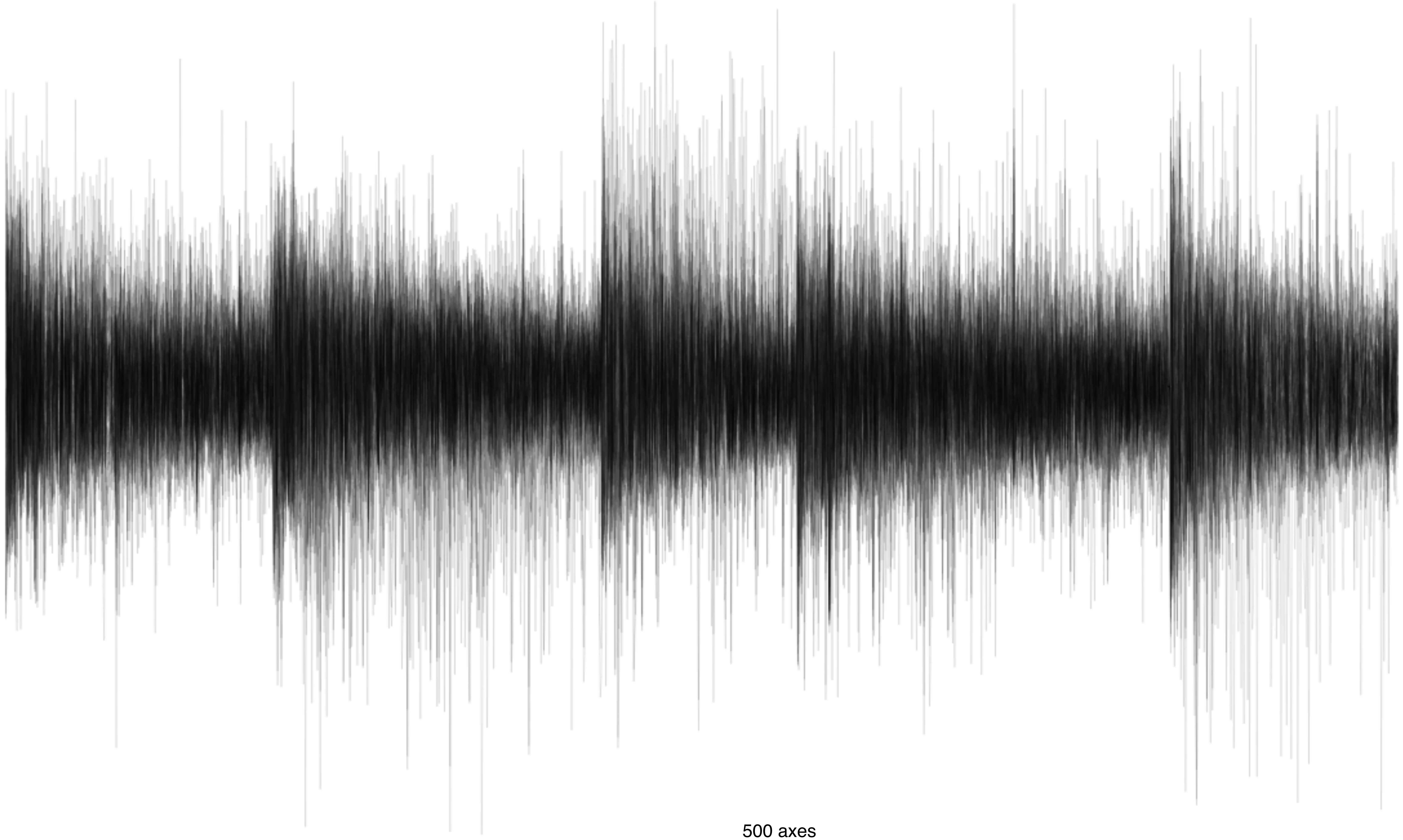
Lines connecting axis represent records

Suitable for

- all tabular data types
- heterogeneous data



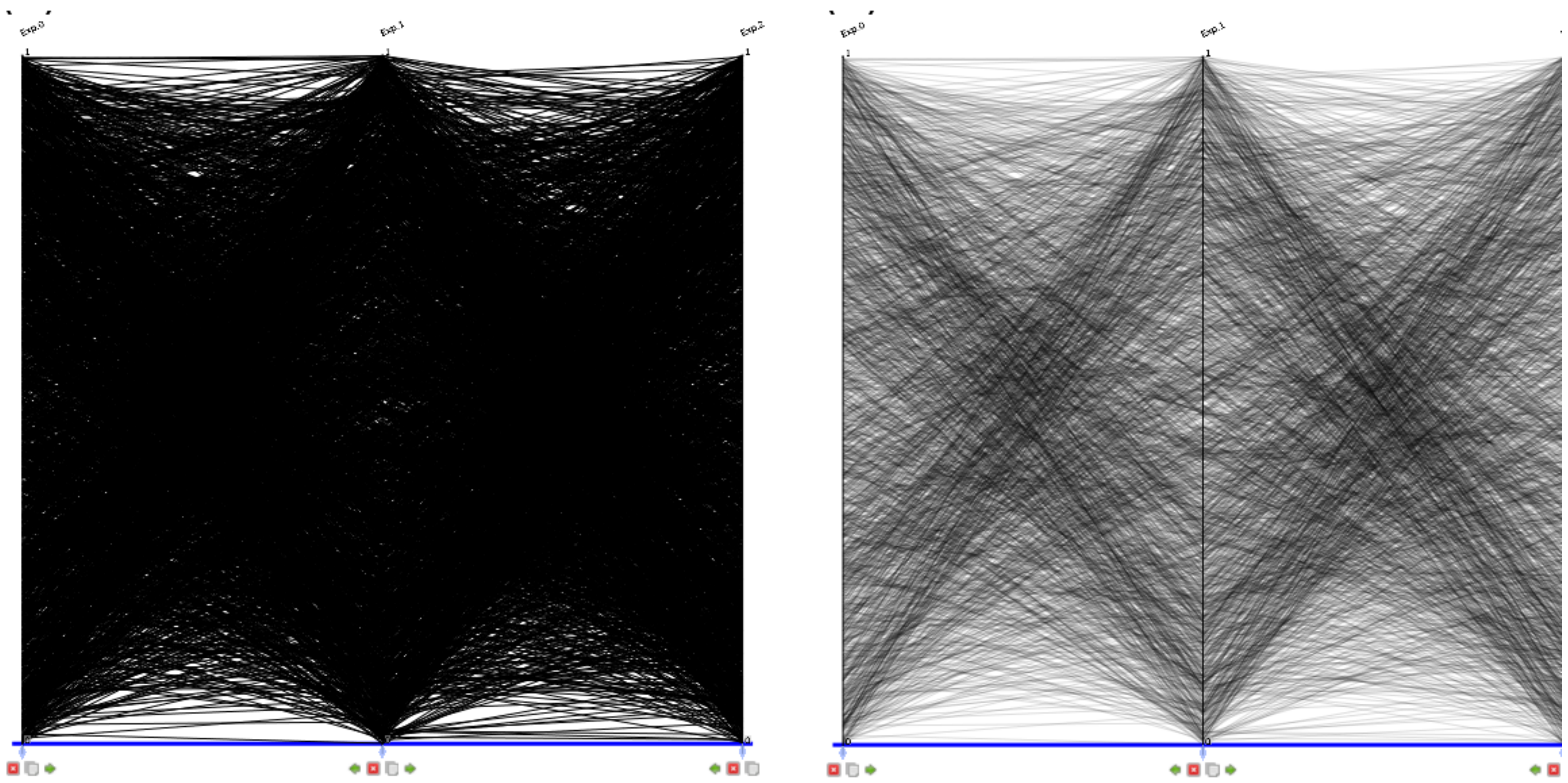
PC Limitation: Scalability to Many Dimensions



PC Limitation: Scalability to Many Items

Solutions:

- Transparency
- Bundling, Clustering
- Sampling

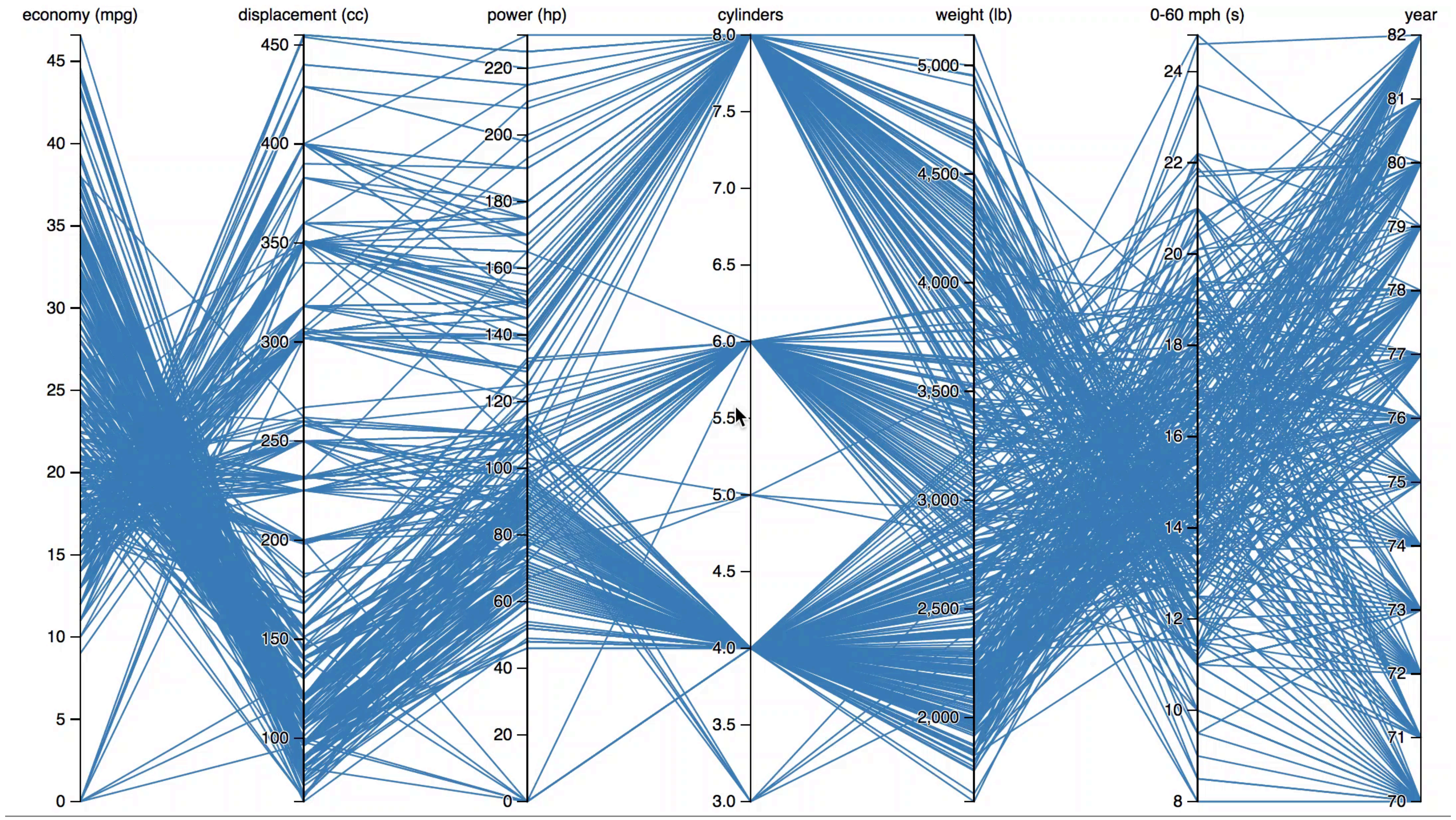


PC Limitations

Correlations only between adjacent axes

Solution: Interaction

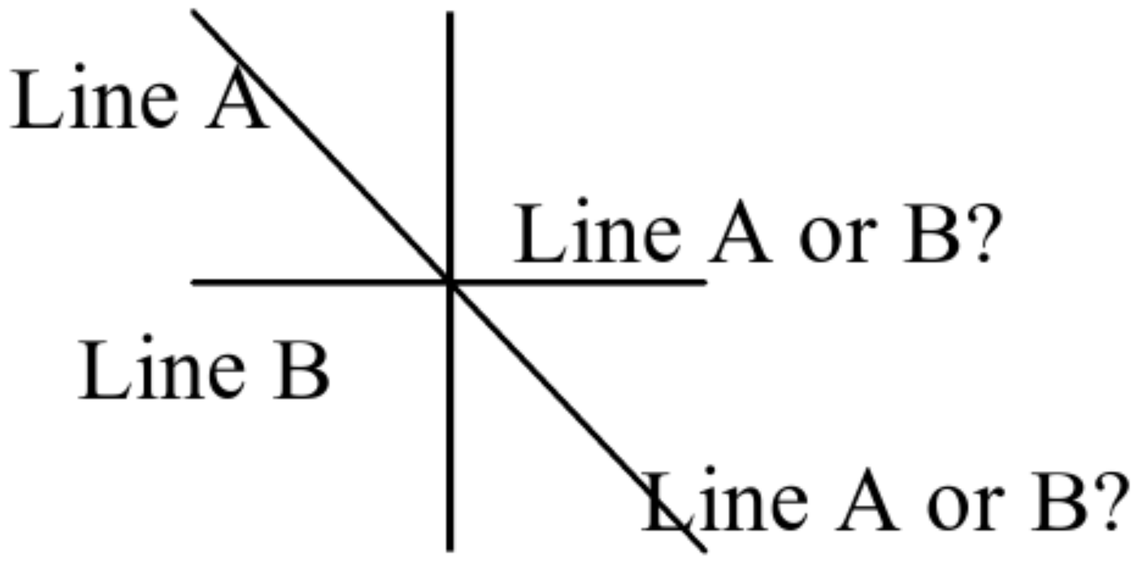
- Brushing
- Let user change order

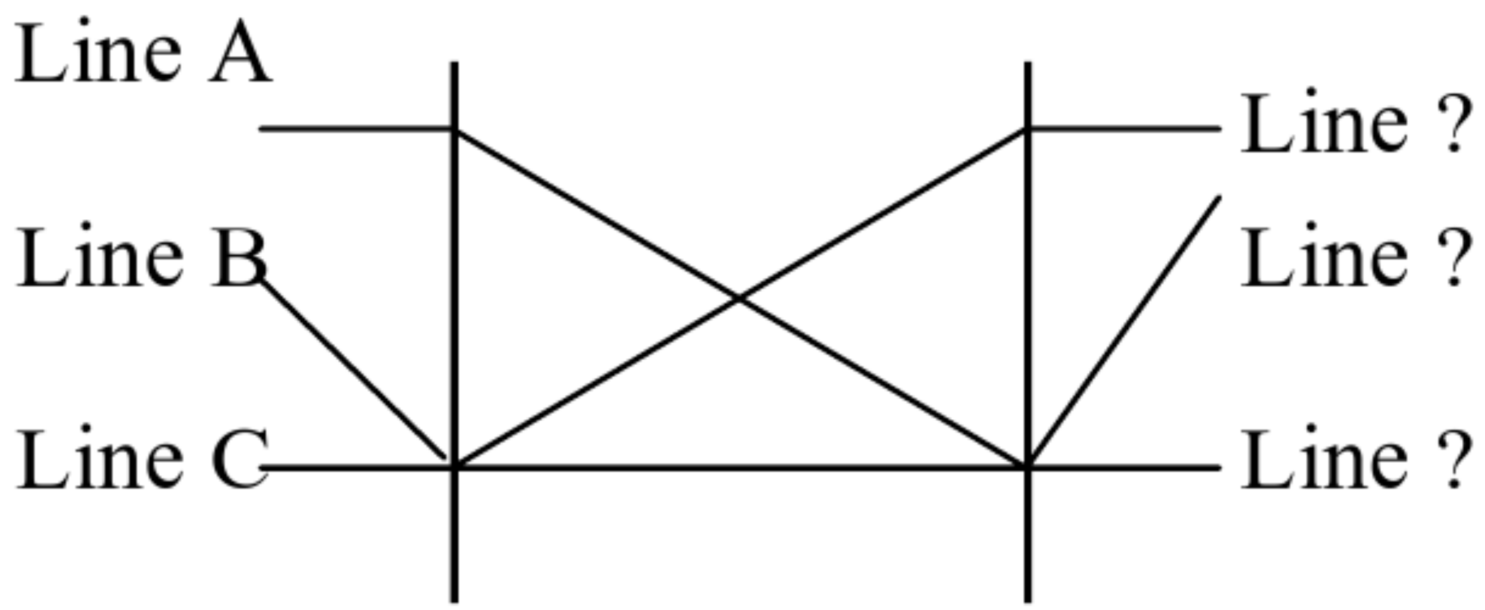


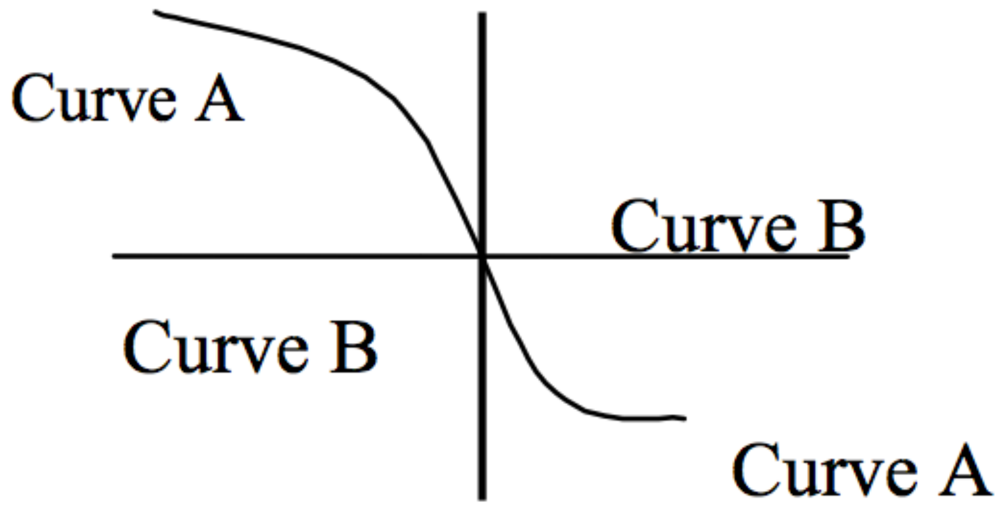
PC Limitation: Ambiguity

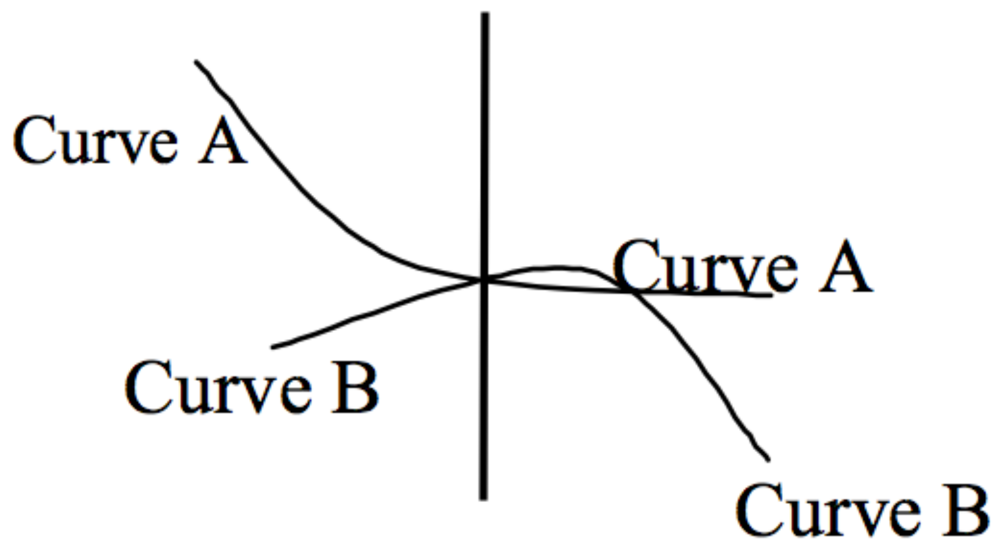
Solutions:

