

Visualization for Data Science

The Zoo



<https://www.youtube.com/watch?v=dbazk3fIWBU>

This lecture is very dense; I suggest you do it in phases.

It exposes you to a wide variety of charts (i.e., idioms)

You can watch the video and take notes on the slides.

You can also read the textbook (Chapter 7, [available through UBC library](#)) and take notes on the slides.

Either way, welcome to the Visualization Zoo of charts

Textbook name: Visualization Analysis and Design by Tamara Munzner

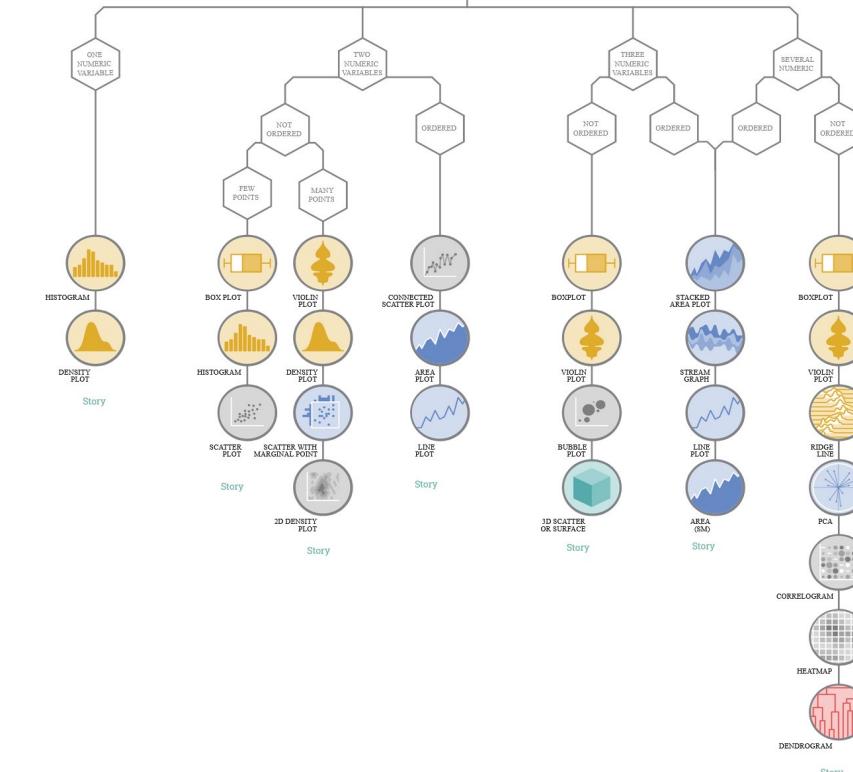
Visualization “Catalogues”

- The Data Visualization Catalogue

<http://www.datavizcatalogue.com/>

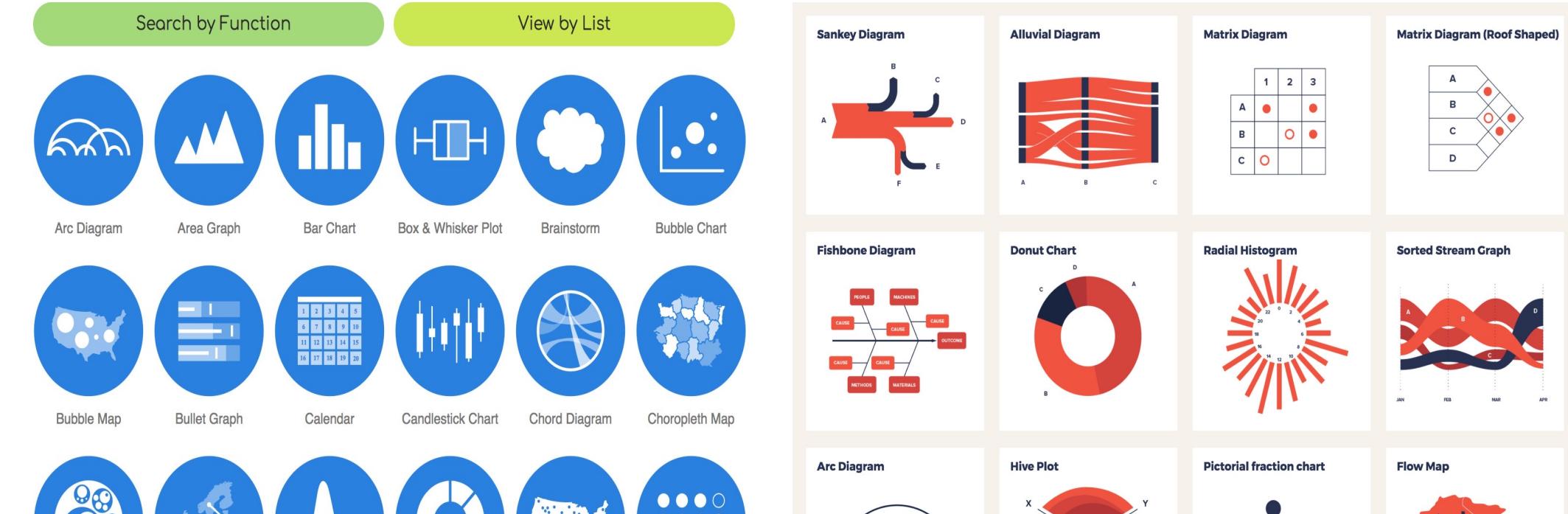
What kind of data do you have? Pick the main type using the buttons below. Then let the decision tree guide you toward your graphic possibilities.

Numeric Categoric Num & Cat Maps Network Time series



- Data to Viz

<https://www.data-to-viz.com/>

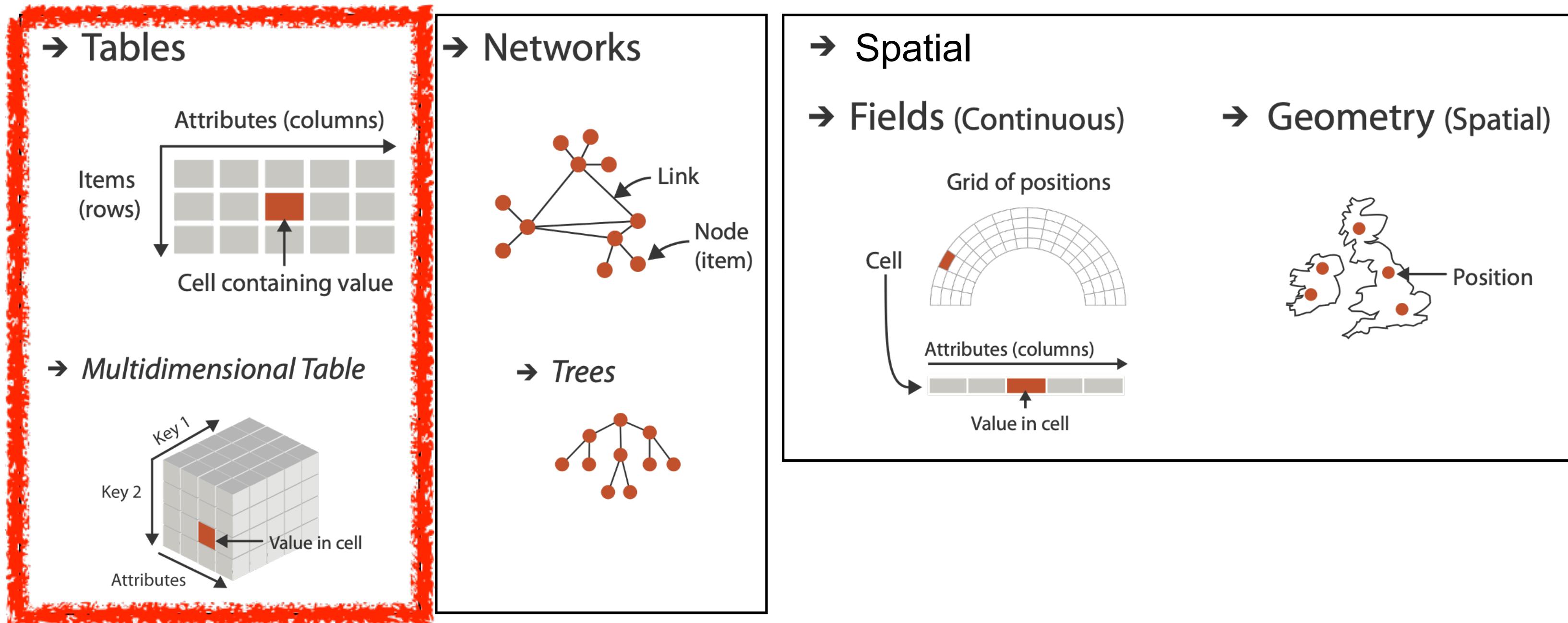


- DataVizProject

<http://datavizproject.com/>

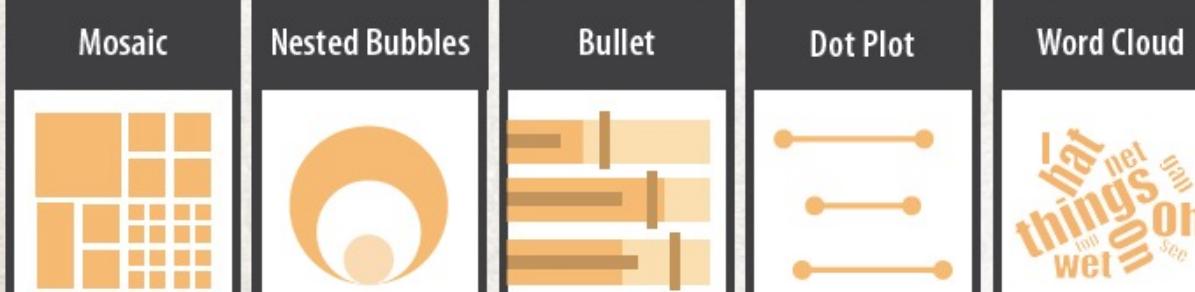
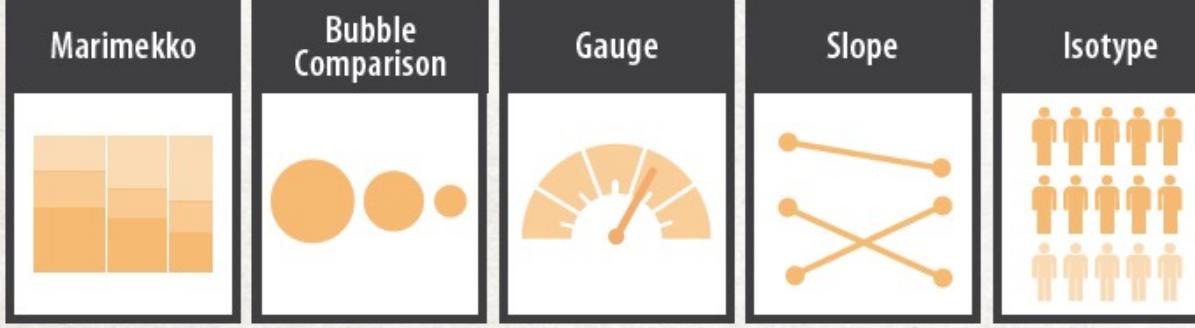
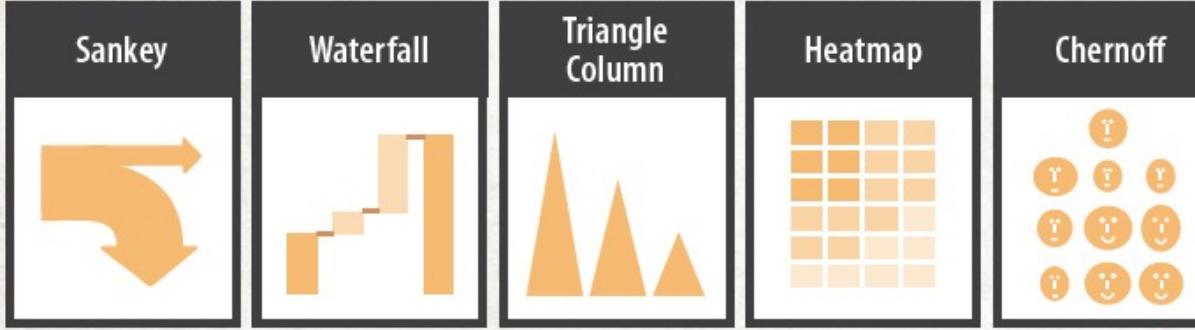
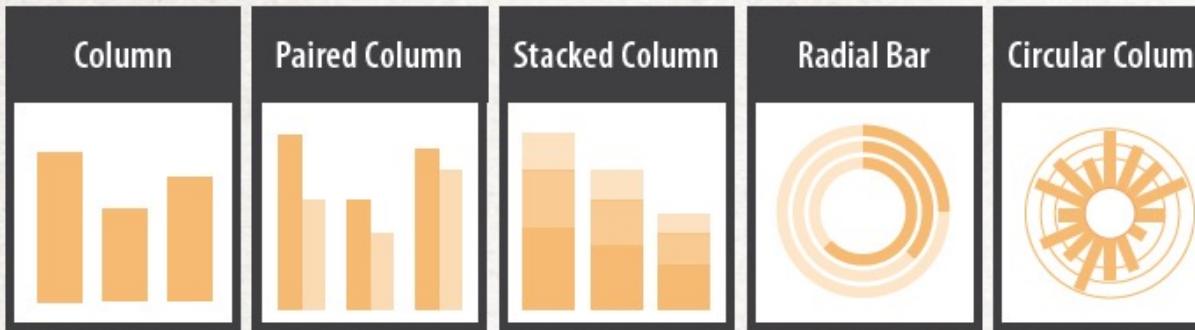
Focus on Tables

→ Dataset Types



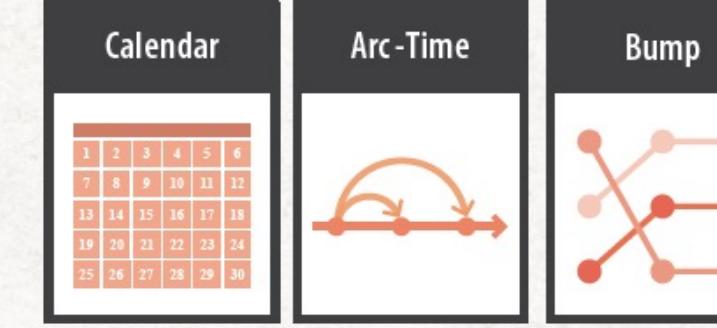
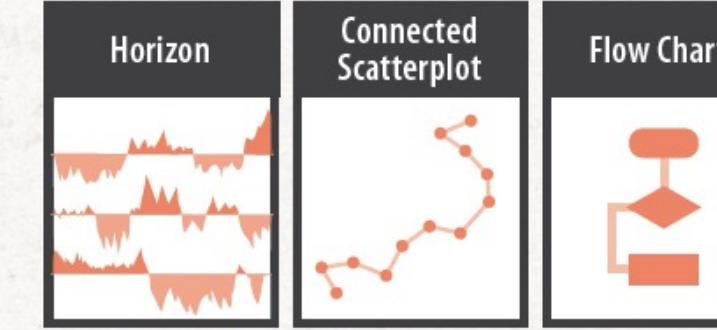
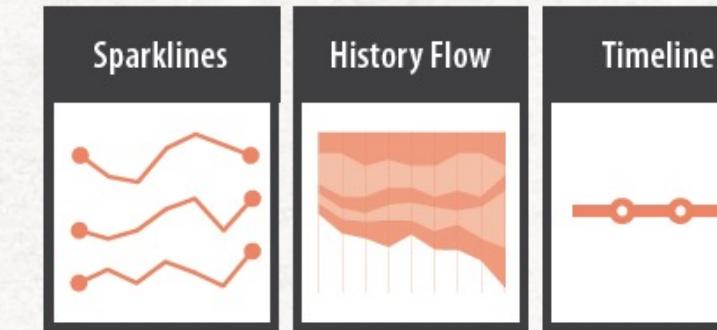
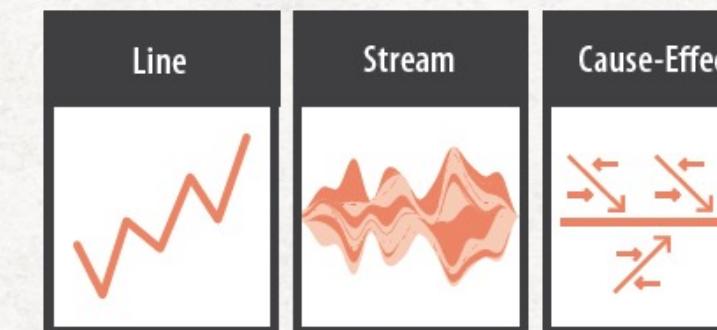
COMPARING CATEGORIES

Compare values across categories



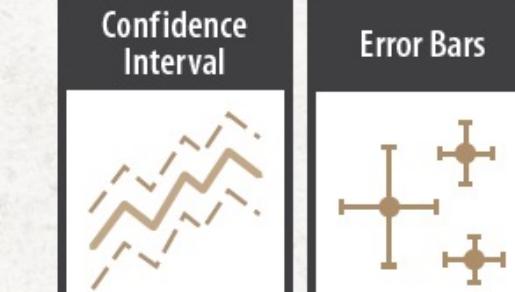
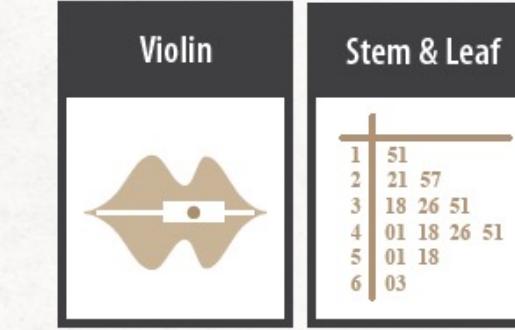
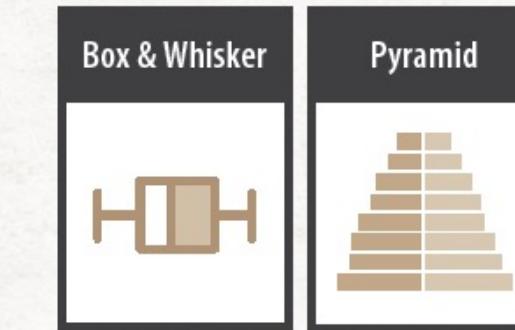
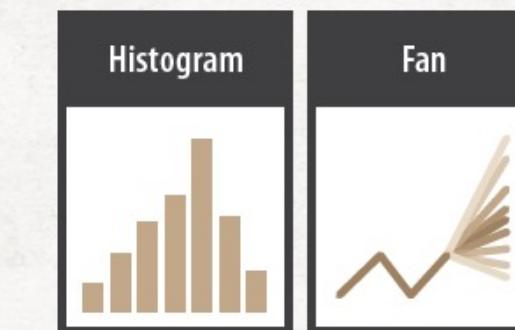
TIME