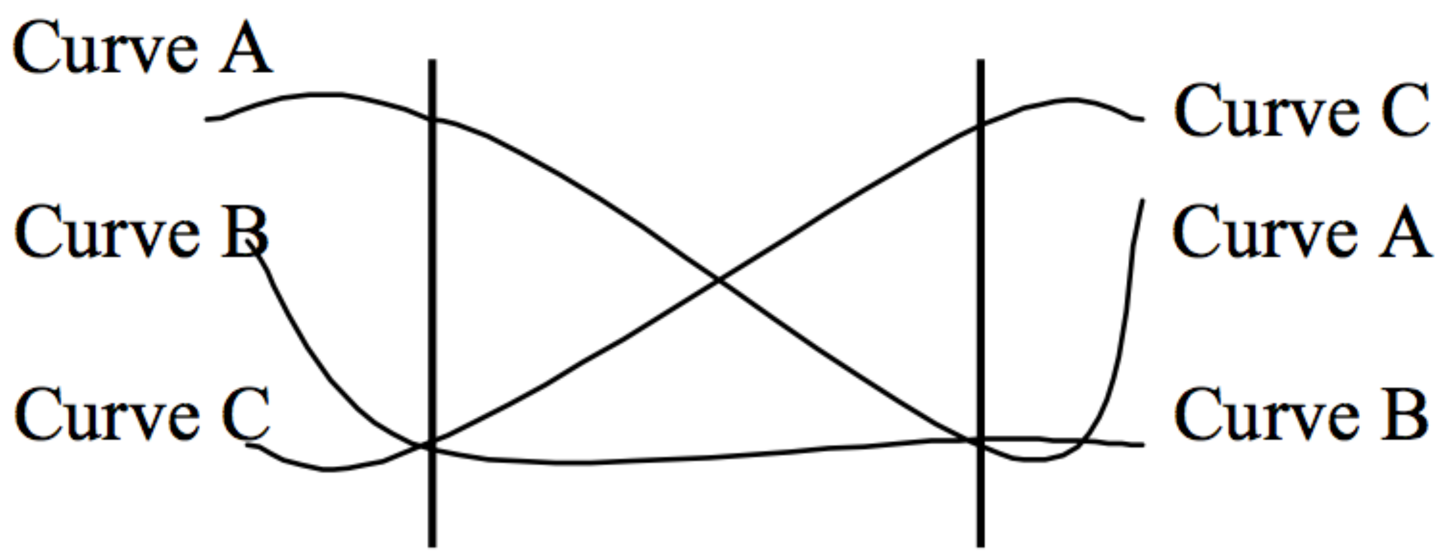
- Brushing
- Curves











Graham and Kennedy 2003

Parallel Coordinates

Shows primarily relationships between adjacent axis

Limited scalability (~50 dimensions, ~1-5k records)

- Transparency of lines

Interaction is crucial

- Axis reordering
- Brushing
- Filtering

Algorithmic support:

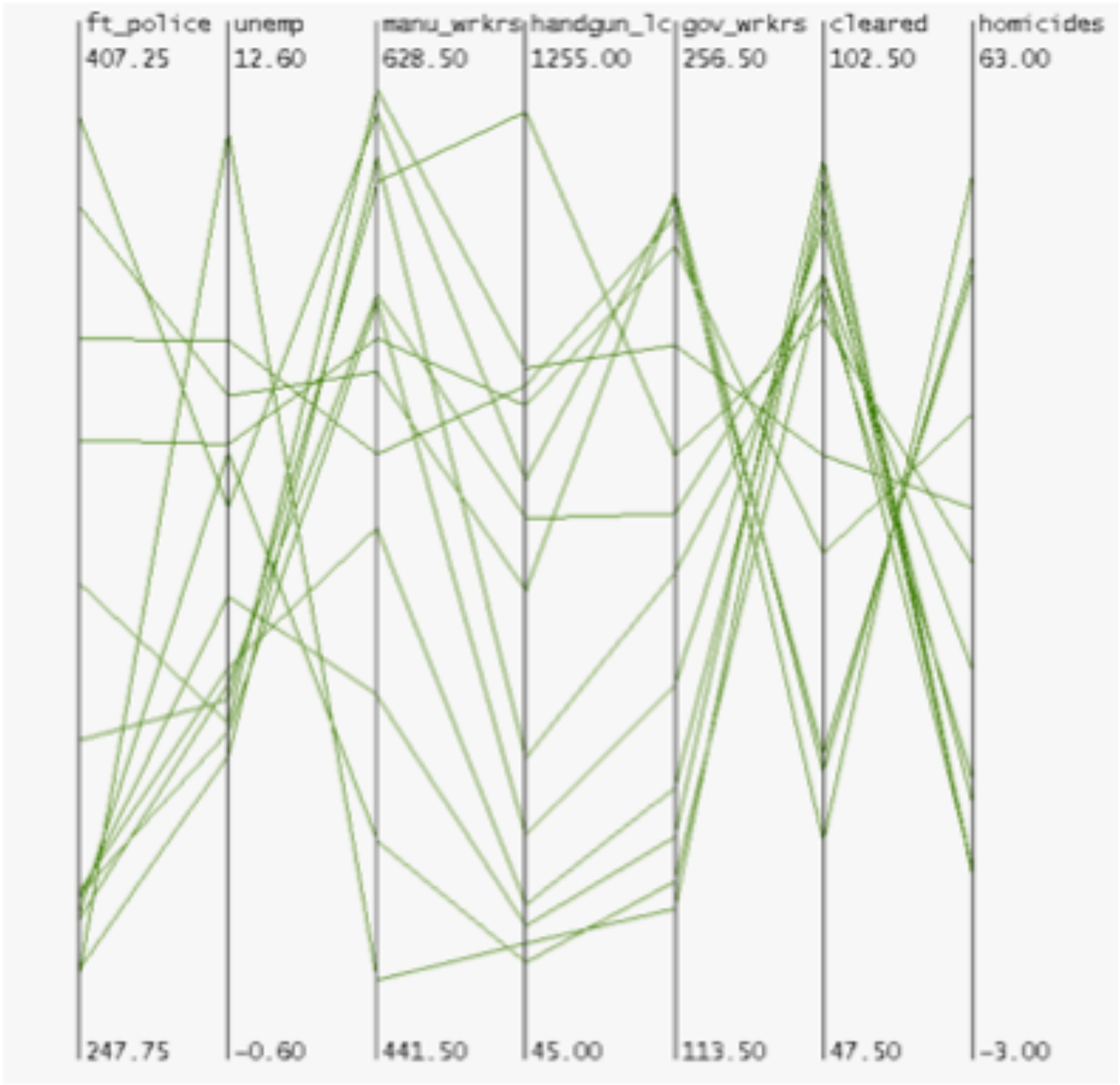
- Choosing dimensions
- Choosing order
- Clustering & aggregating records

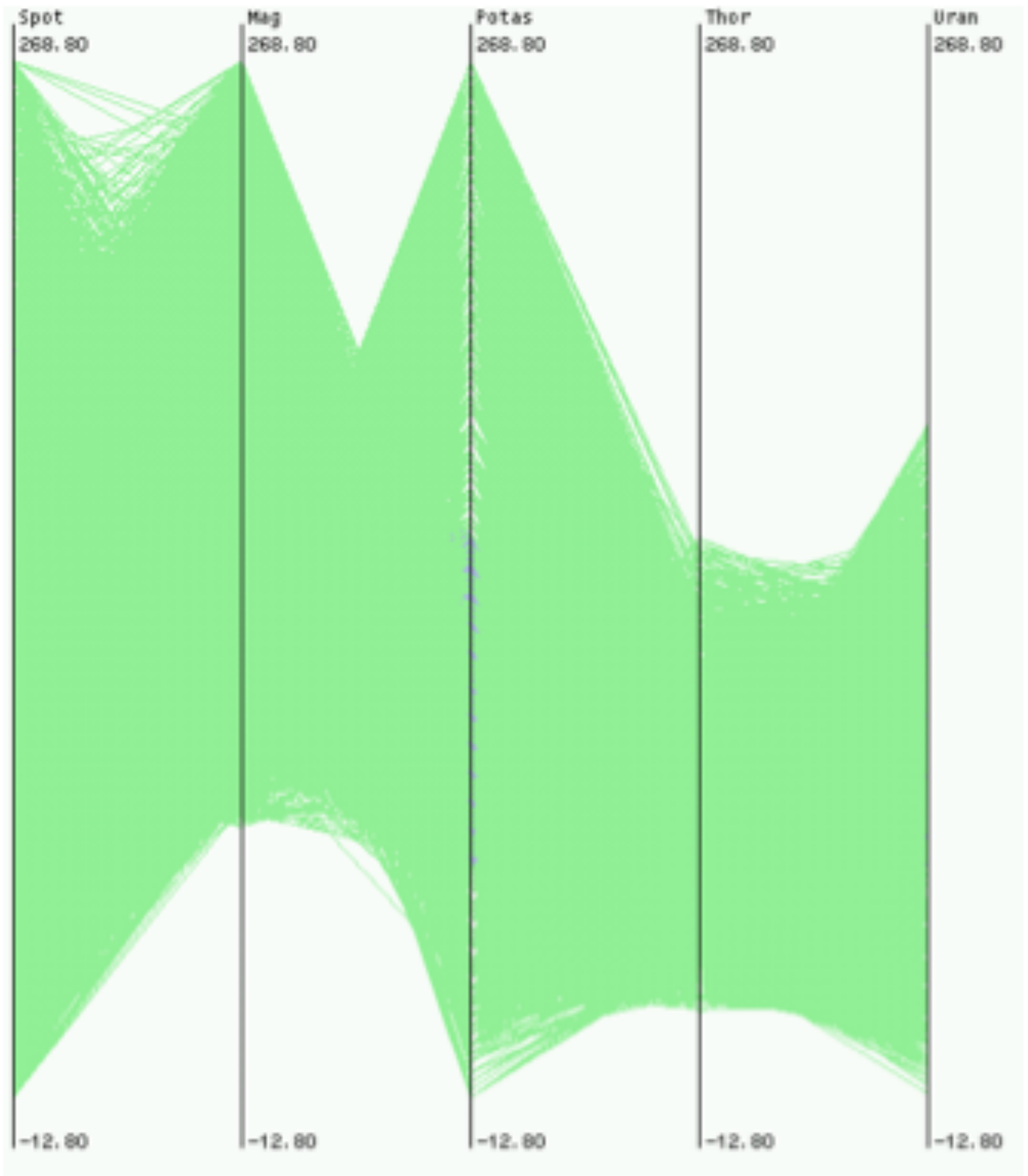
http://bl.ocks.org/jasondavies/1341281

HIERARCHICAL PARALLEL COORDINATES

goal: scale up parallel coordinates to large datasets

- challenge: overplotting/occlusion



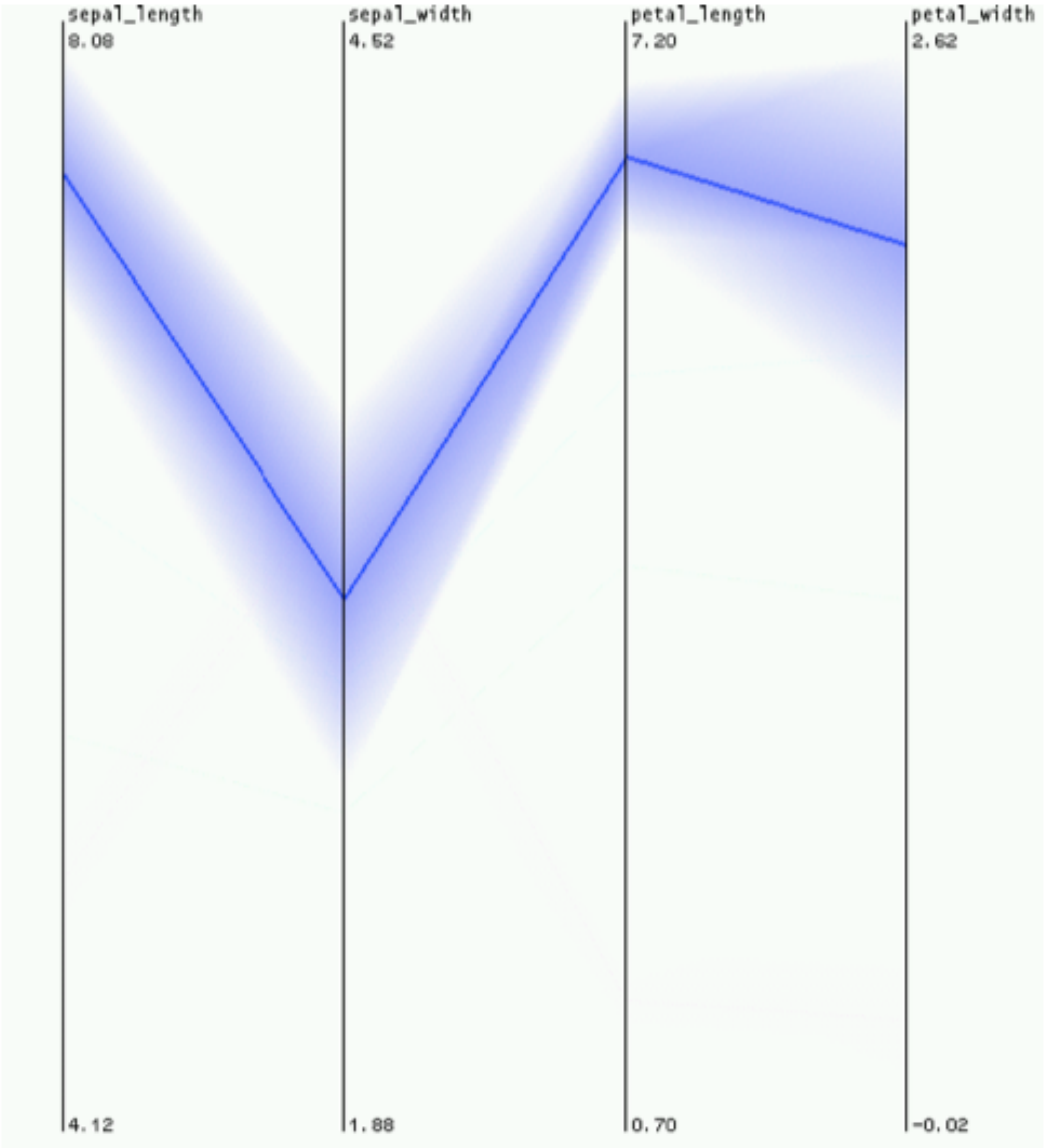


Fua 1999

HPC: ENCODING DERIVED DATA

visual representation: variable-width opacity bands

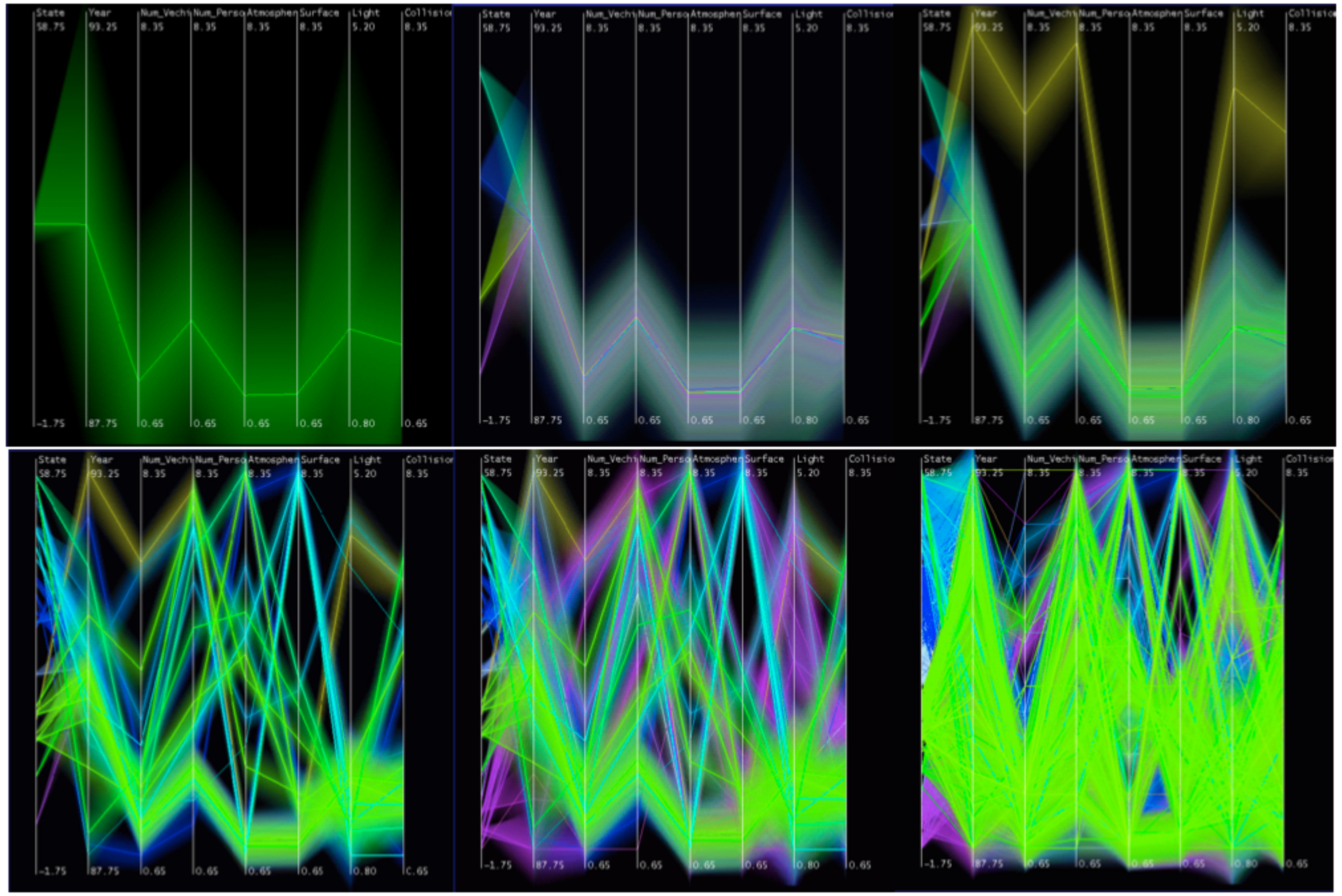
- show whole cluster, not just single item
- min / max: spatial position
- cluster density: transparency
- mean: opaque