Track changes over time



DISTRIBUTION

Representation of the distribution of data



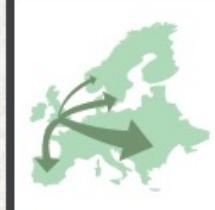
GEOSPATIAL

Relates data to its geography

Map



Flow Map



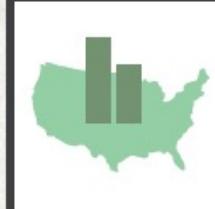
Icon Map



Choropleth



Map with Columns



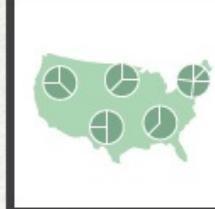
Isopleth



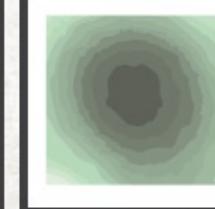
Cartogram



Map with Pie Charts



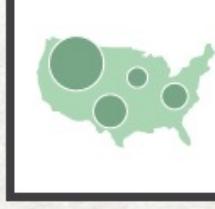
Contour



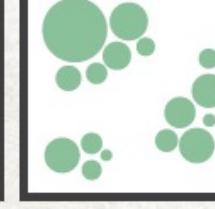
Non-Contiguous Cartogram



Bubble Map



Dorling Map



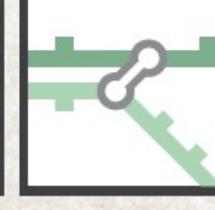
Connection Map



Point Map



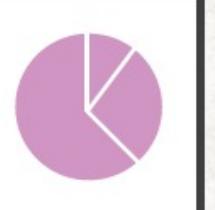
Subway Map



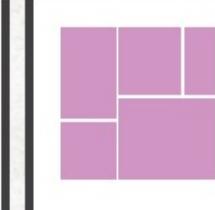
PART-TO-WHOLE

Relates the part of a variable to its total

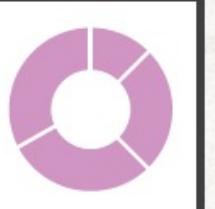
Pie



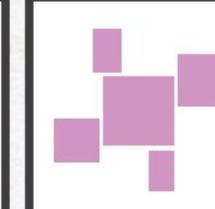
Treemap



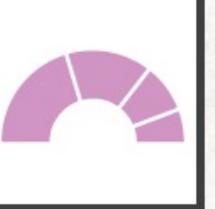
Donut



Square Cloud



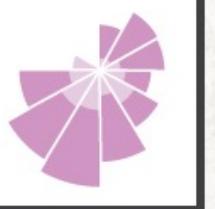
Arc



Voronoi



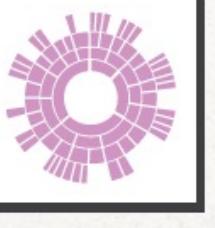
Nightingale



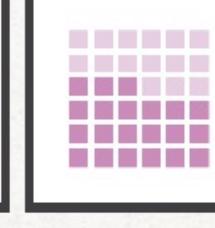
Triangle Treemap



Sunburst



Waffle



RELATIONSHIP

Illustrates correlations or relationships between variables

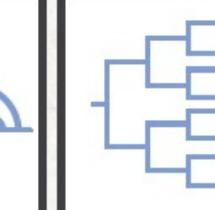
Scatterplot



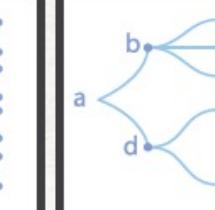
Arc-Connection



Dendrogram



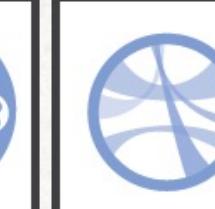
Word Tree



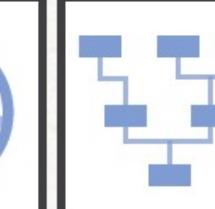
Circle Packing



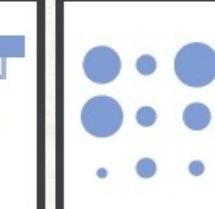
Chord



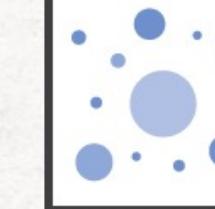
Tree



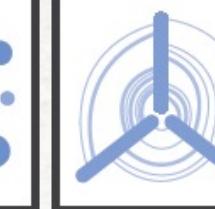
Correlation Matrix



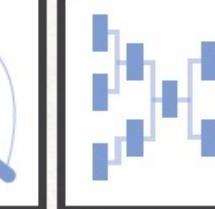
Bubble



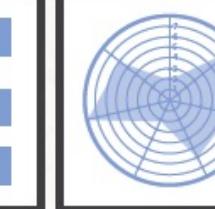
Hive



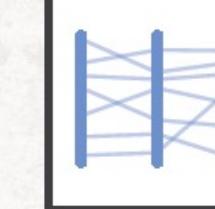
Double Tree



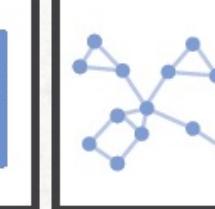
Radar



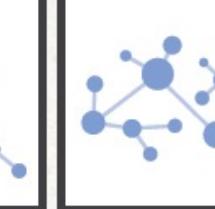
Parallel Coordinates



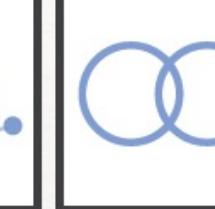
Force-Directed



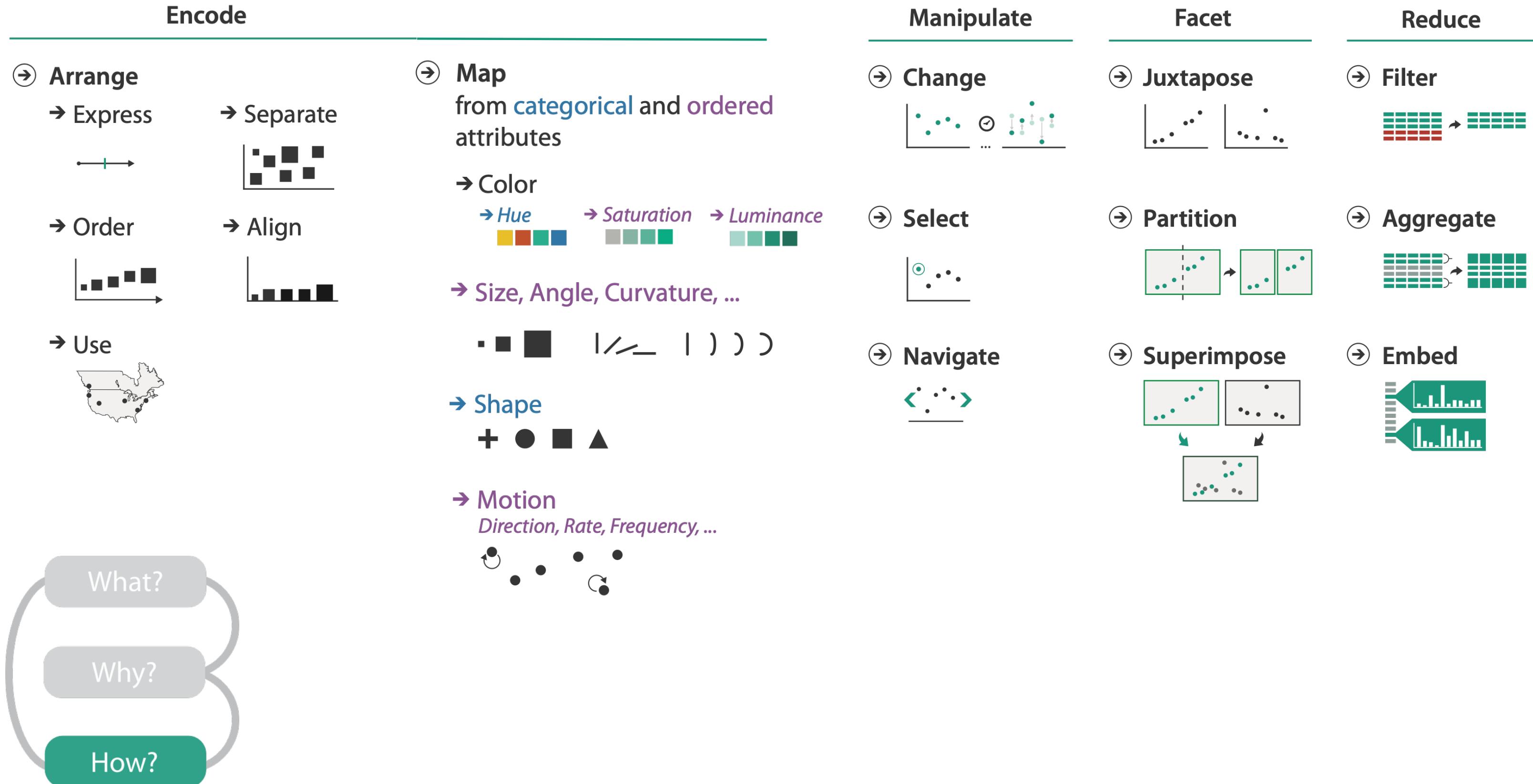
Network



Venn Diagram



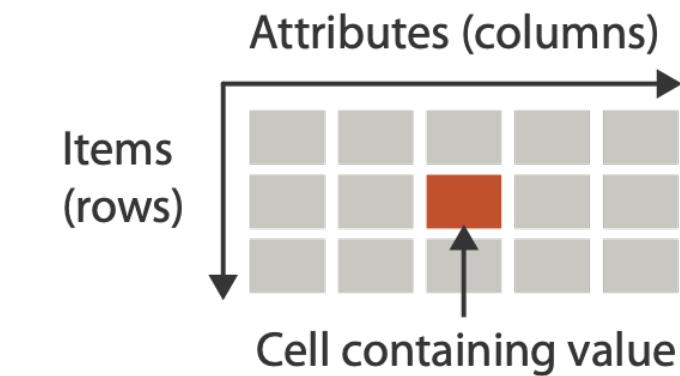
How?



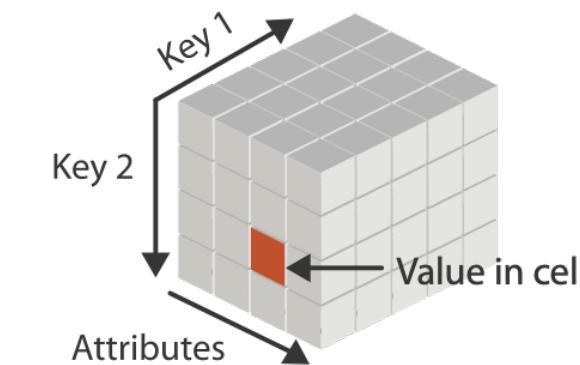
Keys and values

- key
 - independent attribute
 - used as unique index to look up items
 - simple tables: 1 key
 - multidimensional tables: multiple keys
- value
 - dependent attribute, value of cell
- classify arrangements by keys used
 - 0, 1, 2, ...