Fua 1999

HPC: INTERACTING WITH DERIVED DATA

interactively change level of detail to navigate cluster hierarchy



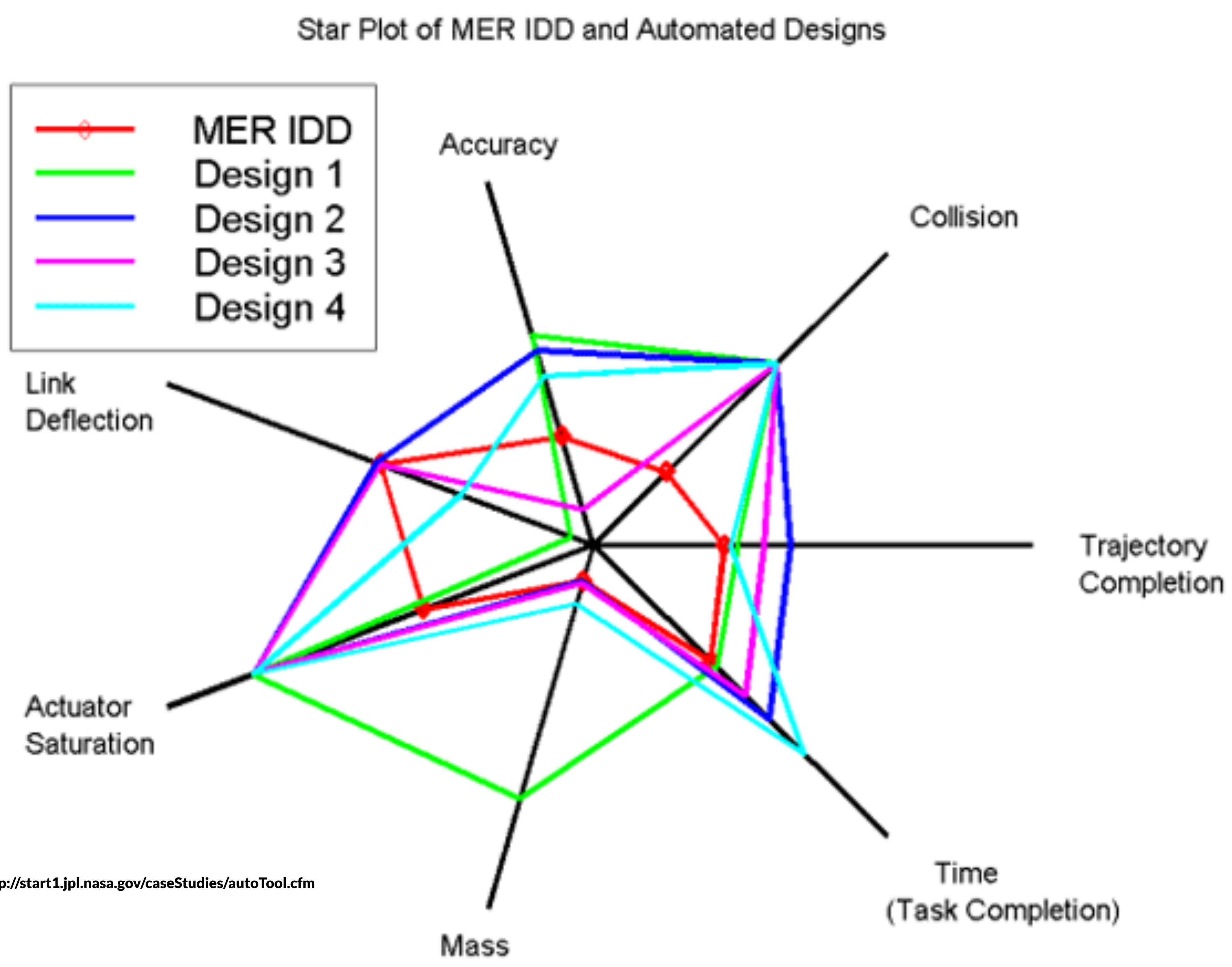
Fua 1999

Star Plot

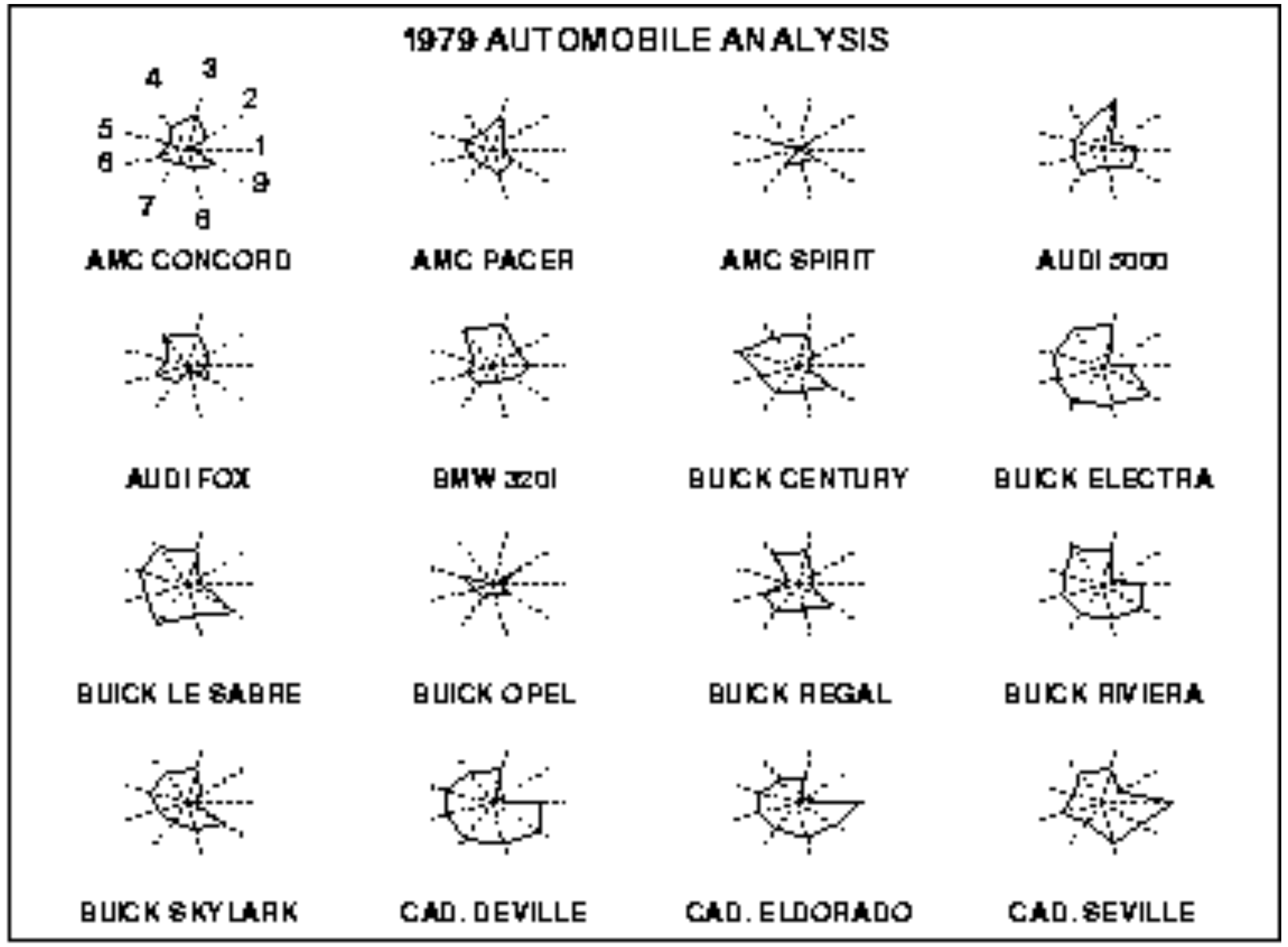
[Coekin1969]

Similar to parallel coordinates

Radiate from a common origin



http://start1.jpl.nasa.gov/caseStudies/autoTool.cfm



http://www.itl.nist.gov/div898/handbook/eda/section3/starplot.htm

http://bl.ocks.org/kevinschaul/raw/8833989/

Data Reduction

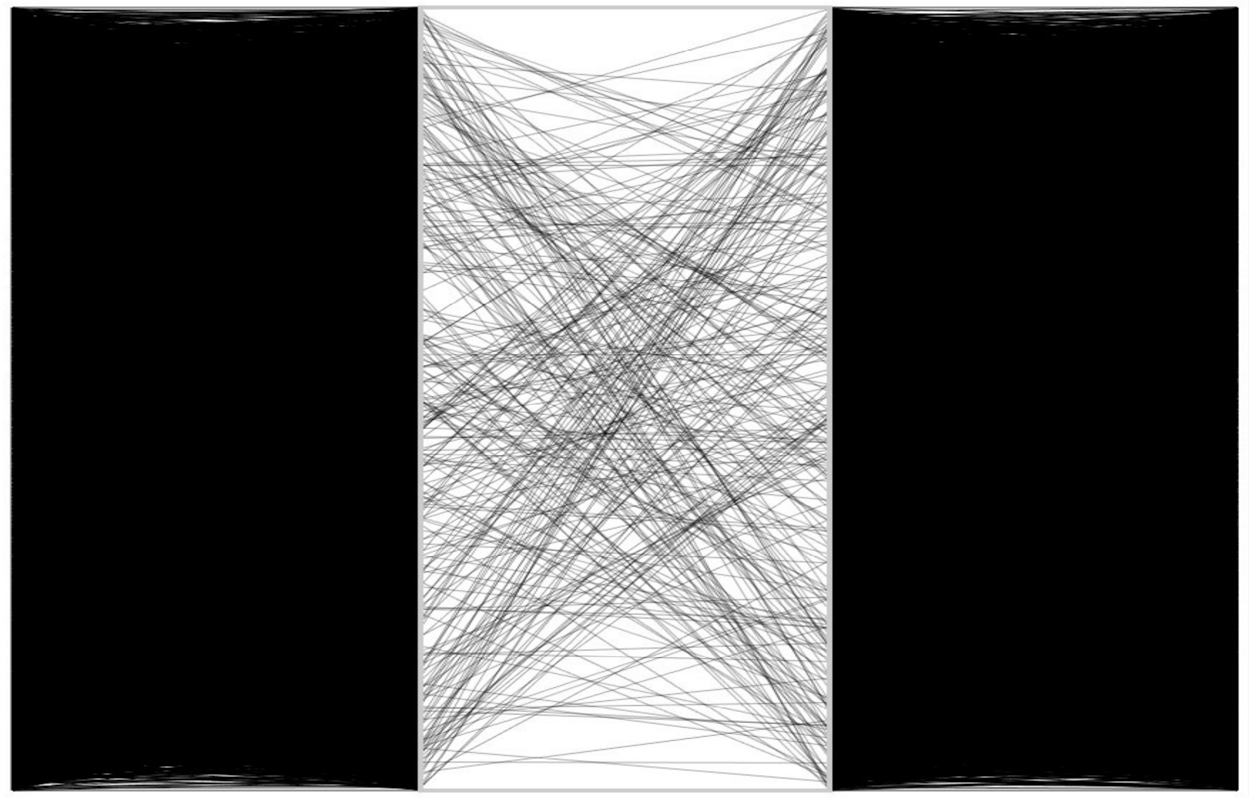
Sampling

Don’t show every element, show a (random) subset

Efficient for large dataset

Apply only for display purposes

Outlier-preserving approaches



[Ellis & Dix, 2006]

Filtering

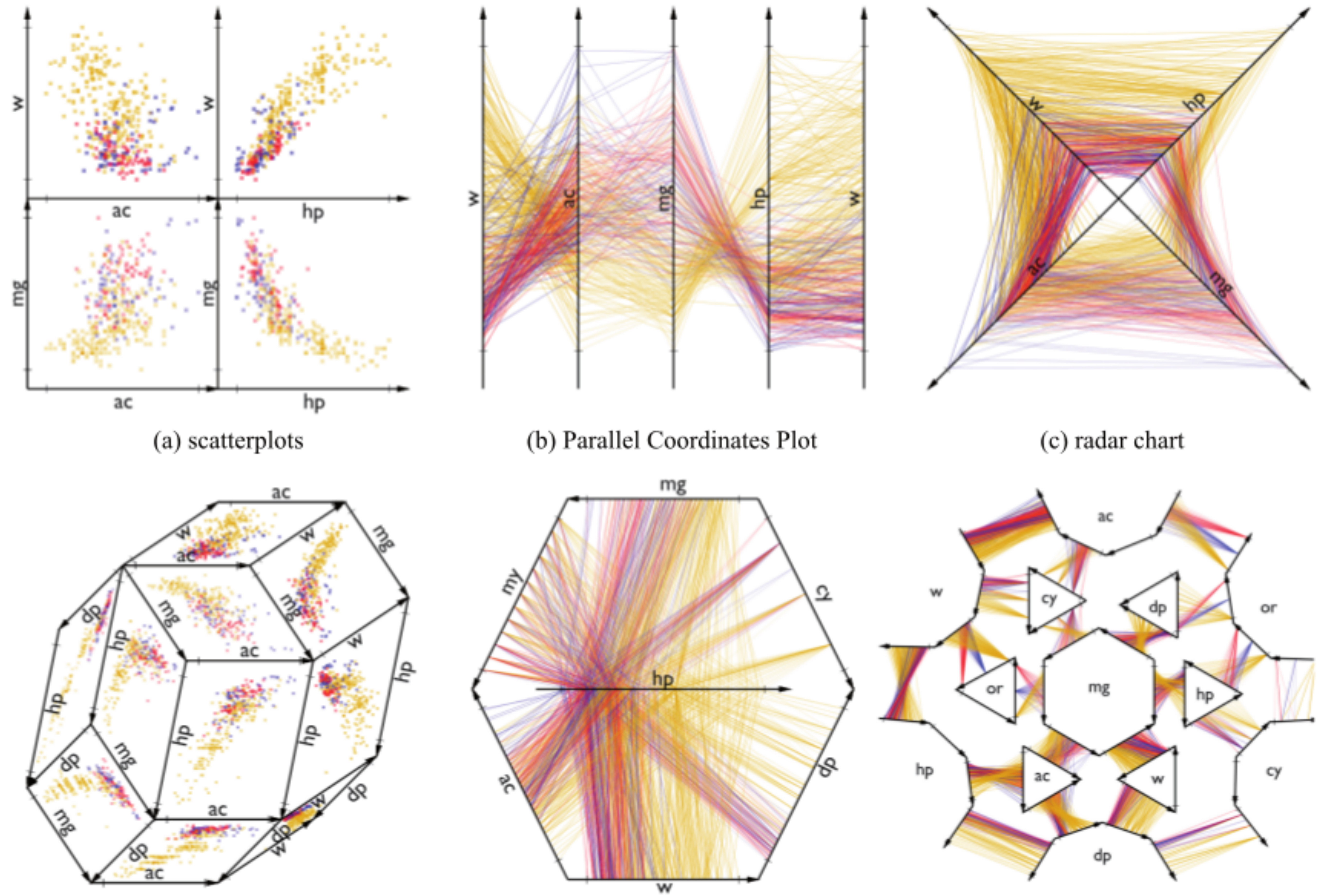
Define criteria to remove data, e.g.,

- minimum variability
- > / < / = specific value for one dimension
- consistency in replicates, …

Can be interactive, combined with sampling

Hybrids with Axis

Flexible Linked Axes (FLINA)