→ Tables



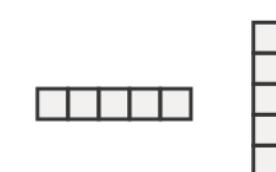
→ *Multidimensional Table*



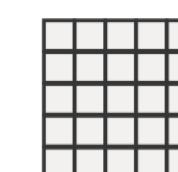
→ 0 Keys

④ Express Values

→ 1 Key
List



→ 2 Keys
Matrix



Encode

→ Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



Idiom: scatterplot

- express values (magnitudes)

- quantitative attributes

- no keys, only values

- data

- 2 quant attrs

- mark: points

- channels

- horiz + vert position

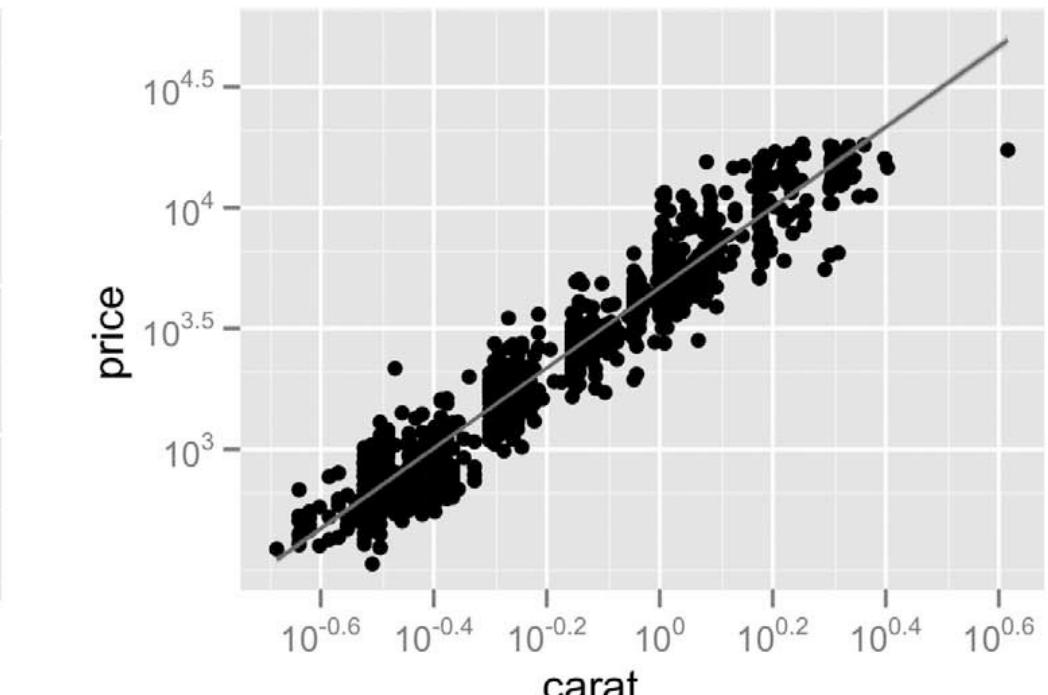
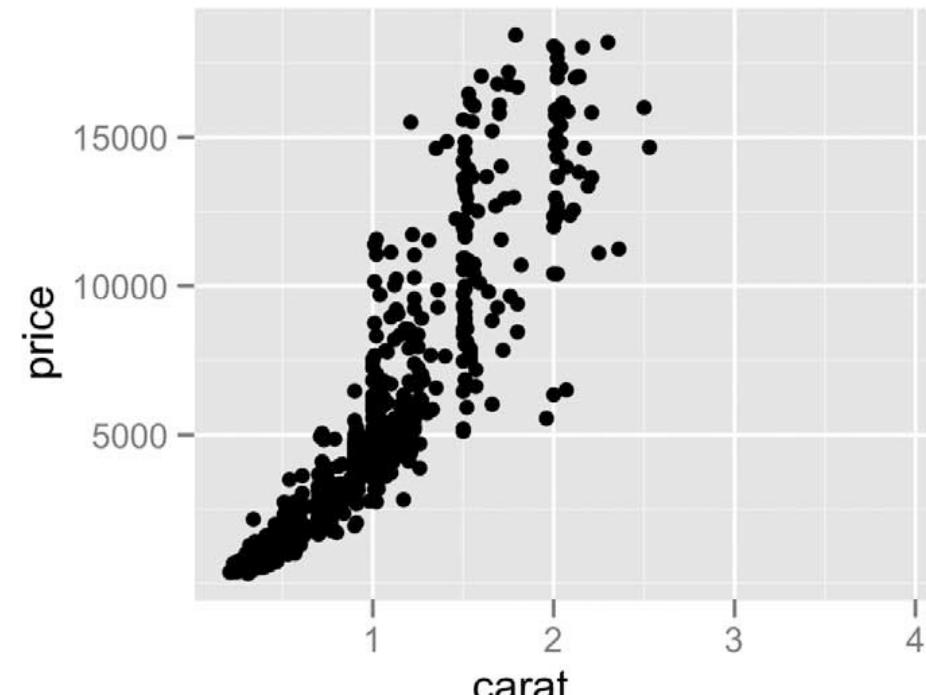
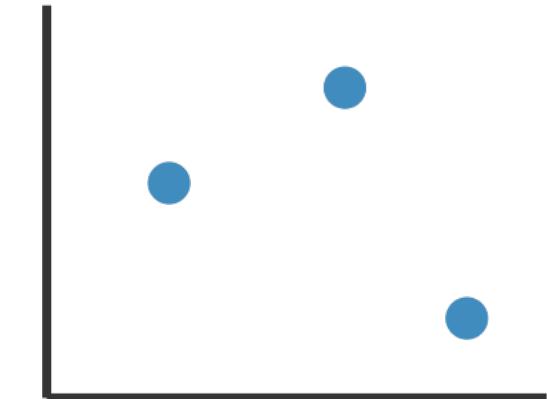
- tasks

- Providing overviews, characterize distributions, find trends, outliers and correlation, locate clusters

- scalability

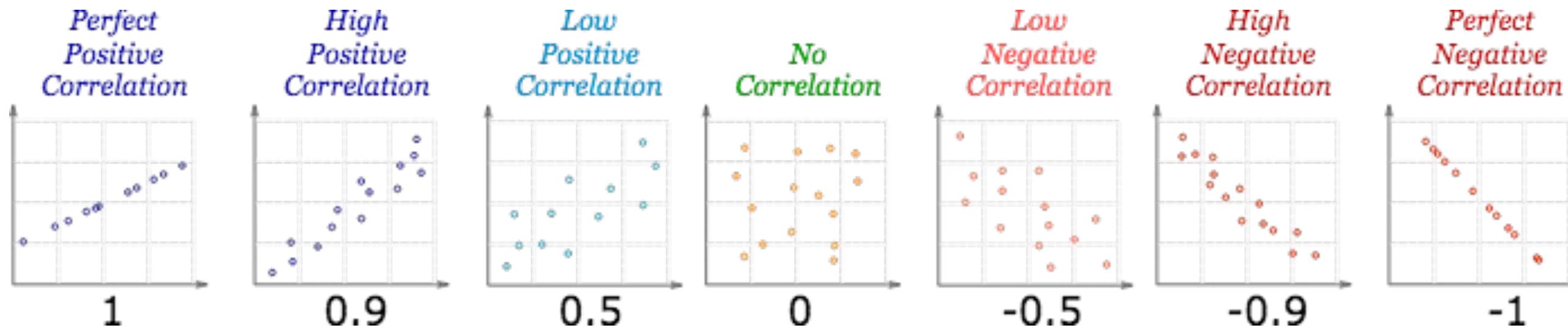
- hundreds of items

→ Express Values



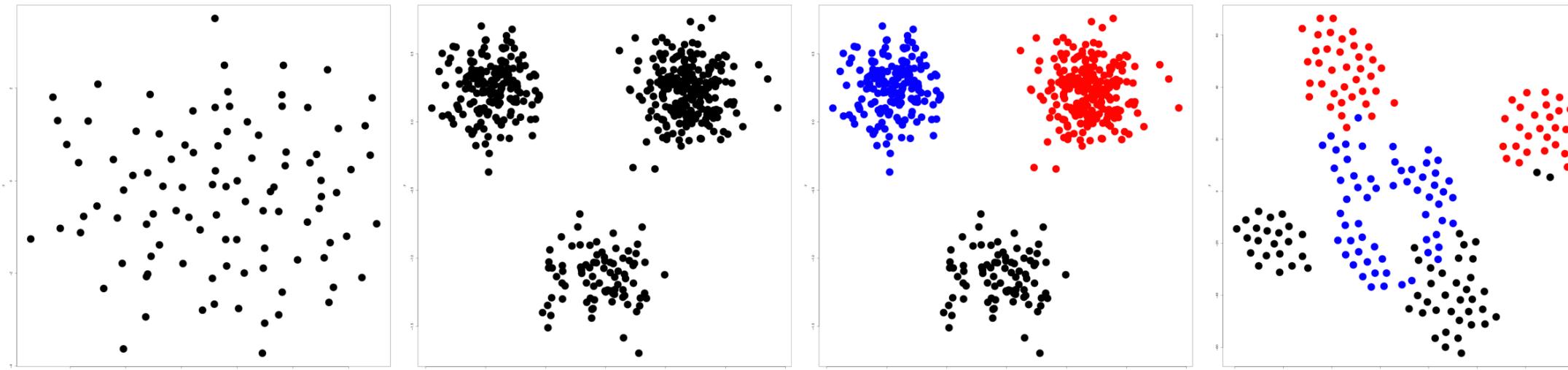
Scatterplot tasks

- correlation



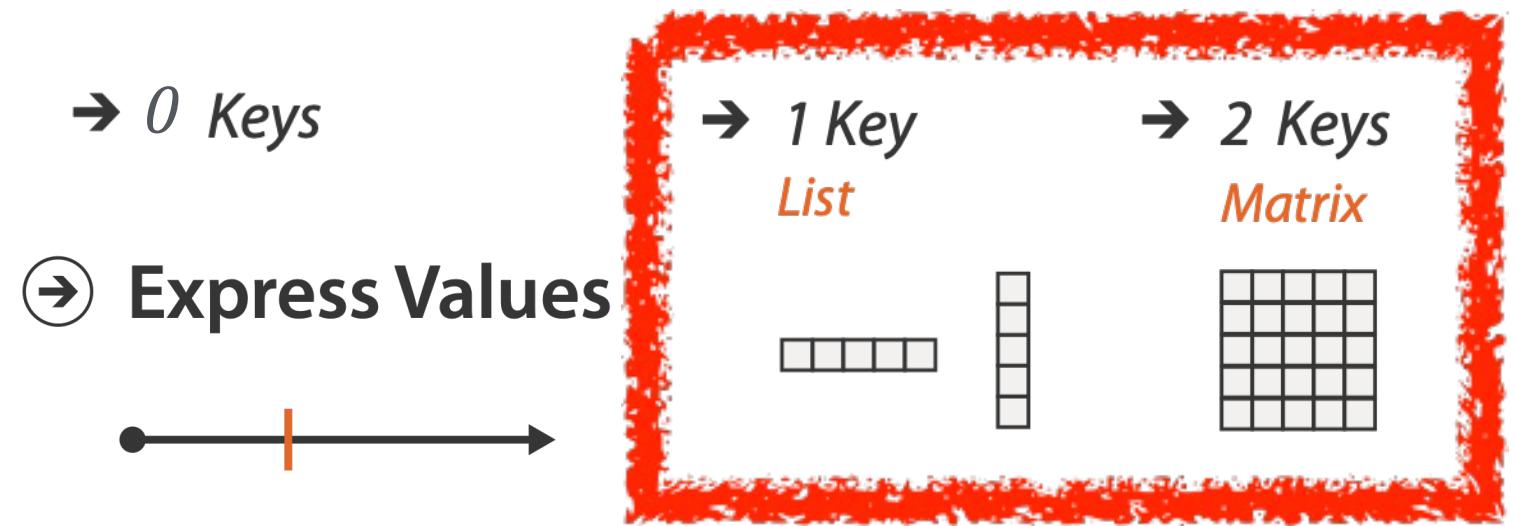
<https://www.mathsisfun.com/data/scatter-xy-plots.html>

- clusters/groups, and clusters vs classes



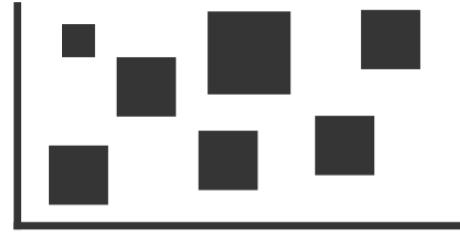
<https://www.cs.ubc.ca/labs/imager/tr/2014/DRVisTasks/>

Some keys



Some keys: Categorical regions

→ Separate



→ Order



→ Align

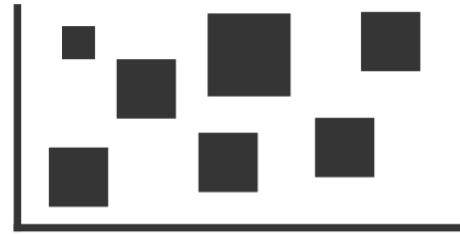


The **expressiveness principle** dictates that the visual encoding should express all of, and only, the information in the dataset attributes.

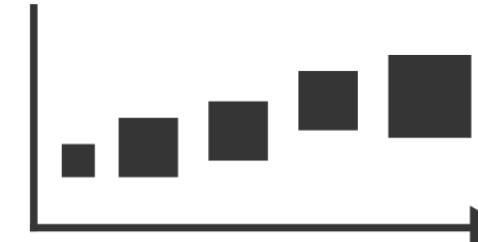
The most fundamental expression of this principle is that **ordered data** should be shown in a way that our perceptual system **intrinsically senses as ordered**. Conversely, **unordered data** should not be shown in a way that perceptually implies an **ordering** that does not exist.

Regions: Separate, order, align

→ Separate



→ Order



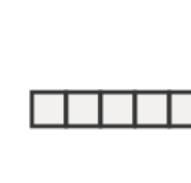
→ Align



- regions: contiguous bounded areas distinct from each other
 - separate into spatial regions: one mark per region (for now)
- use categorical or ordered attribute to separate into regions
 - no conflict with expressiveness principle for categorical attributes
- use ordered attribute to order and align regions