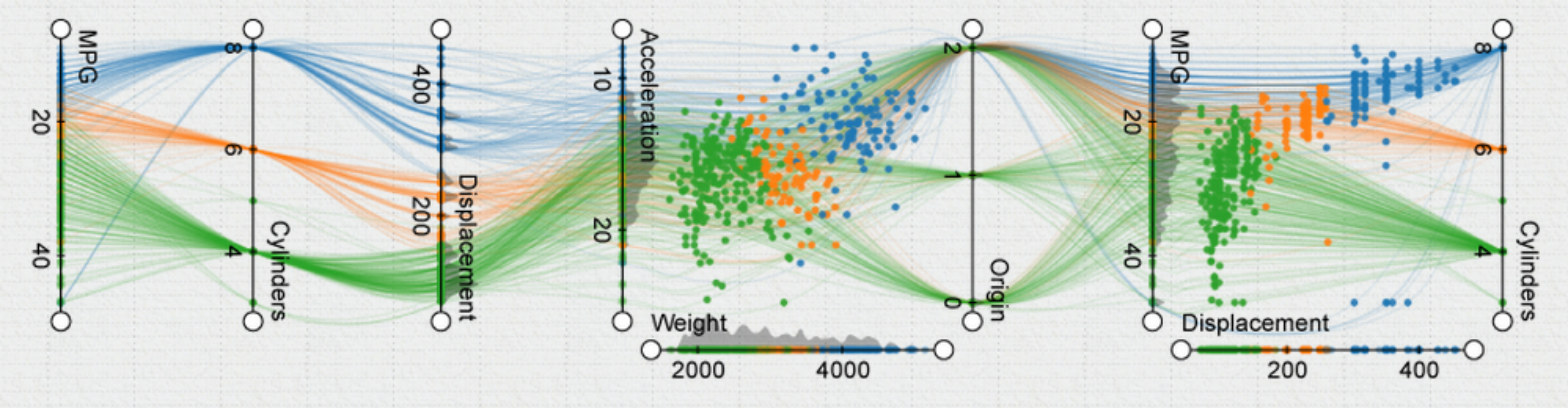


(a) scatterplots (b) Parallel Coordinates Plot (c) radar chart

(d) Hyperbox (e) Time Wheel (f) Many-to-many PCP

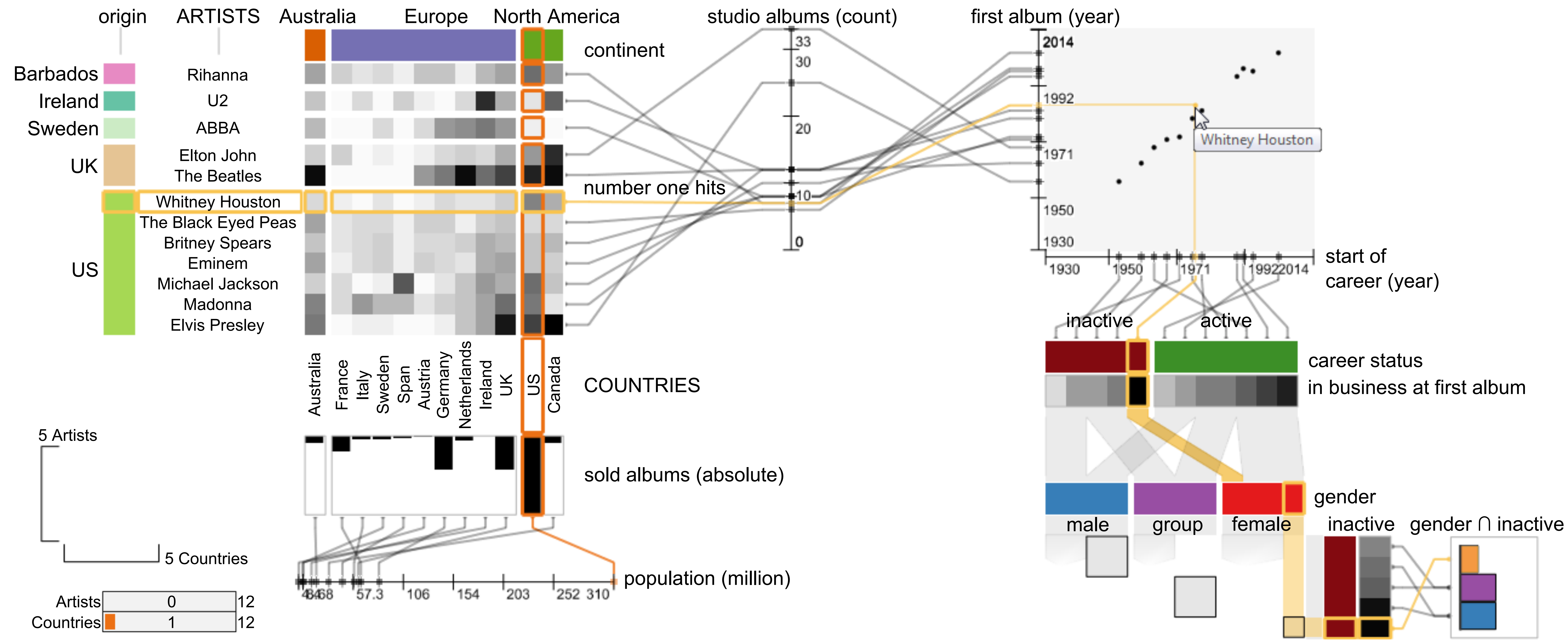
Claessen & van Wijk 2011

Web-based implementation of FLINA concept



http://vis.pku.edu.cn/mddv/val/

Domino



Gratzl et al. 2014

Parallel Sets

Parallel Sets

builds on PC to better handle categorical data

- discrete
- small number of values
- no implied ordering between attributes

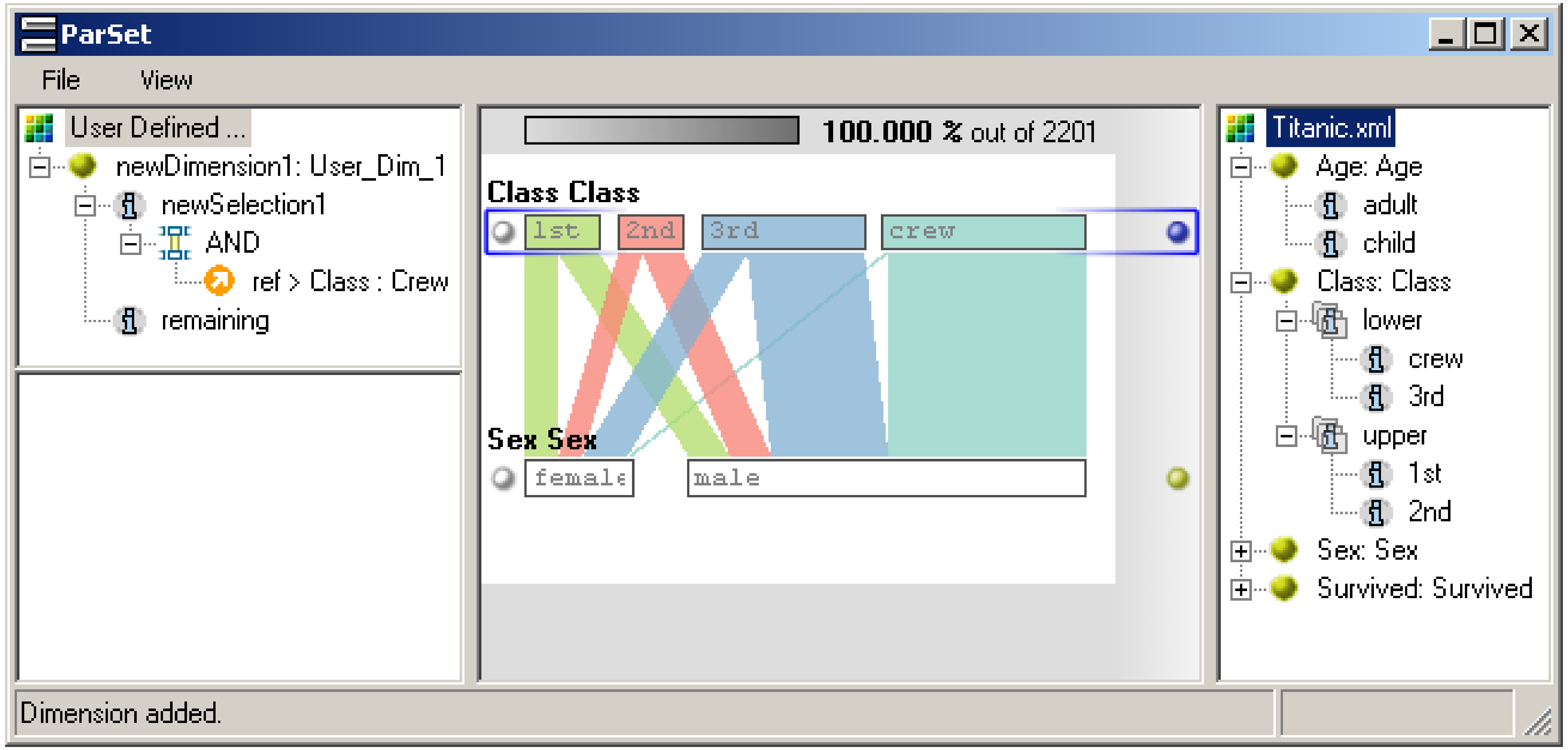
task: find relationship between attributes

interaction driven technique

Visual Encoding

boxes scaled by frequency

color coded by values for current active dimension

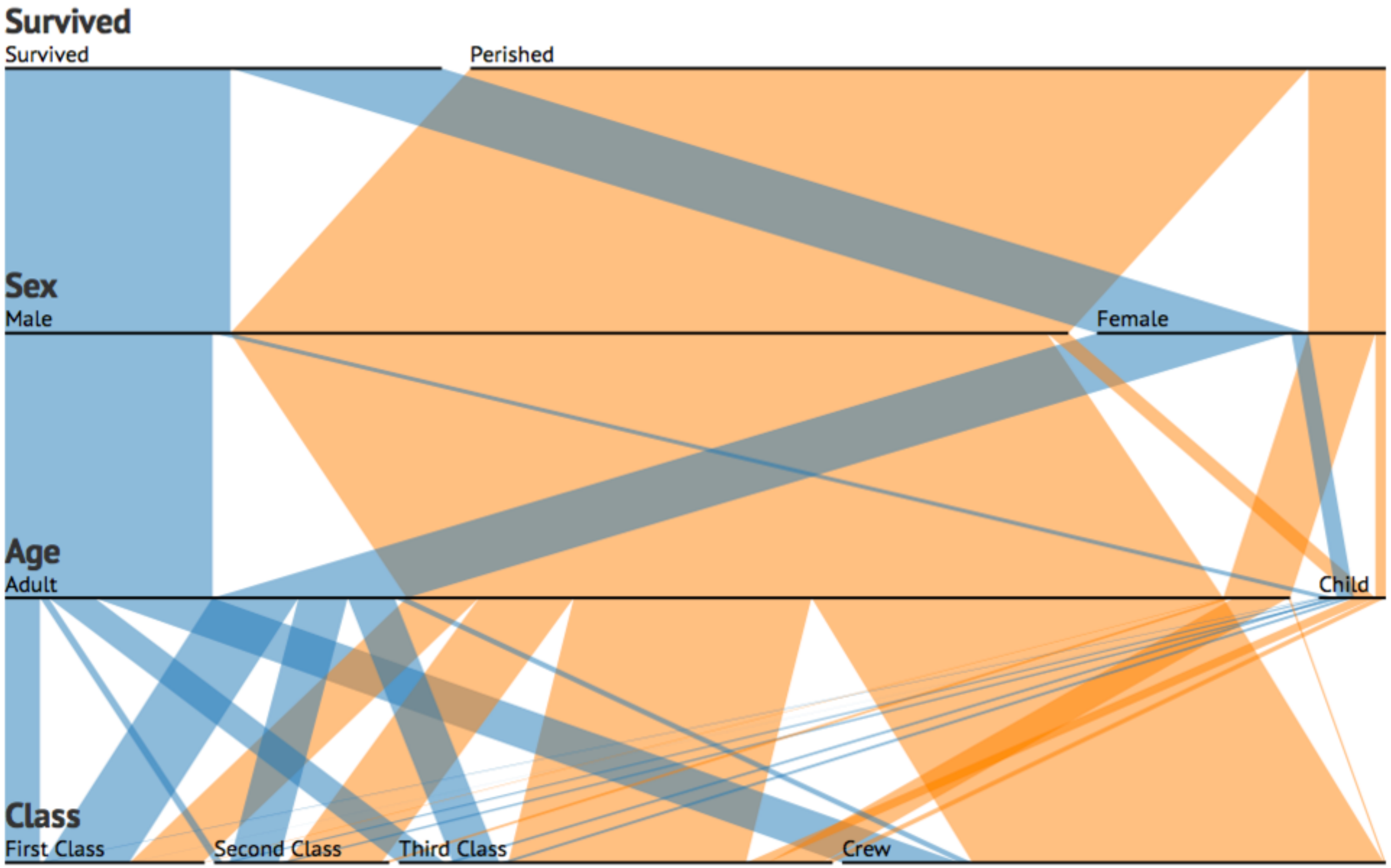


Bendix, Kosara, Hauser, 2005

Parallel Sets

A visualisation technique for multidimensional categorical data.

Titanic Survivors

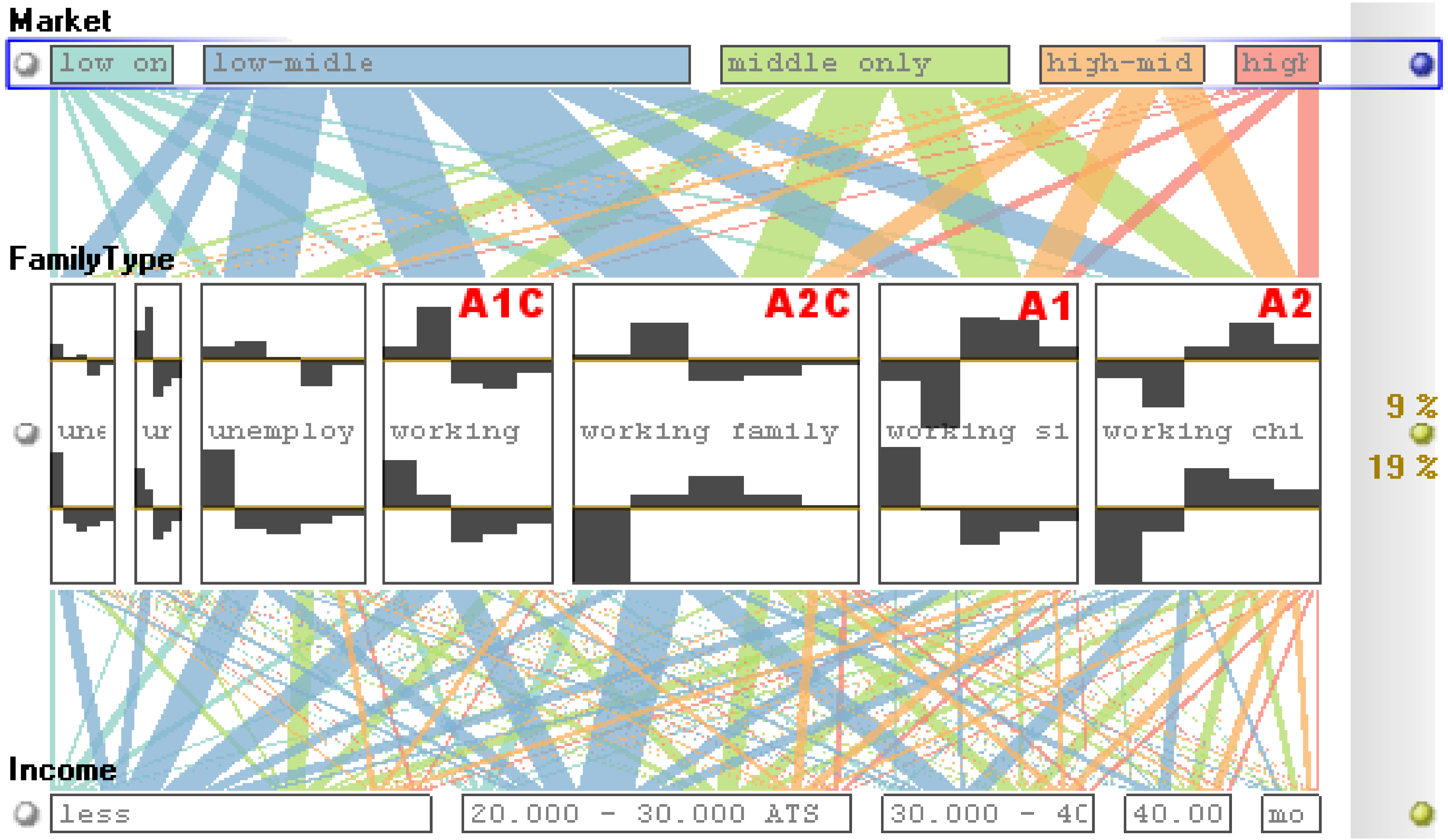


Curves?

Data: Robert J. MacG. Dawson.