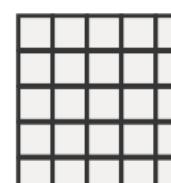
→ 1 Key

List

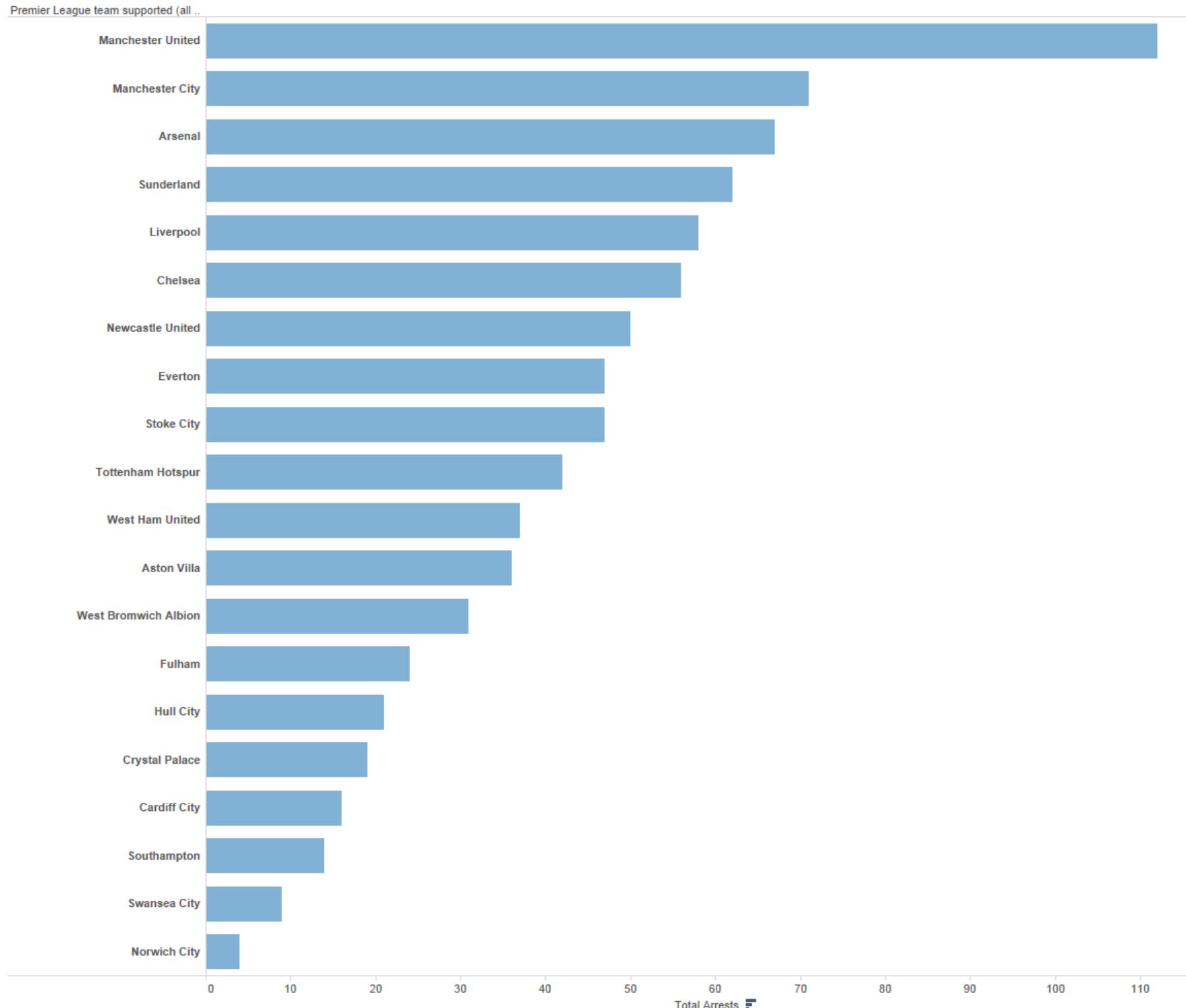


→ 2 Keys

Matrix

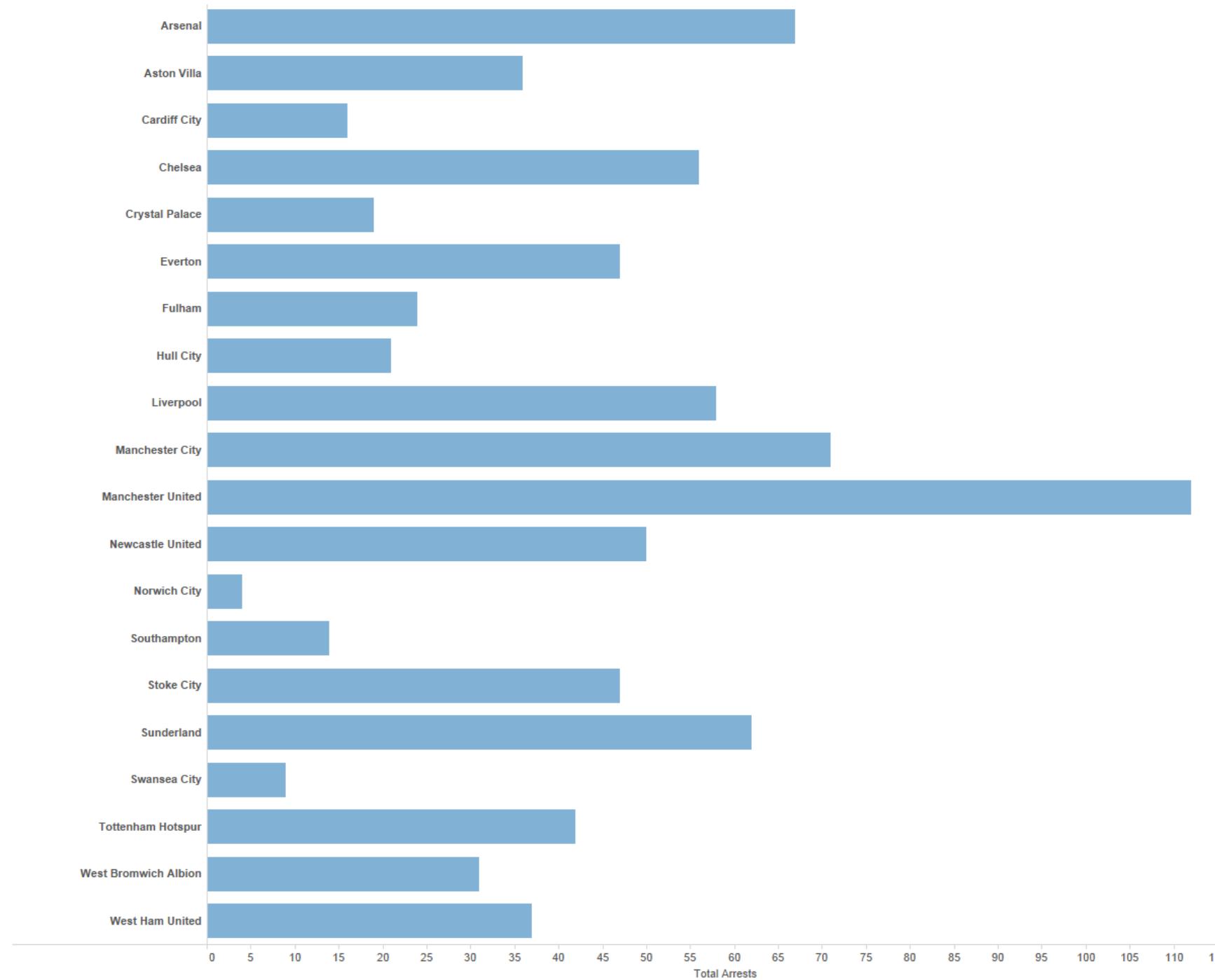


Separated and aligned and ordered best case



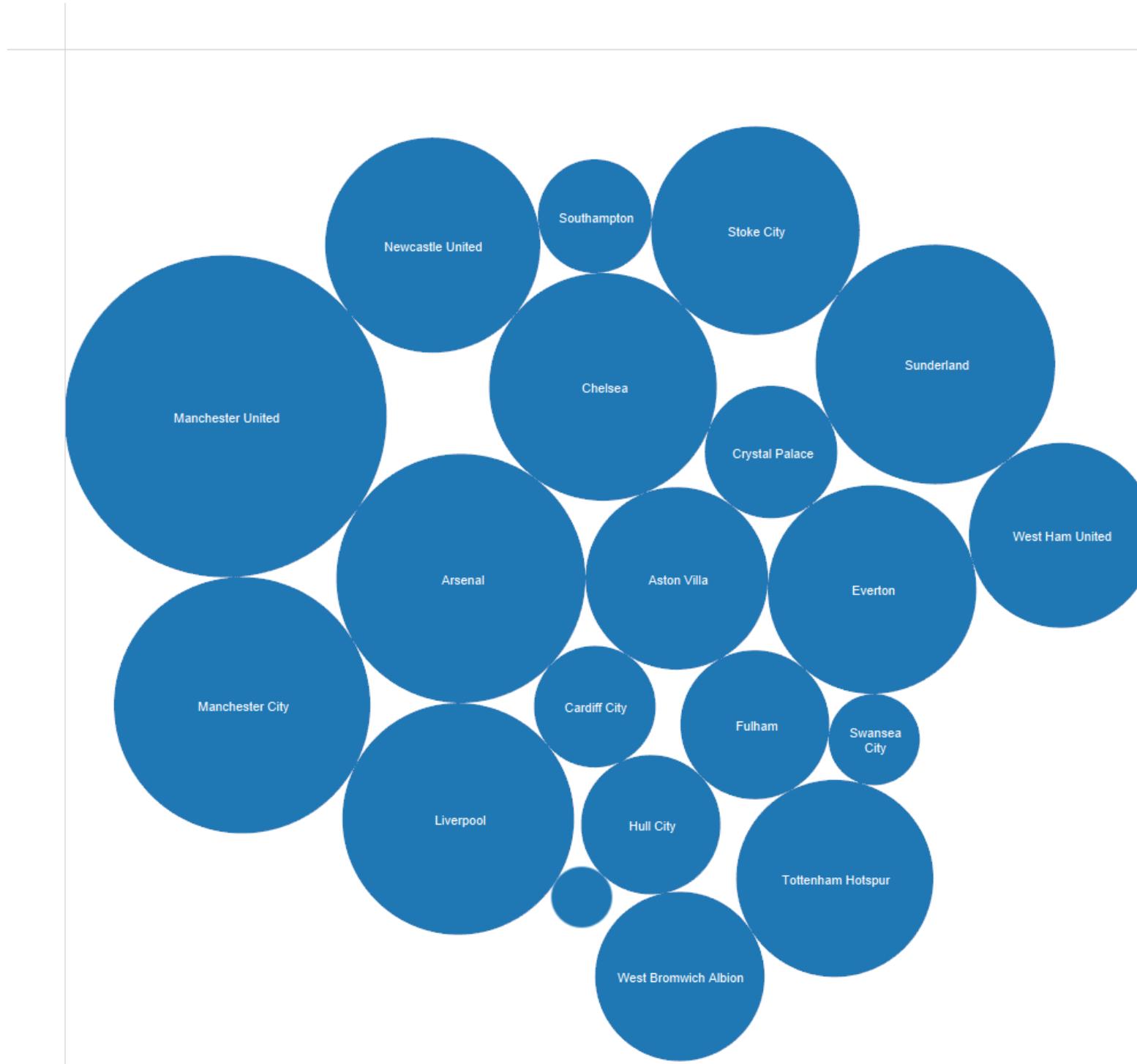
Separated and aligned but not ordered

limitation: hard to know rank. what's 4th? what's 7th?



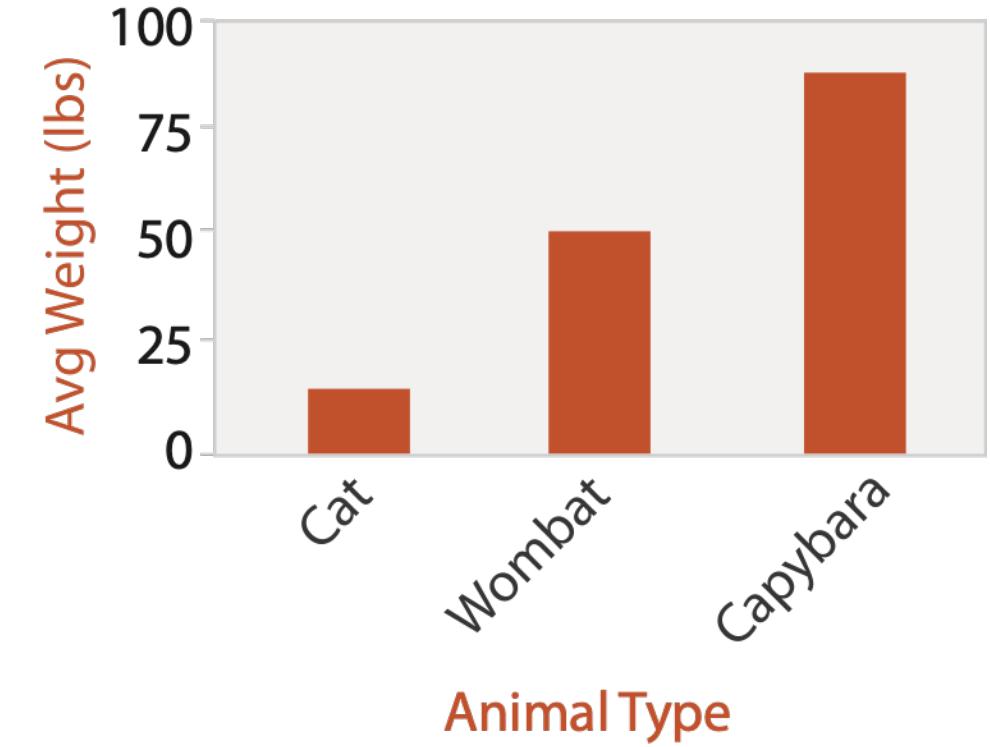
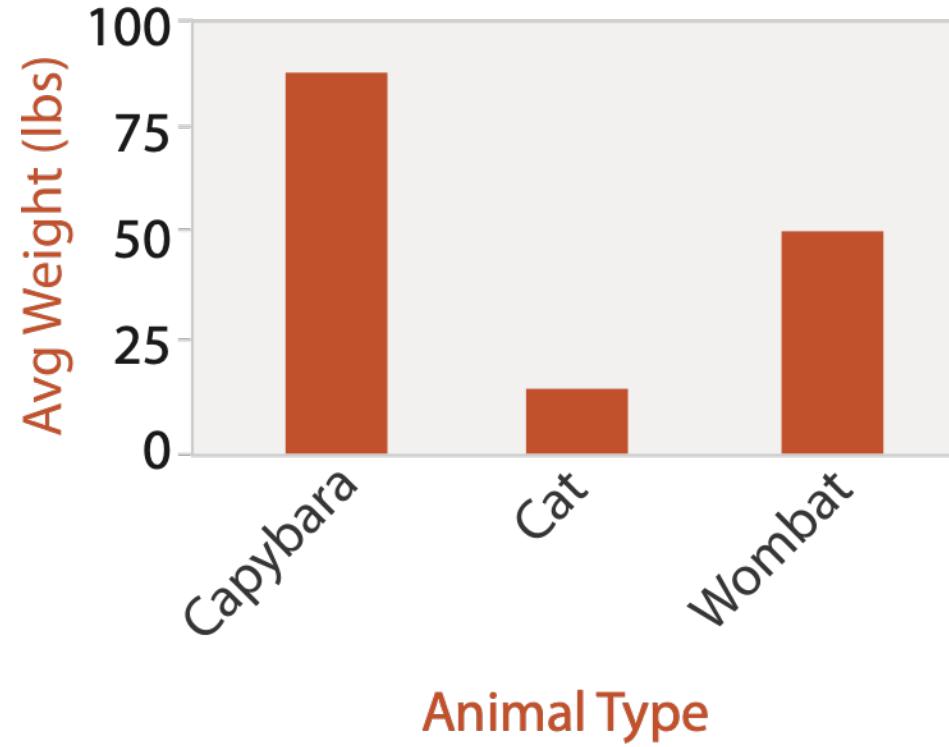
Separated but not aligned or ordered

limitation: hard to make comparisons with size (vs aligned position)



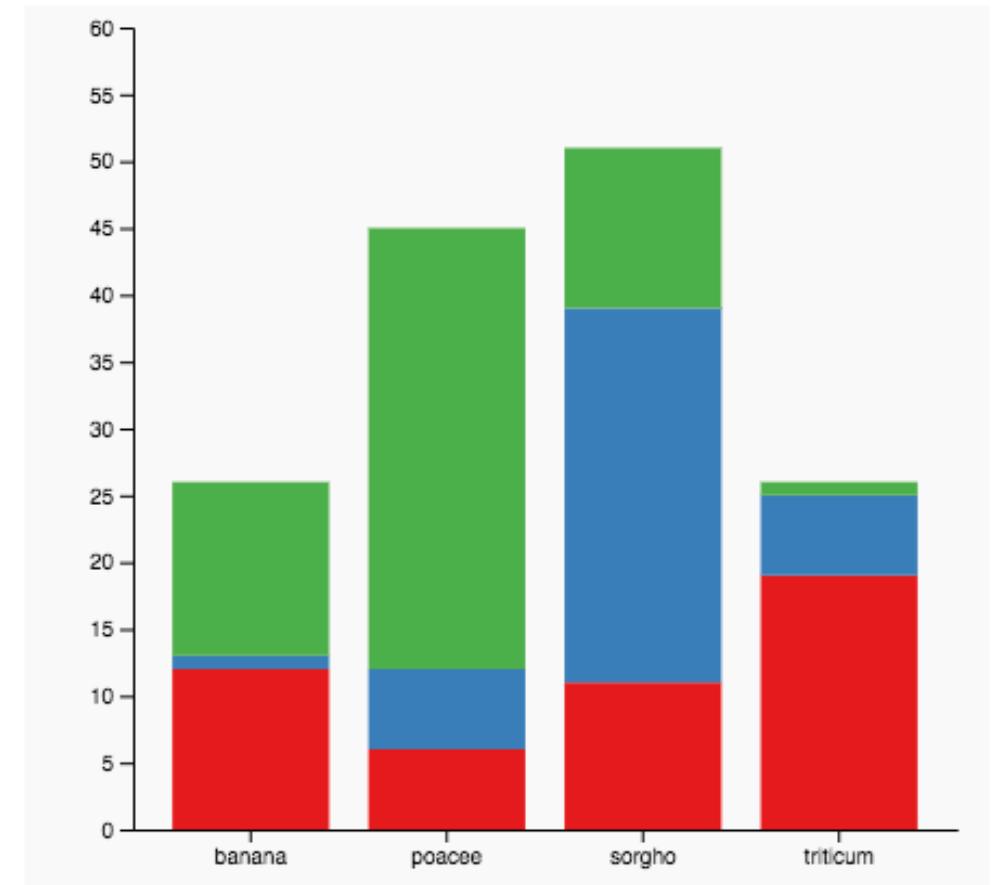
Idiom: bar chart

- one key, one value
 - data
 - 1 categ attrib, 1 quant attrib
 - mark: lines
 - channels
 - length to express quant value
 - spatial regions: one per mark
 - separated horizontally, aligned vertically
 - ordered by quant attrib
 - » by label (alphabetical), by length attrib (data-driven)
 - task
 - compare, lookup values
 - scalability
 - dozens to hundreds of levels for key attrib [bars], hundreds for values



Idiom: stacked bar chart

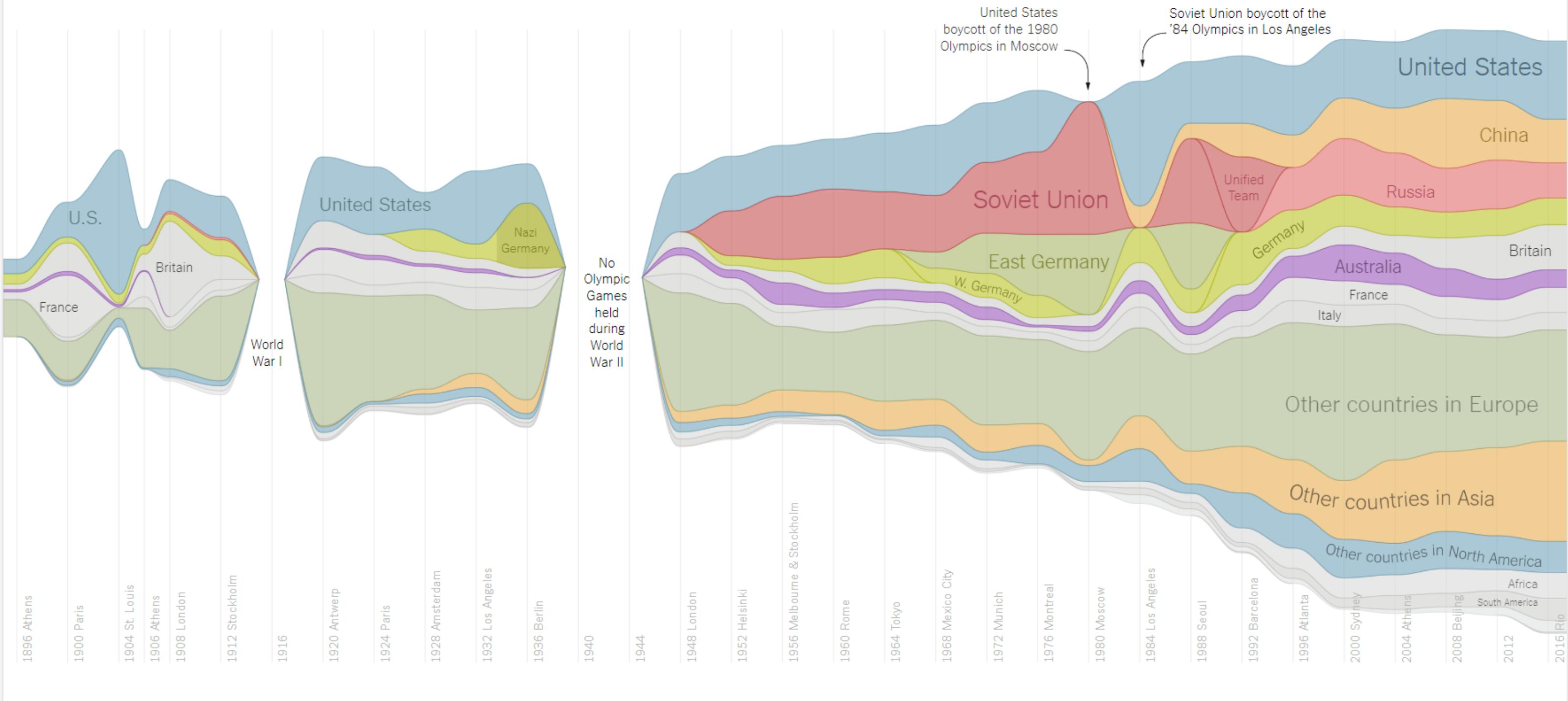
- one more key
 - data
 - 2 categ attrib, 1 quant attrib
 - mark: vertical stack of line marks
 - **glyph**: composite object, internal structure from multiple marks
 - channels
 - length and color hue
 - spatial regions: one per glyph
 - aligned: full glyph, lowest bar component
 - unaligned: other bar components
 - task
 - part-to-whole relationship
 - scalability: asymmetric
 - for *stacked* key attrib, 10-12 levels [segments]
 - for *main* key attrib, dozens to hundreds of levels [bars]