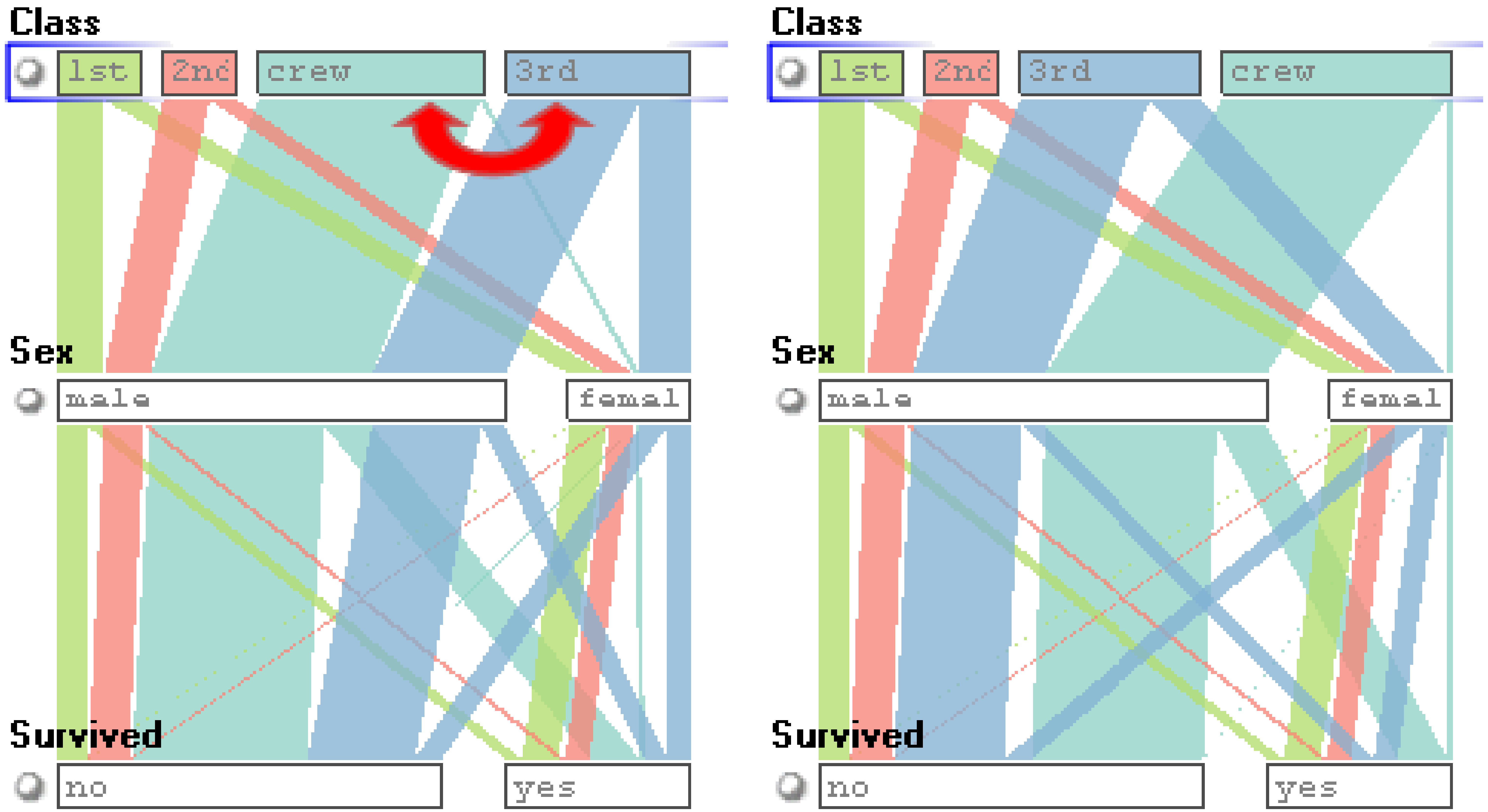
Visual Encoding

Boxes expand to show histogram



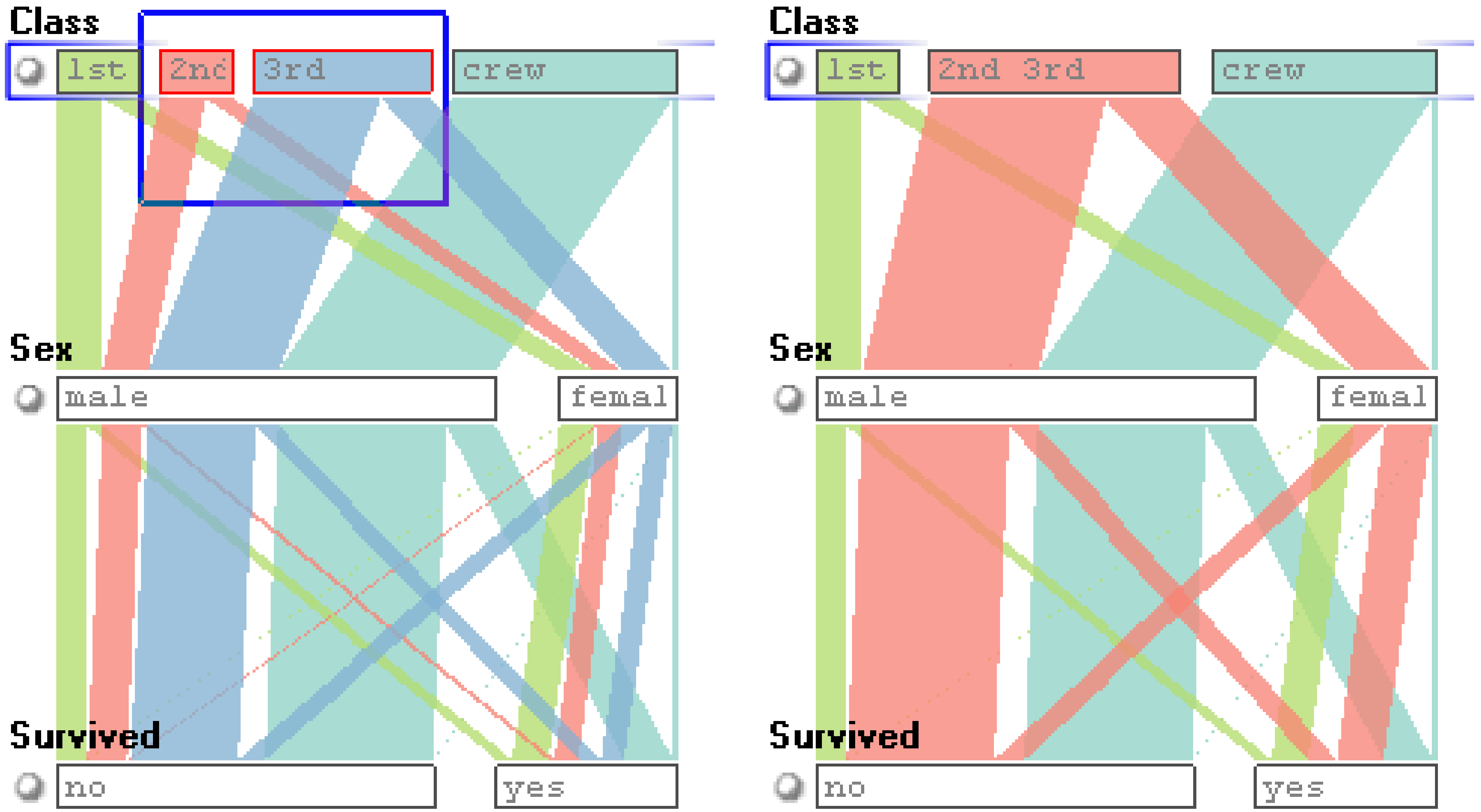
Bendix, Kosara, Hauser, 2005

Interaction: Reorder



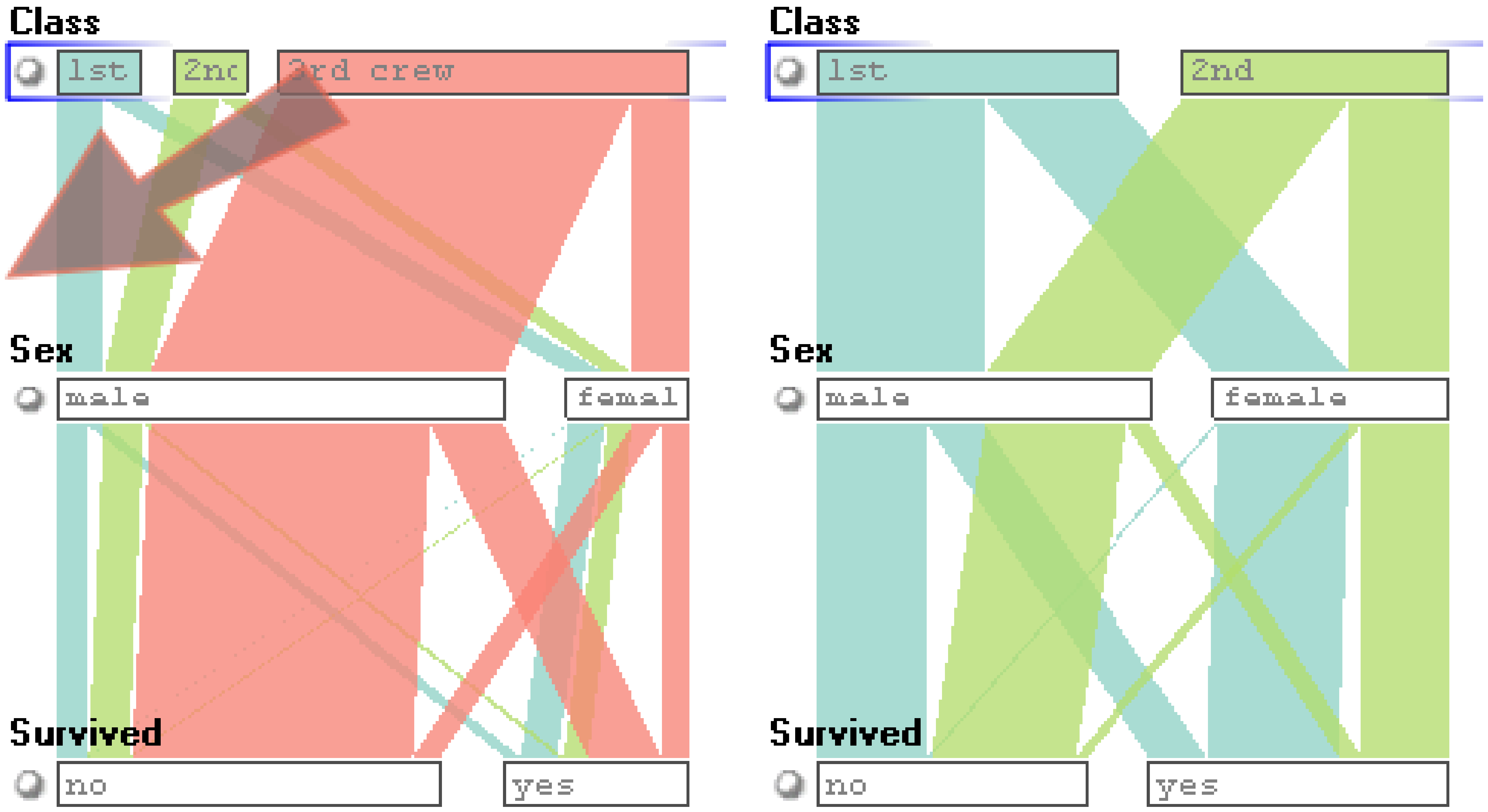
Bendix, Kosara, Hauser, 2005

Interaction: Aggregate



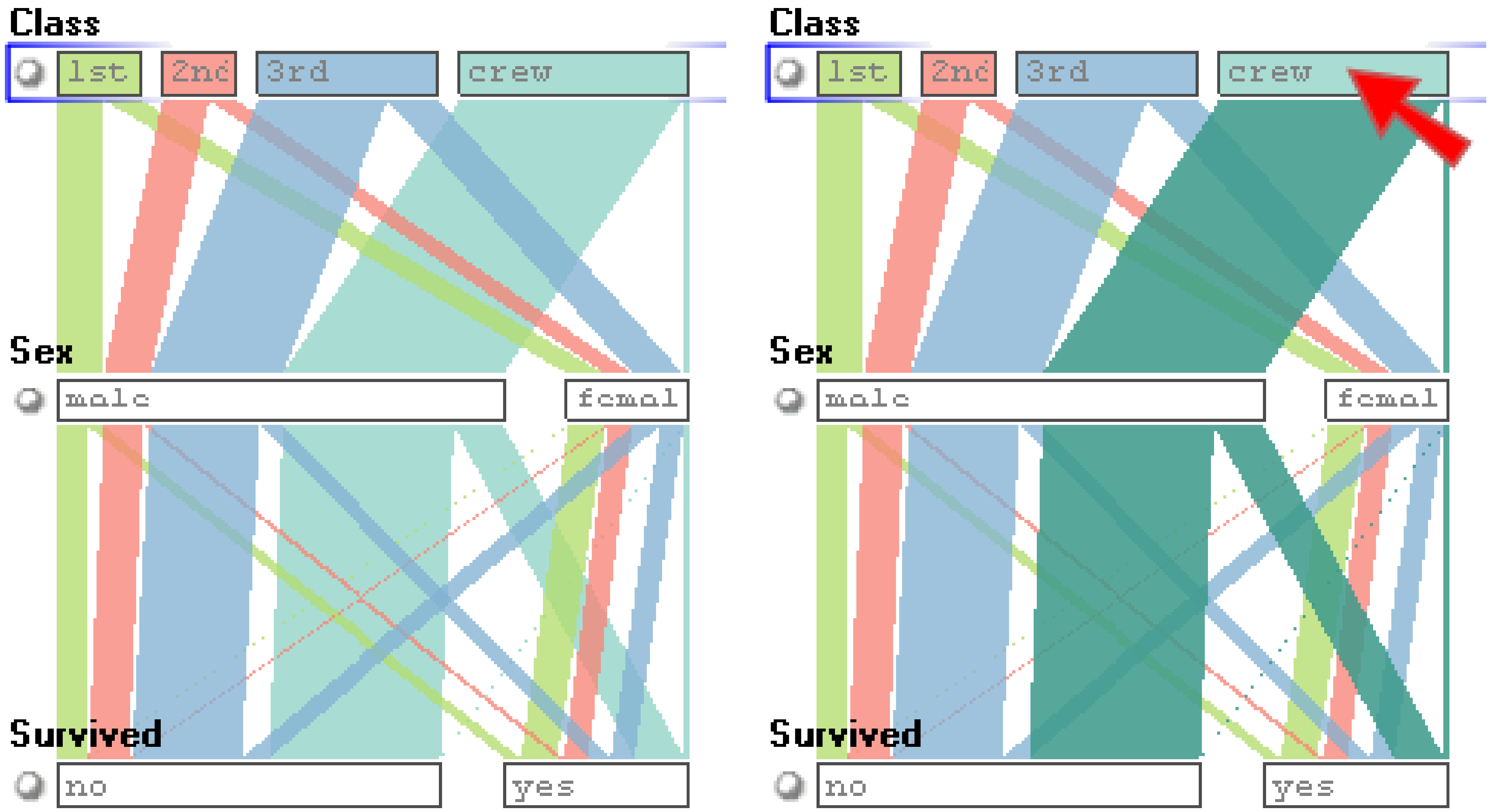
Bendix, Kosara, Hauser, 2005

Interaction: Filter



Bendix, Kosara, Hauser, 2005

Interaction: Highlight



Bendix, Kosara, Hauser, 2005

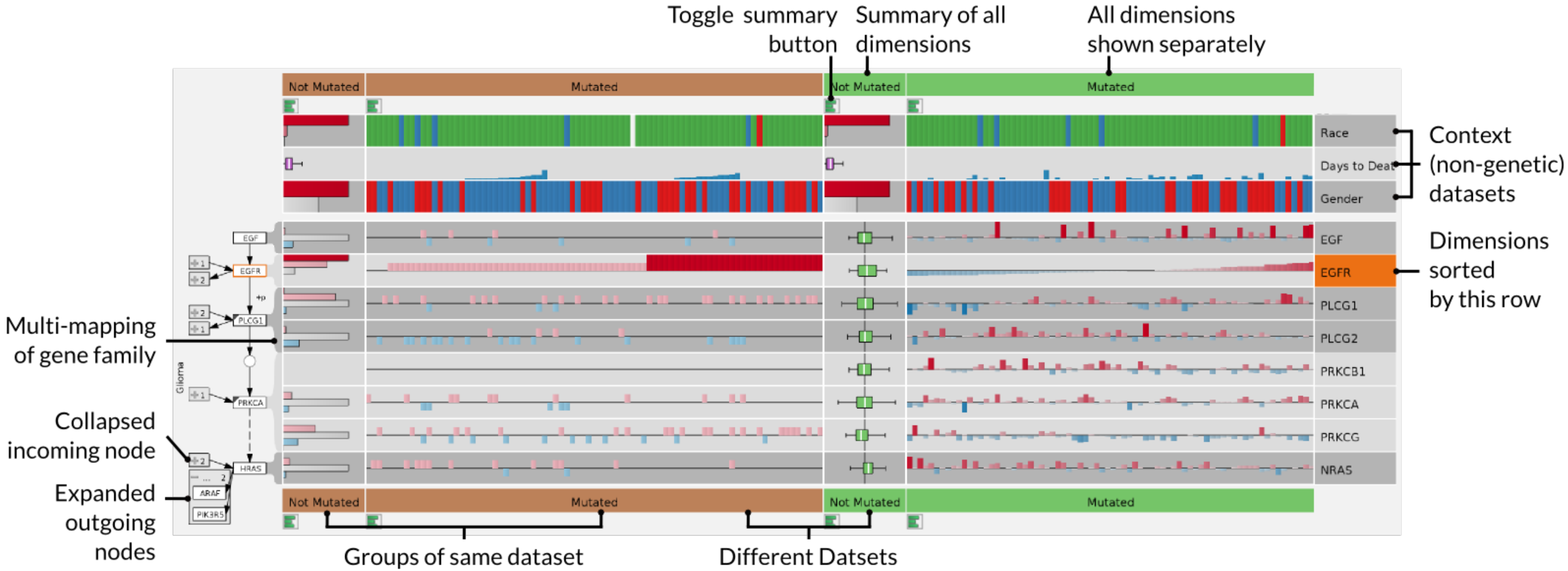
Tabular / Grid / Matrix - Based Representations

Tabular Representation

Like spreadsheet: each variable in it’s own column

Visual encodings to make it scalable

Combining Various Charts



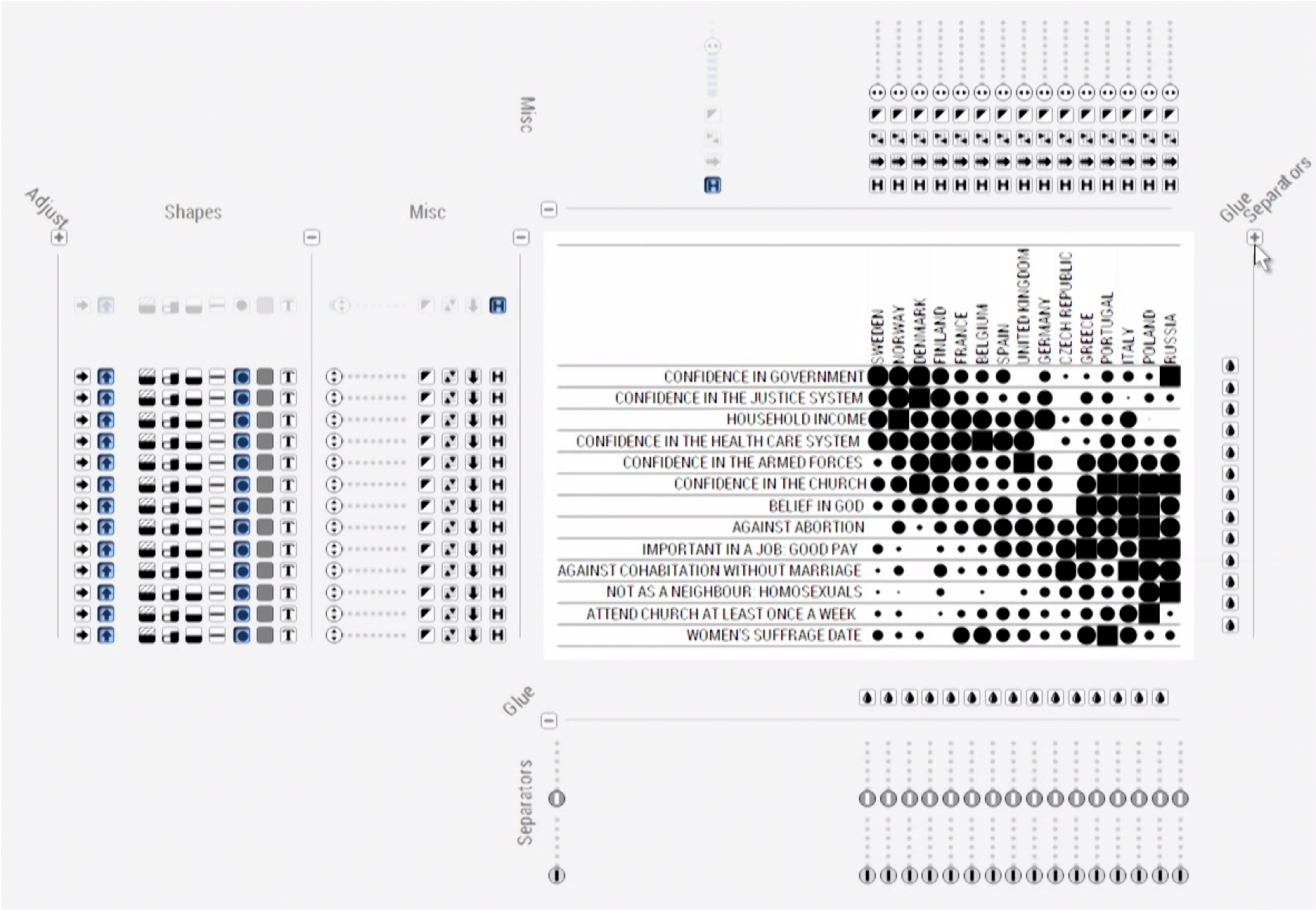
Taggle

A	Rank	S	AIDS_Countries	Continent	Human deve...	Ppl knowing...	Discriminat...	Urban Pop (...	Discriminat...	Density (P/...
	1		Singapore	Asia	4 Very hig...		Unknown		Unknown	
	2		Malta	Europe	4 Very hig...		Unknown		Unknown	
	3		Bangladesh	Asia	2 Medium ...		Unknown		Unknown	
	4		Maldives	Asia	3 High hu...		Unknown		Unknown	
	5		Barbados	North Ame...	3 High hu...		Unknown		Unknown	
	6		Mauritius	Africa	3 High hu...		Unknown		Unknown	
	7		Lebanon	Asia	3 High hu...		Unknown		Unknown	
	8		Republic of Korea	Asia	4 Very hig...		Unknown		Unknown	
	9		Netherlands	Europe	4 Very hig...		Unknown		Unknown	
	10		Rwanda	Africa	1 Low hu...		Low		Low	
	11		Burundi	Africa	1 Low hu...		Slight		Slight	
	12		India	Asia	2 Medium ...		Unknown		Unknown	
	13		Haiti	North Ame...	1 Low hu...		Medium		Medium	
	14		Israel	Asia	4 Very hig...		Unknown		Unknown	
	15		Belgium	Europe	4 Very hig...		Unknown		Unknown	
	16		Philippines	Asia	2 Medium ...		Unknown		Unknown	
	17		Japan	Asia	4 Very hig...		Unknown		Unknown	
	18		Sri Lanka	Asia	3 High hu...		Unknown		Unknown	
	19		Viet Nam	Asia	2 Medium ...		Unknown		Unknown	
	20		El Salvador	North Ame...	2 Medium ...		Unknown		Unknown	
	21		United Kingdom of Great Britain	Europe	4 Very hig...		Unknown		Unknown	
	22		Trinidad and Tobago	North Ame...	3 High hu...		Unknown		Unknown	
	23		Jamaica	North Ame...	3 High hu...		Predomina...		Predomina...	
	24		Pakistan	Asia	2 Medium ...		Medium		Medium	
	25		Germany	Europe	4 Very hig...		Unknown		Unknown	
	26		Luxembourg	Europe	4 Very hig...		Unknown		Unknown	
	27		Dominican Republic	North Ame...	3 High hu...		Medium		Medium	
	28		Switzerland	Europe	4 Very hig...		Unknown		Unknown	
	29		Nigeria	Africa	1 Low hu...		Medium		Medium	
	30		Democratic People's Republic	Asia	2 Medium ...		Unknown		Unknown	

Bertifier

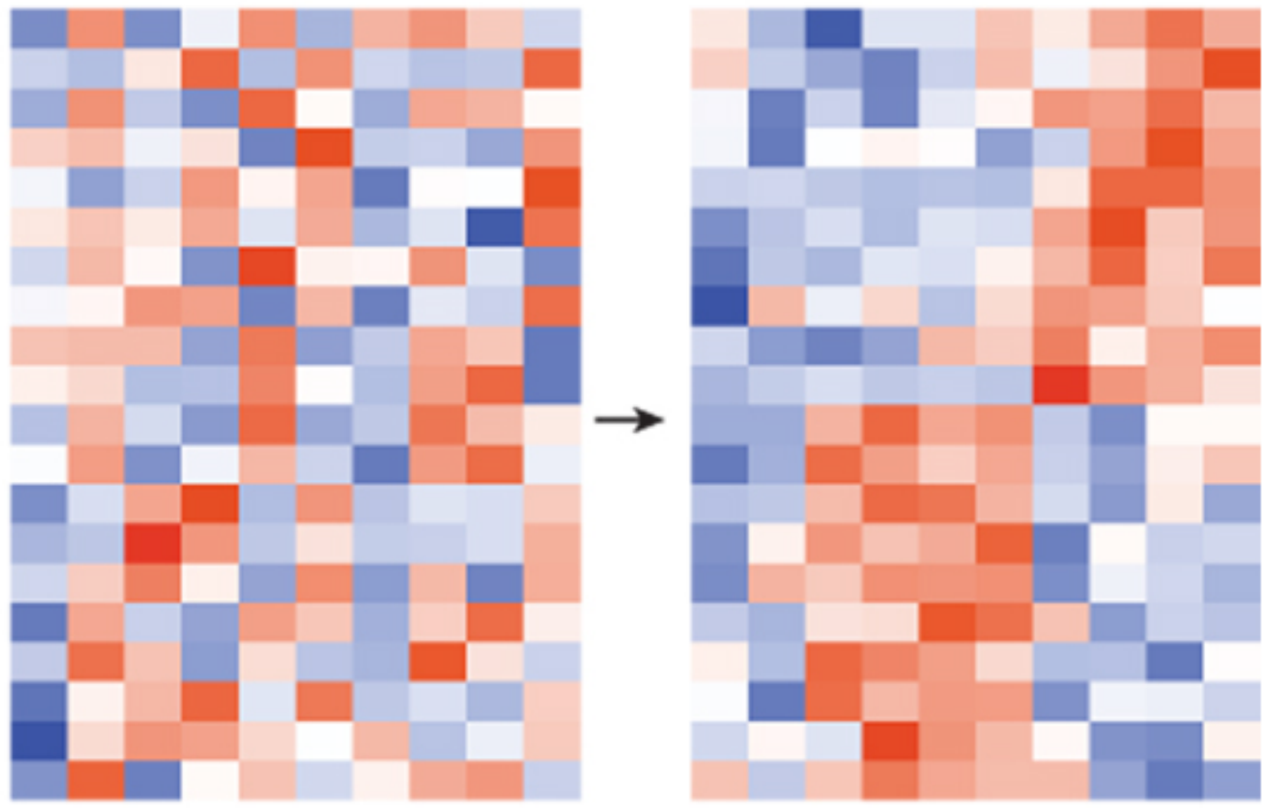
Matrix/Table representation

Authoring Interface



http://www.aviz.fr/bertifier
Charles Perin, Pierre Dragicevic and Jean-Daniel Fekete

Pixel Based Displays



Each cell is a "pixel", value encoded in color / value

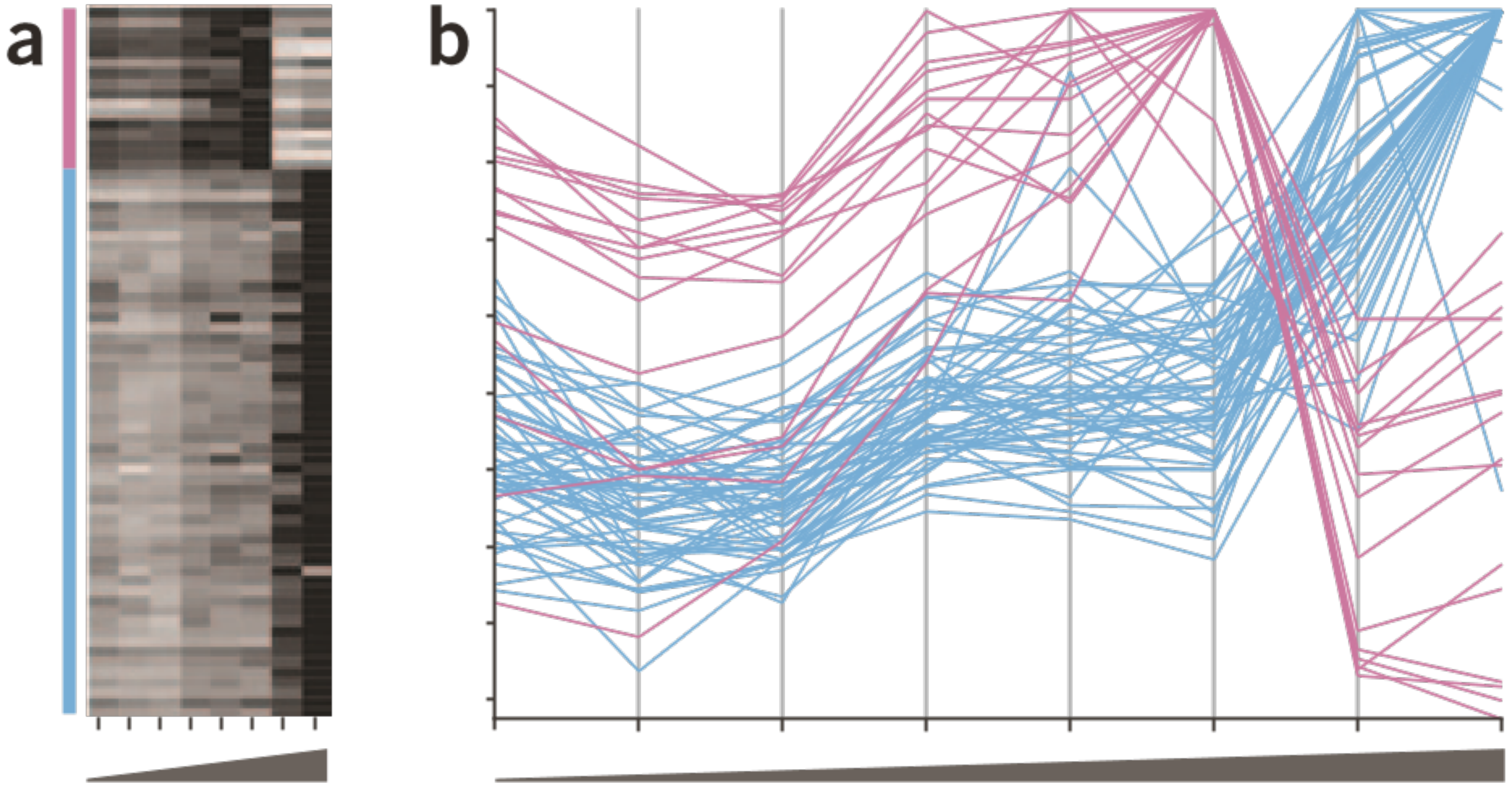
Ordering critical for interpretation

If no ordering inherent, clustering is used

Scalable – 1 px per item

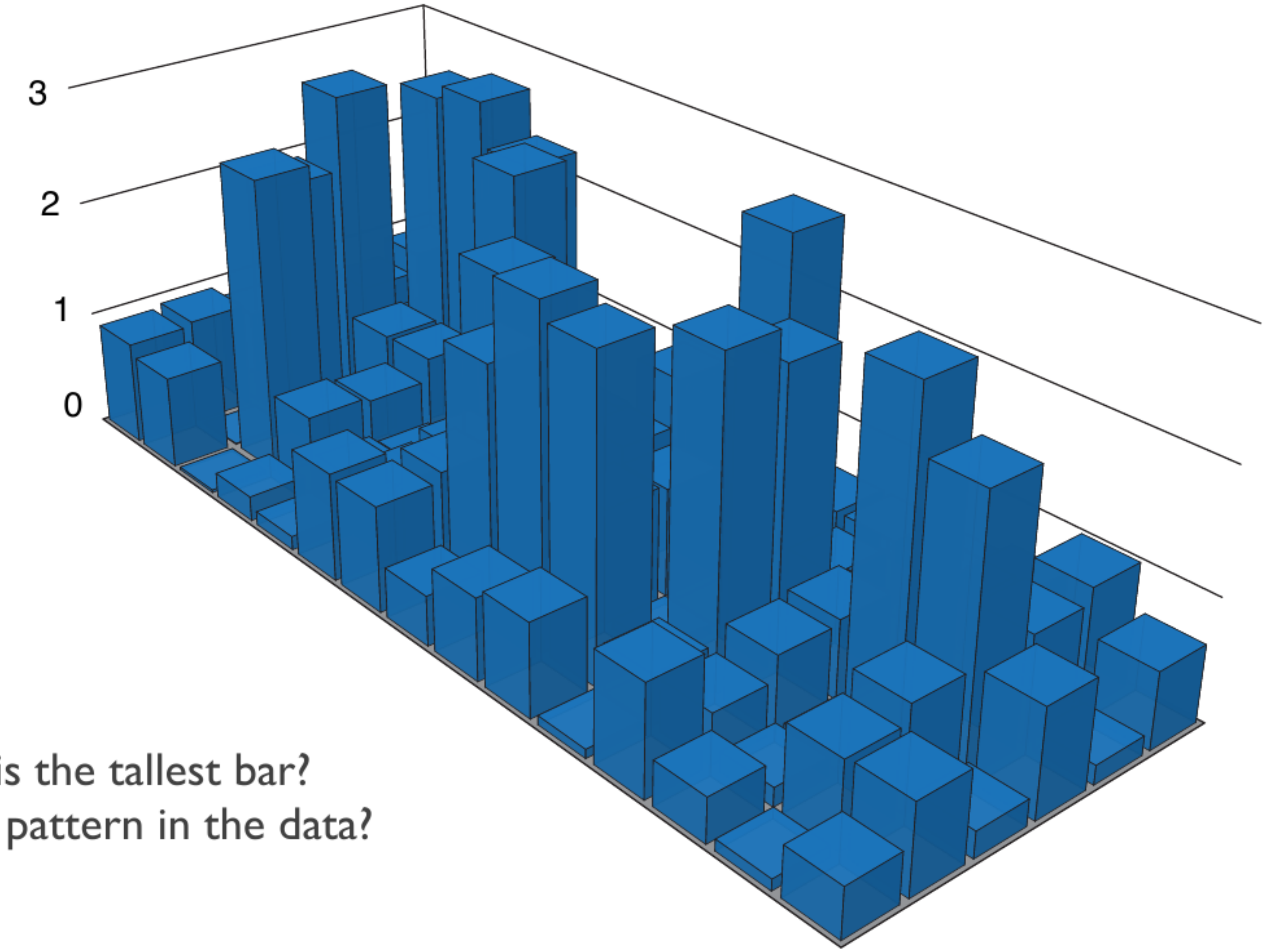
Good for homogeneous data

same scale & type



[Gehlenborg & Wong 2012]

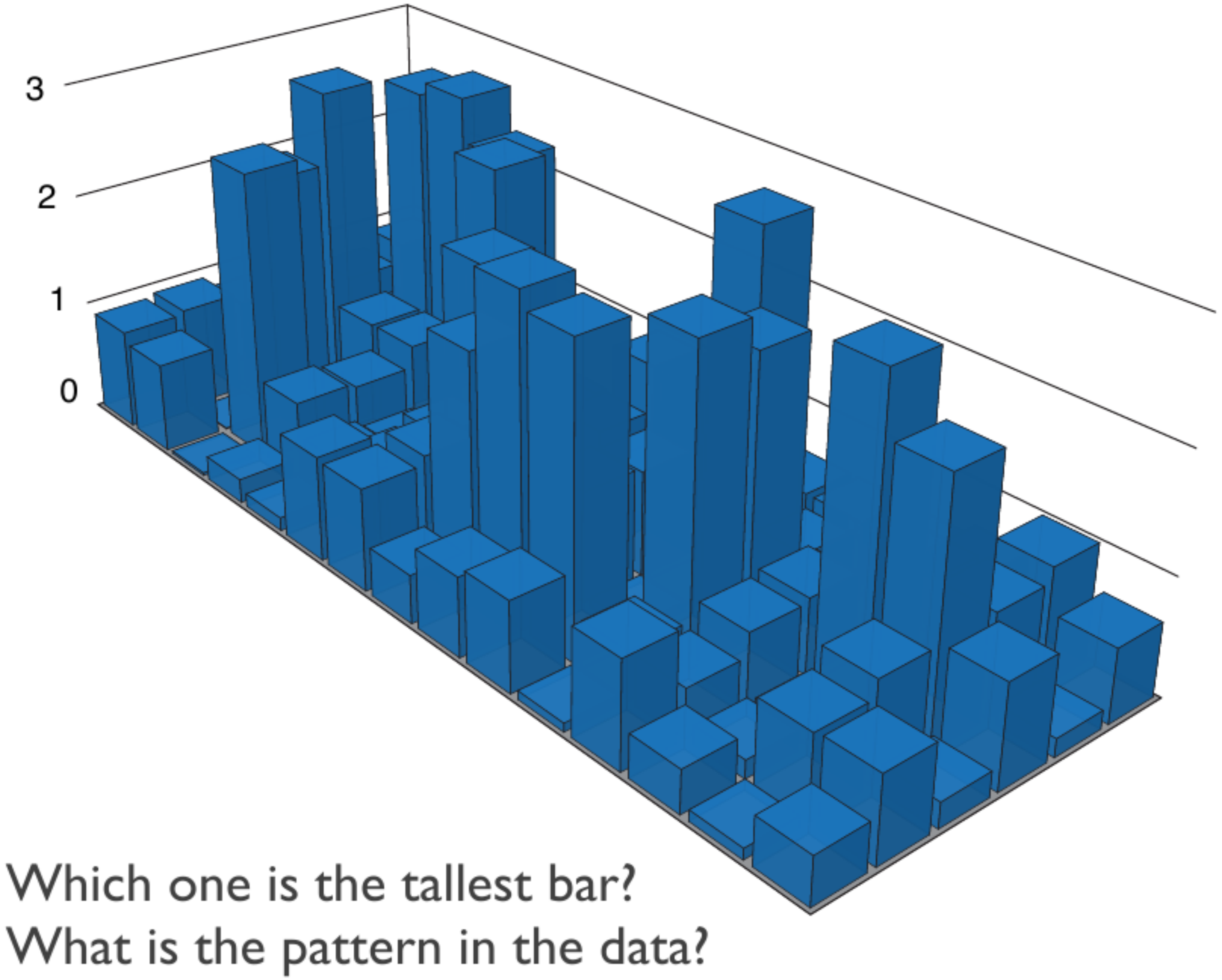
3D Pitfall: Occlusion & Perspective

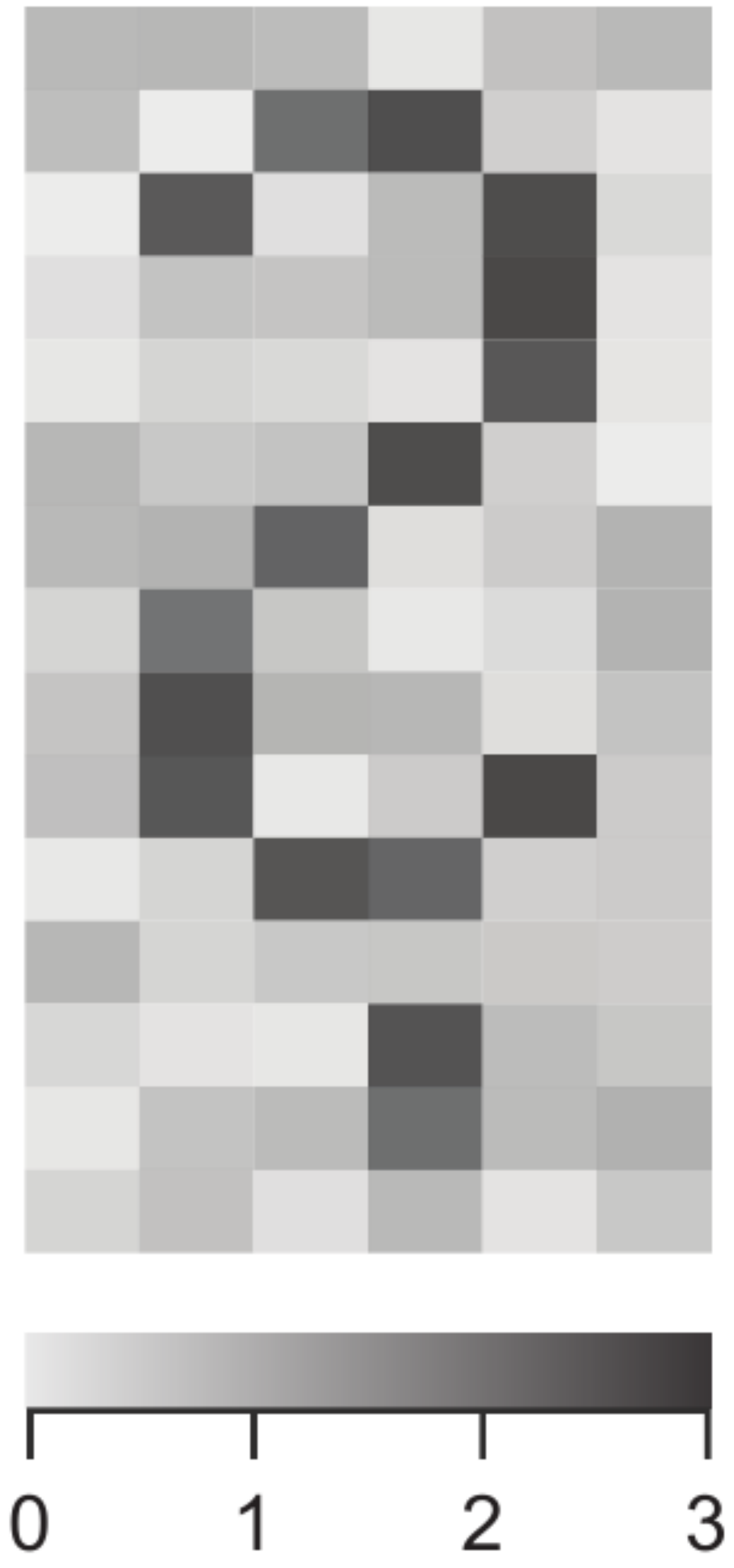


Which one is the tallest bar?
What is the pattern in the data?

[Gehlenborg and Wong, Nature Methods, 2012]

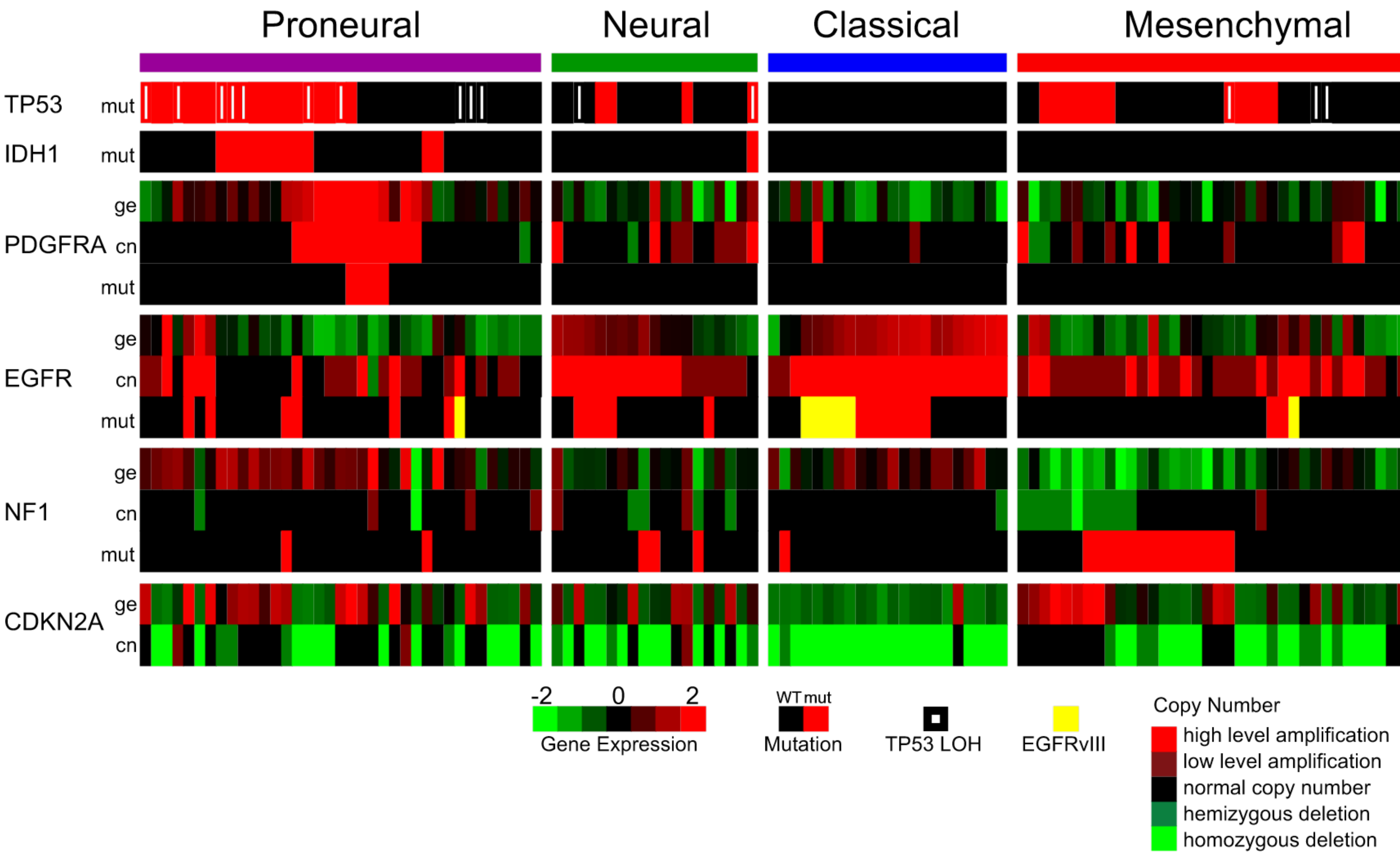
3D Pitfall: Occlusion & Perspective





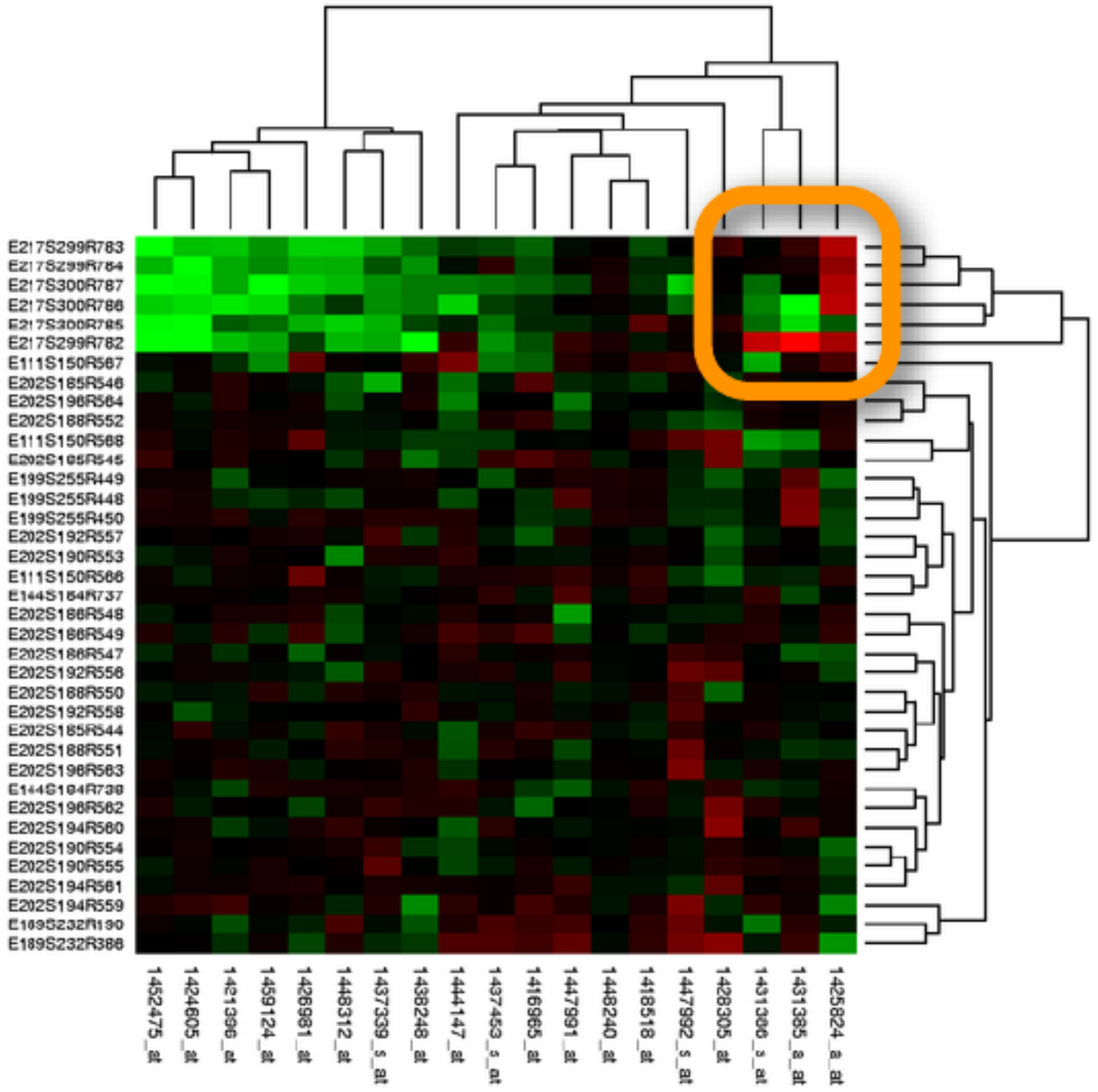
[Gehlenborg and Wong, Nature Methods, 2012]

Heterogeneous Data?

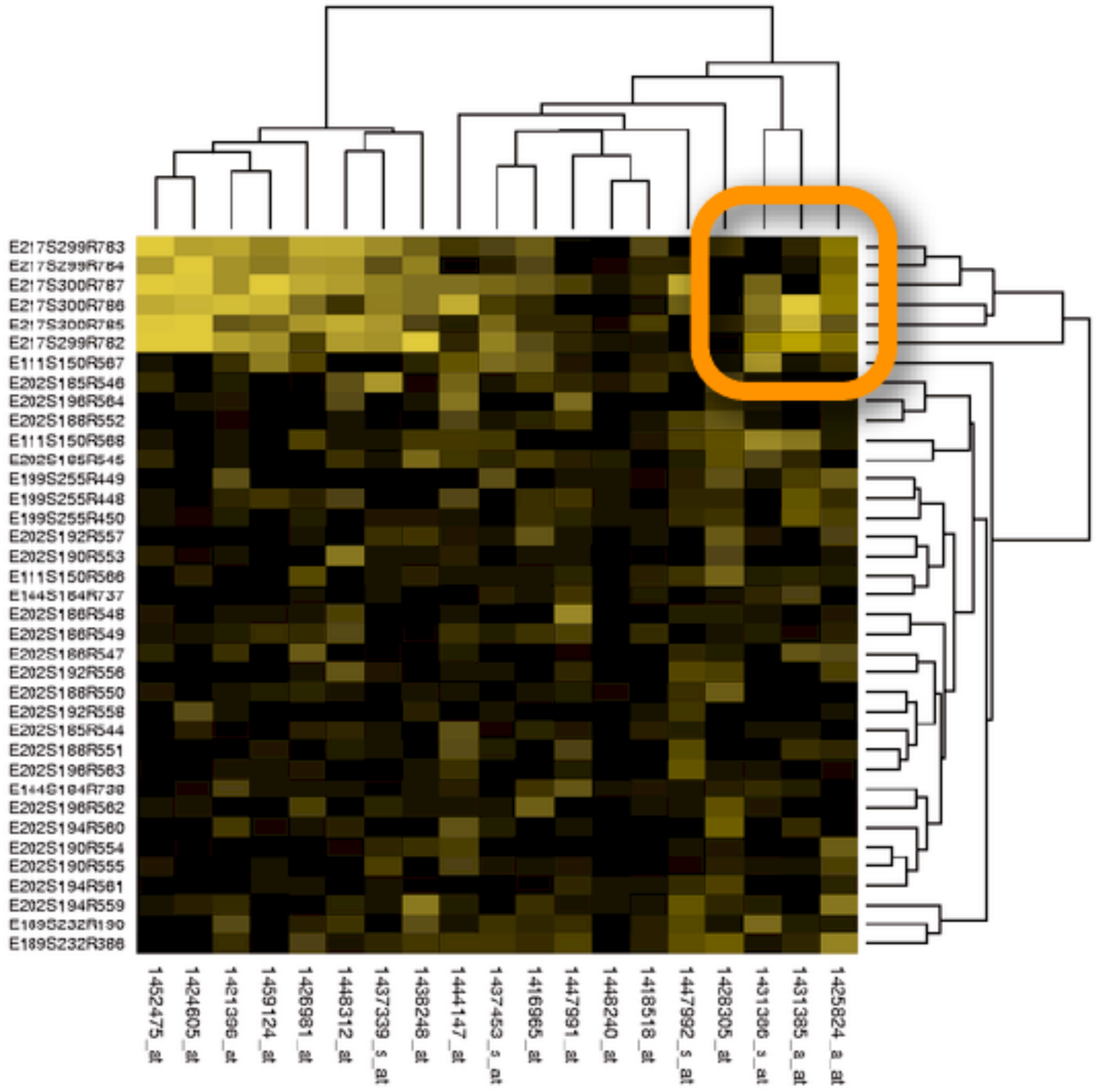


[Verhaak 2012]

Bad Color Mapping

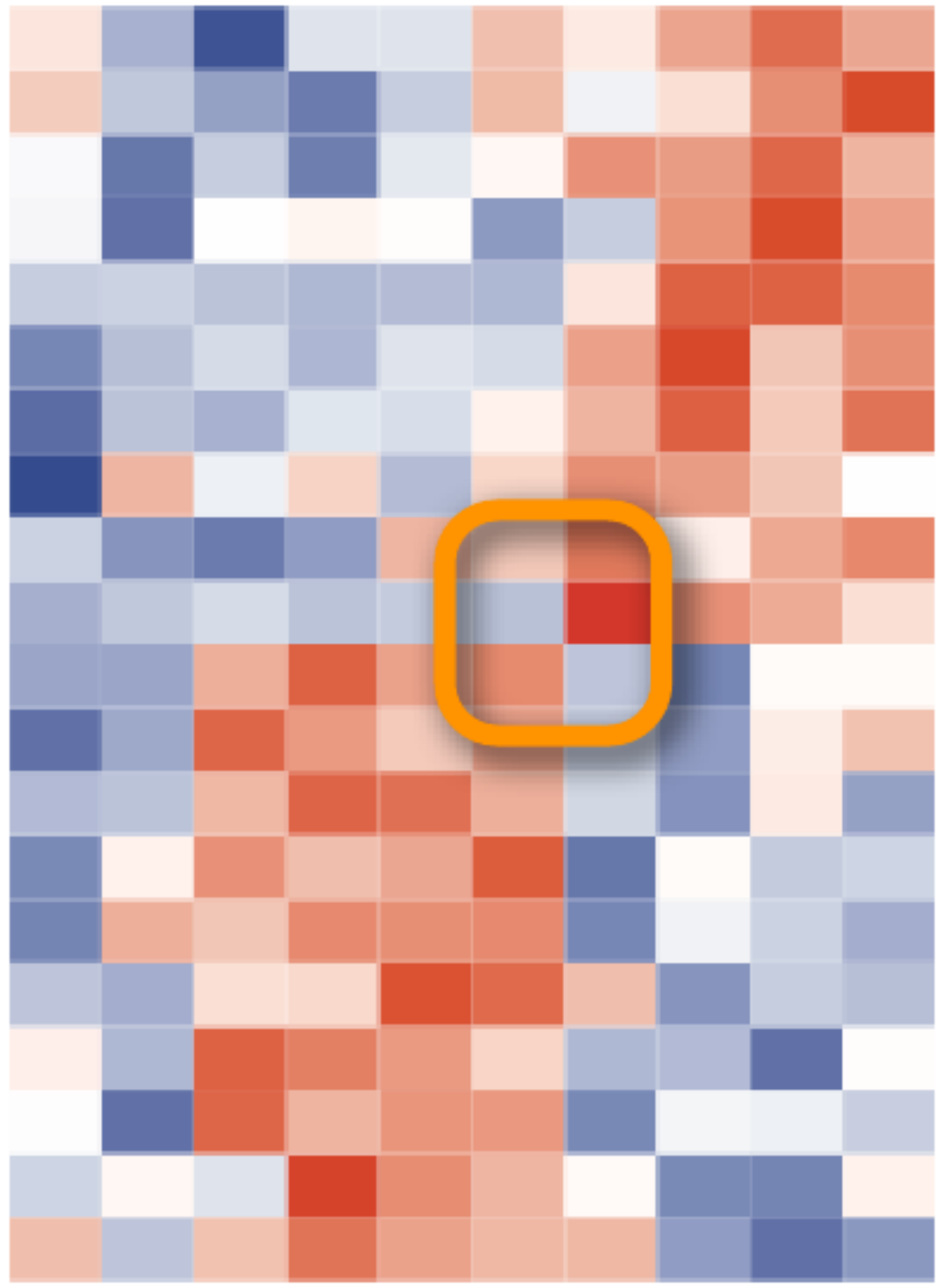


Normal Vision

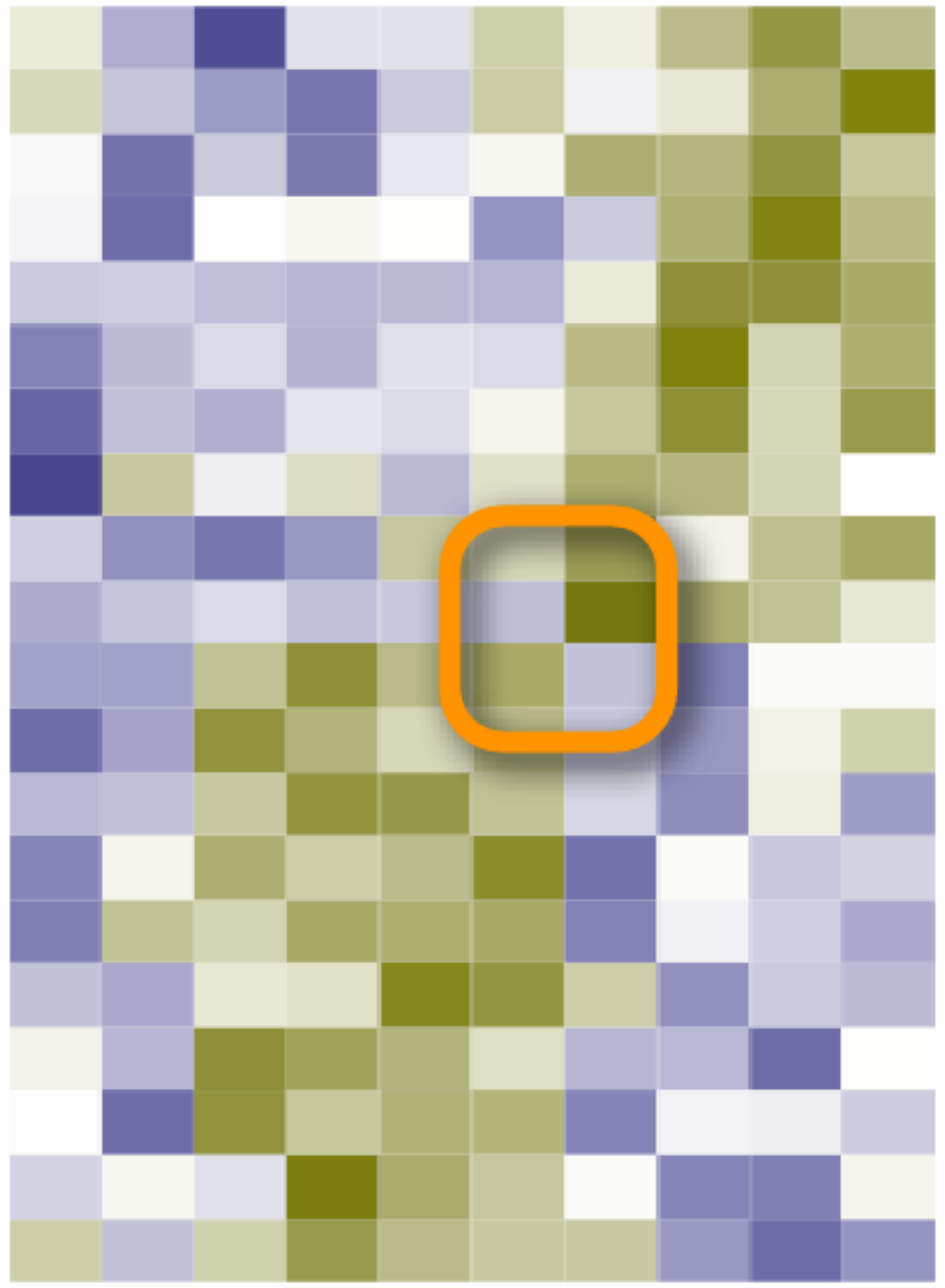


Deuteranope Vision
(“Red-Green Blindness”)

Good Color Mapping

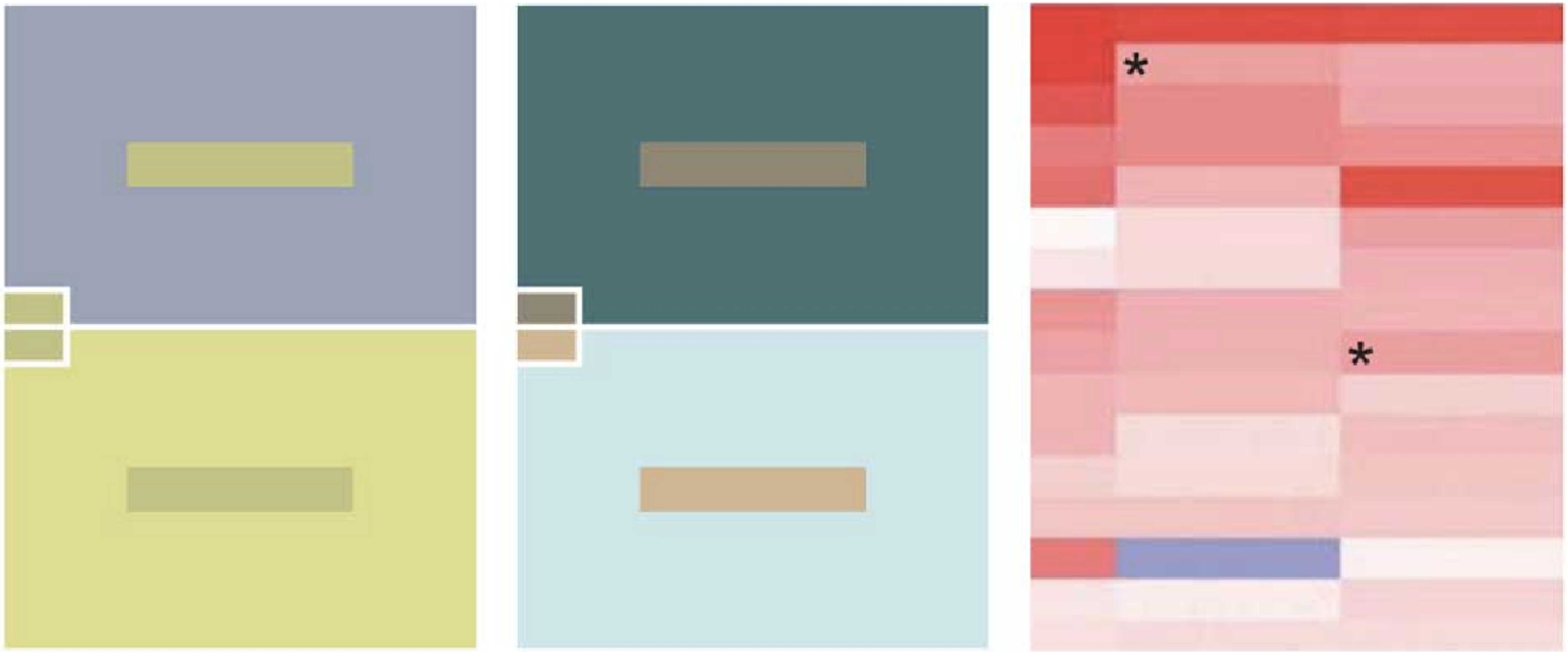


Normal Vision

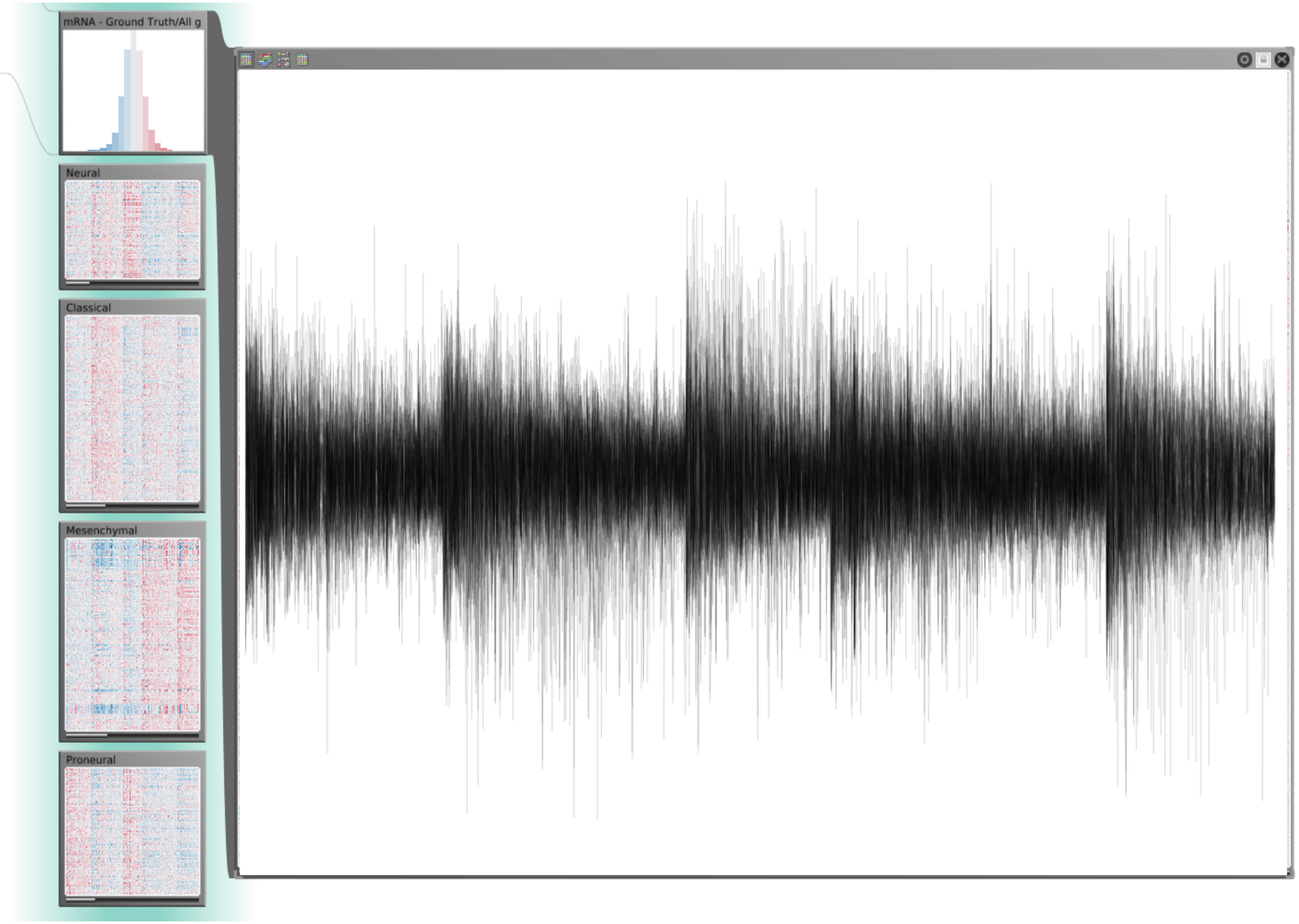


Deuteranope Vision
("Red-Green Blindness")

Color is relative!



Clustered Heat Map



Filling Space

Non-Tabular Space Filling Layouts

HiVE example: London property

partitioning attributes

house type
neighborhood
sale time

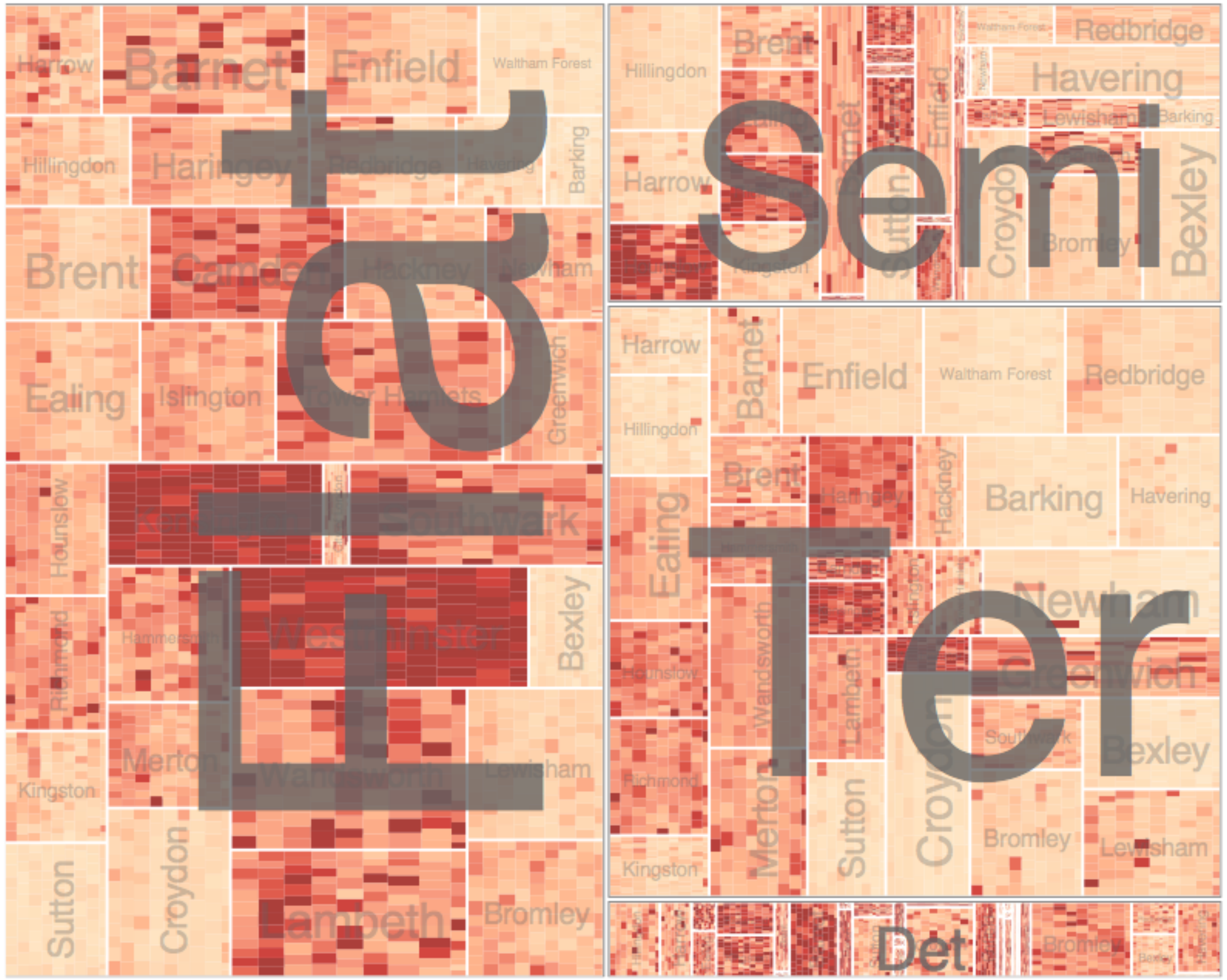
encoding attributes

average price (color)
number of sales (size)

results

between neighborhoods, different housing distributions

within neighborhoods, similar prices



Slingsby 2009

Dense pixel display: VisDB

represent each data item, or each attribute in an item as a single pixel

can fit as many items on the screen as there are pixels, on the order of millions

relies heavily on color coding

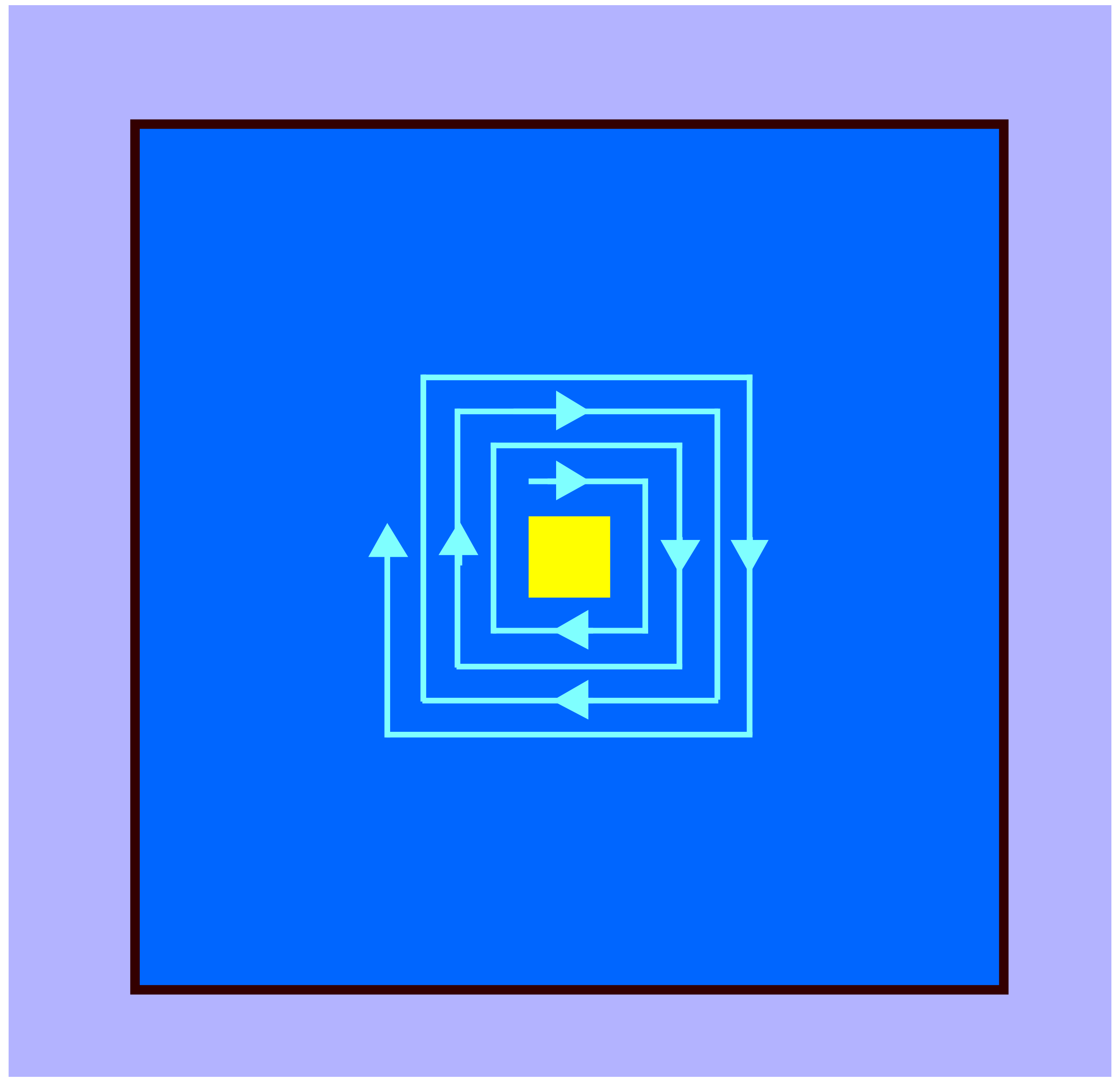
challenge: what's the layout?

The data...

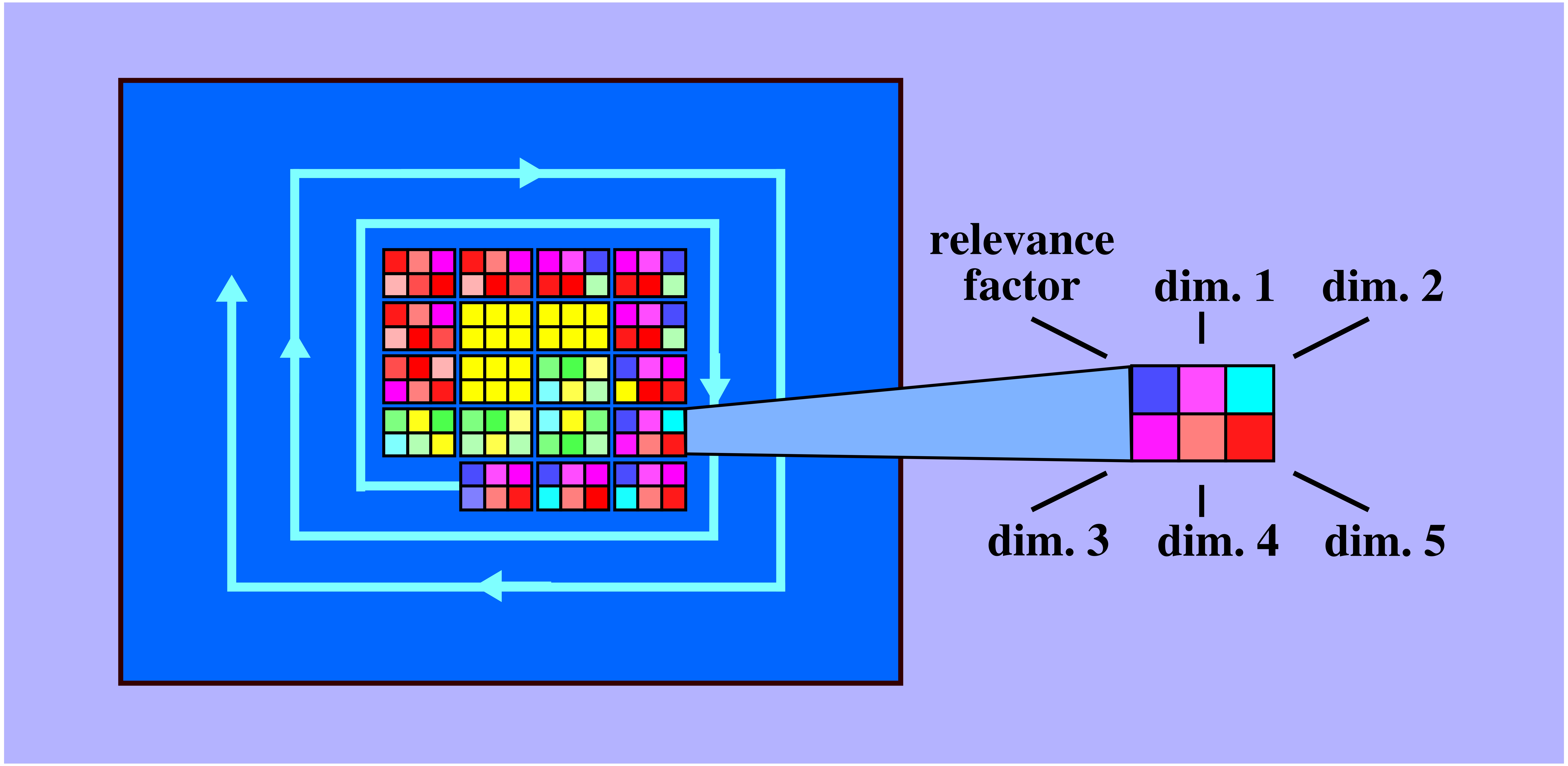
large database where each item has multiple attributes (on the order of 10)

goal: visualize the relevance of set of items which satisfy a query

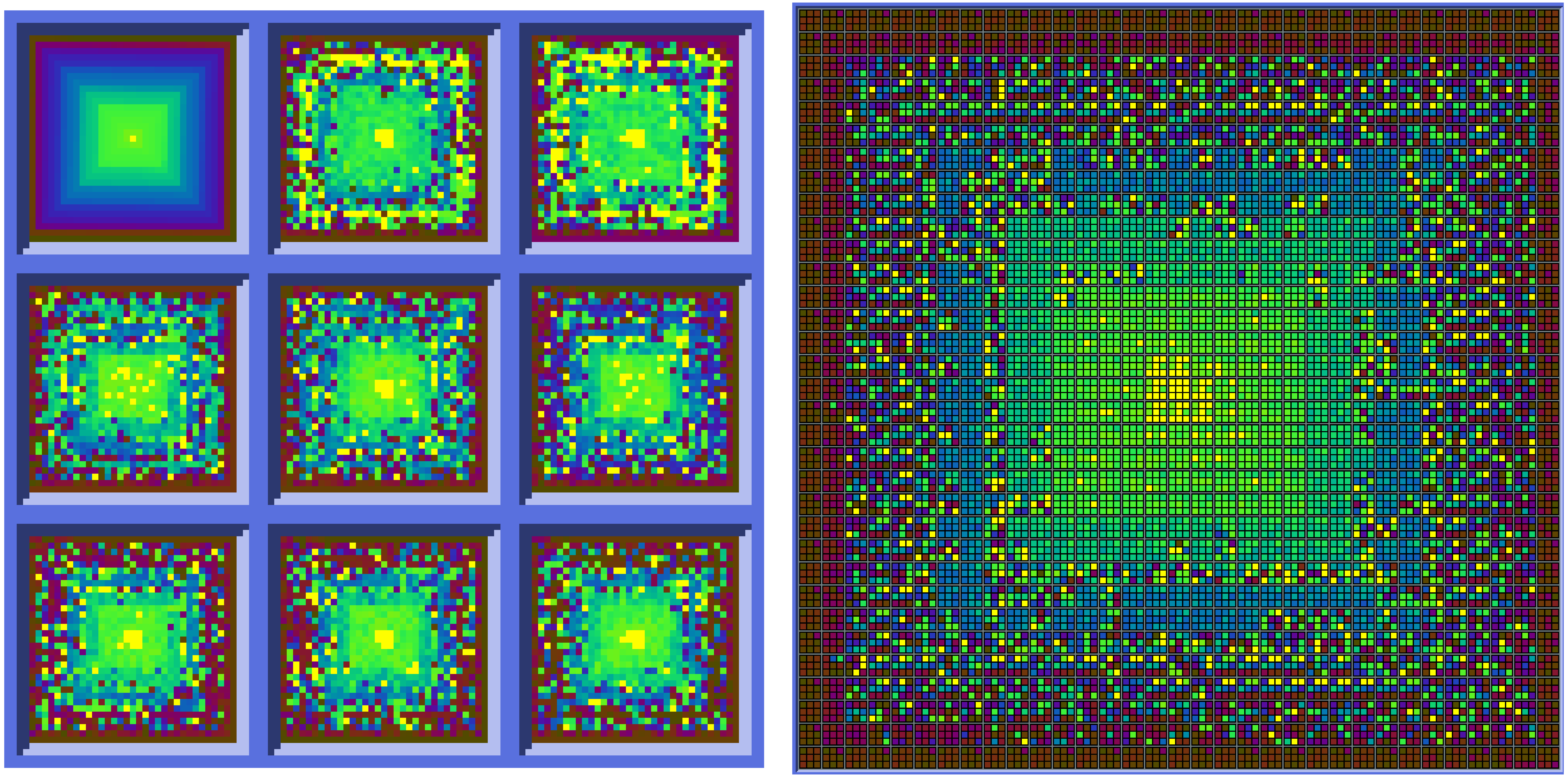
plot out data items in a spiral pattern, ordered by relevance



Keim, Kreigel, 1994



Keim, Kreigel, 1994



Keim, Kreigel, 1994