https://www.d3-graph-gallery.com/graph/barplot_stacked_basicWide.html

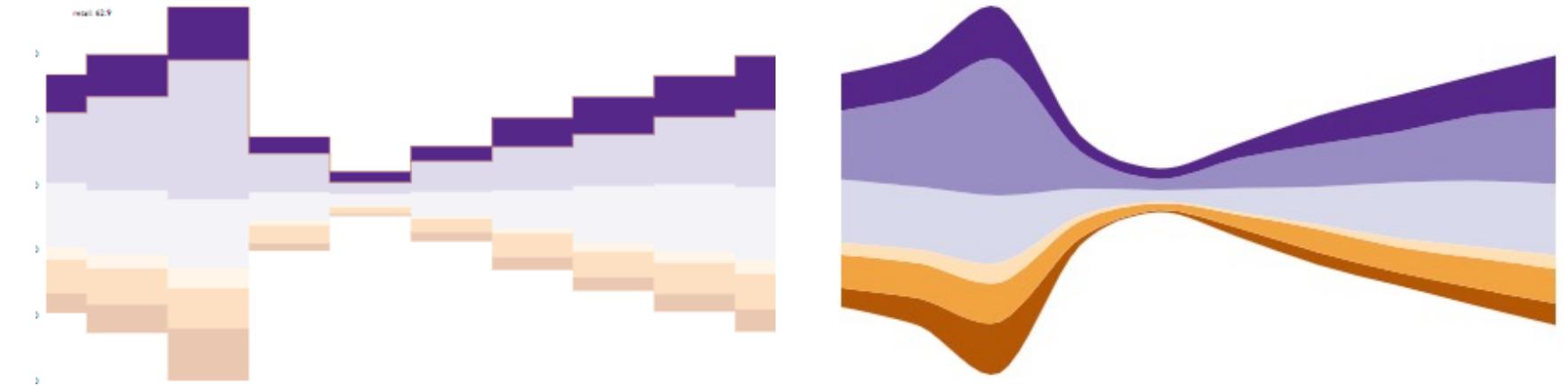
Have Dominated the Summer Olympics

By GREGOR AISCH and LARRY BUCHANAN UPDATED August 22, 2016

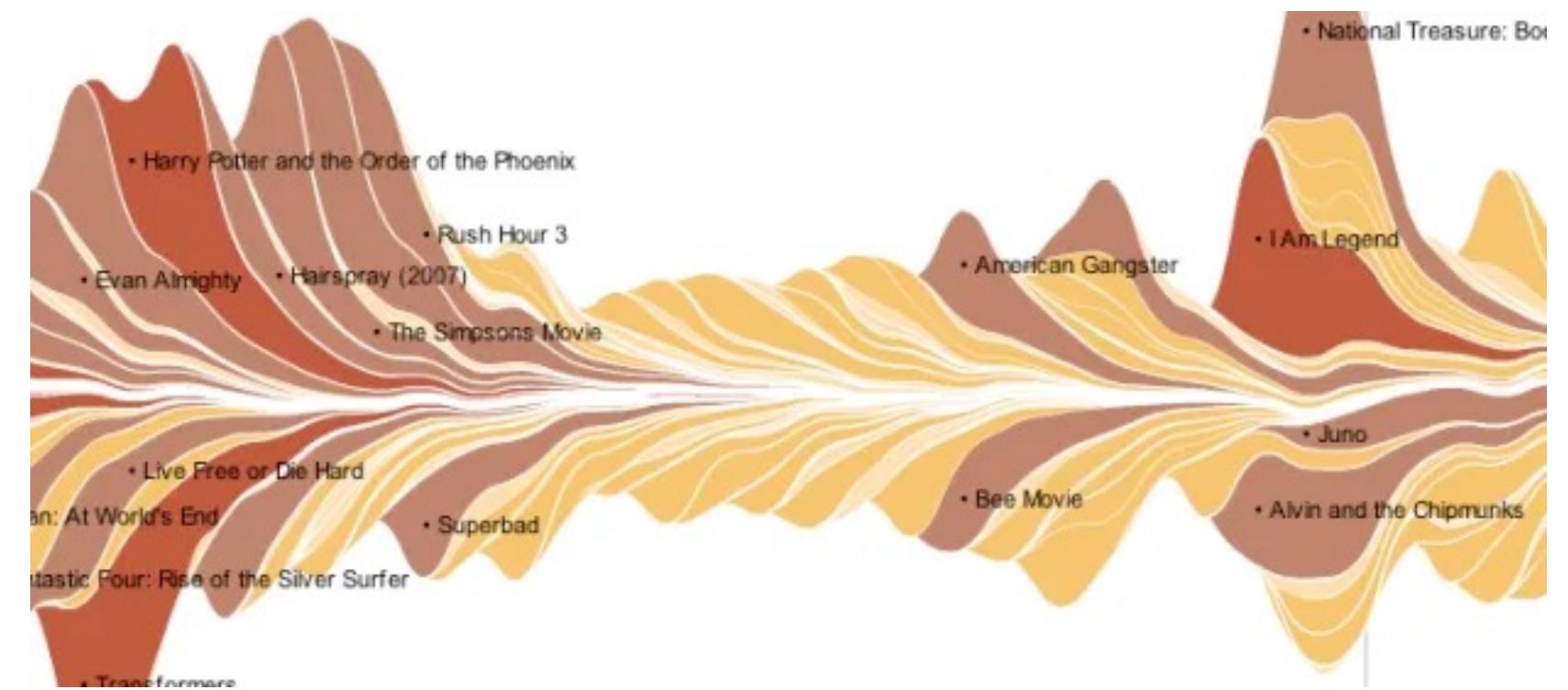


Idiom: streamgraph

- generalized stacked graph
 - emphasizing horizontal continuity
 - vs vertical items
 - data
 - 1 categ key attrib (movies)
 - 1 ordered key attrib (time)
 - 1 quant value attrib (counts)
 - derived data
 - geometry: layers, where height encodes counts
 - 1 quant attrib (layer ordering)
 - scalability
 - hundreds of time keys
 - dozens to hundreds of movies keys
 - more than stacked bars: most layers don't extend across whole chart



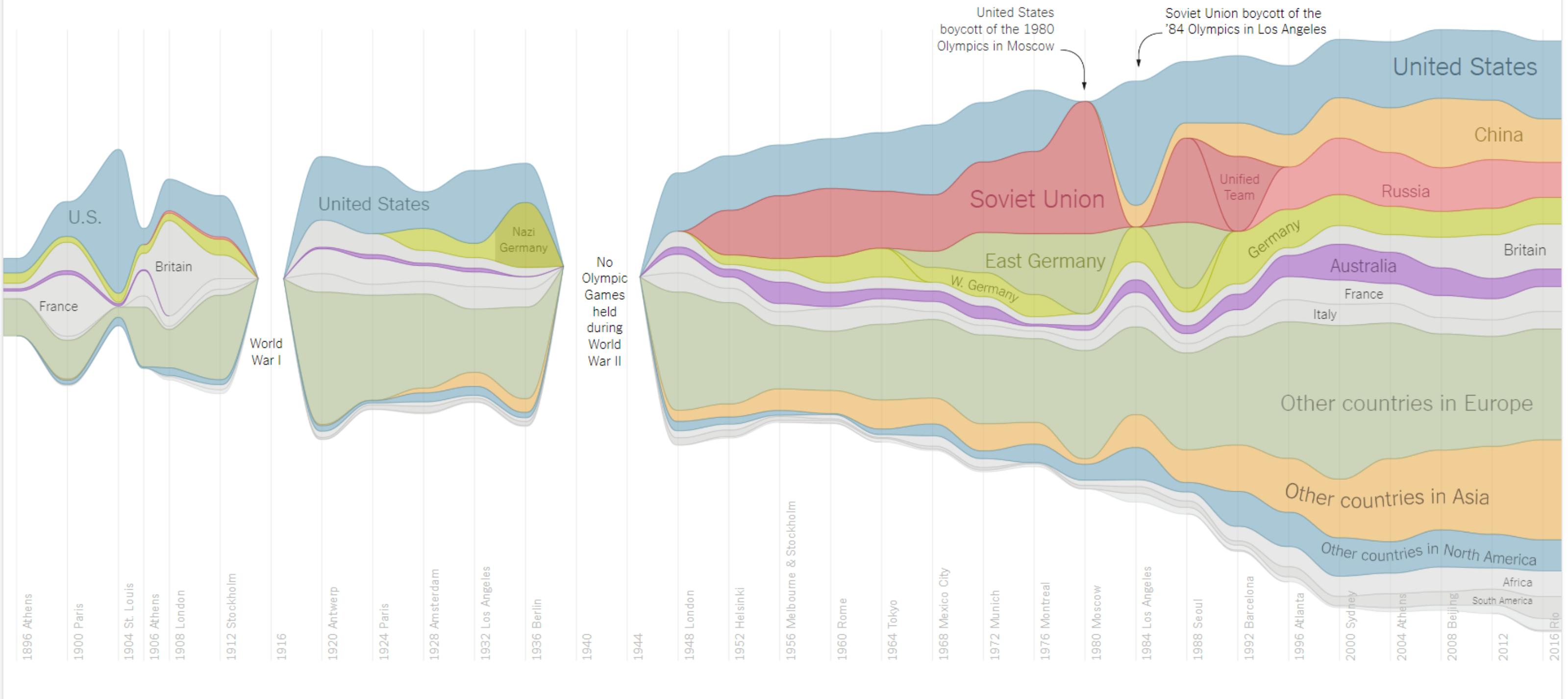
[Stacked Graphs Geometry & Aesthetics. Byron and Wattenberg. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14(6): 1245–1252, (2008).]



<https://flowingdata.com/2008/02/25/ebb-and-flow-of-box-office-receipts-over-past-20-years/>

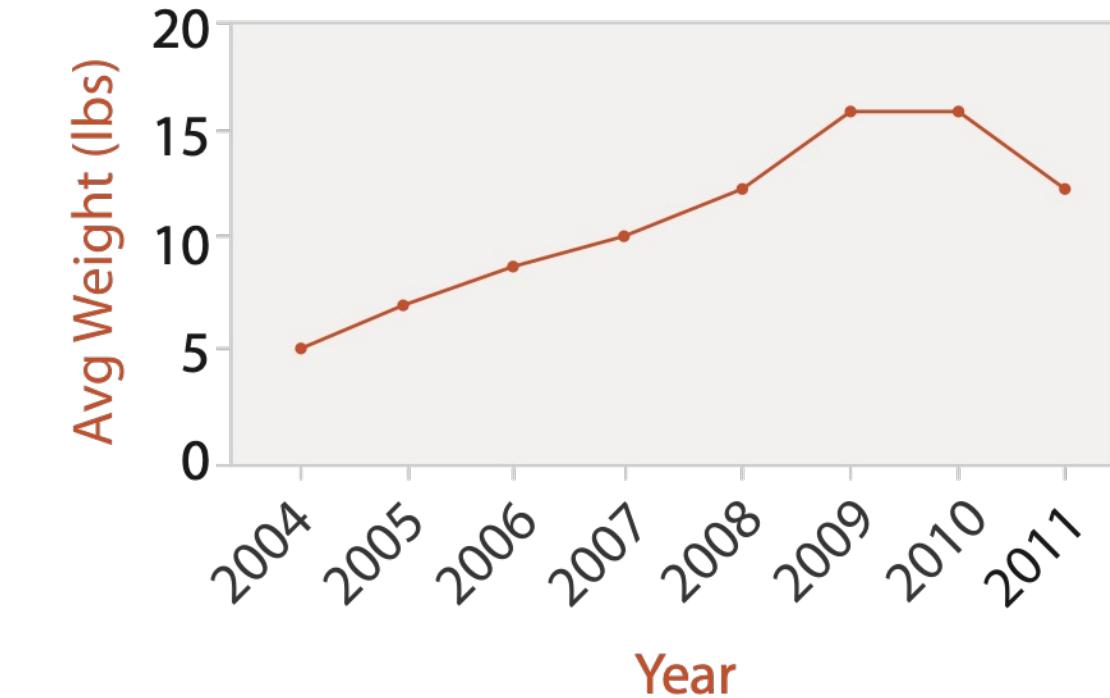
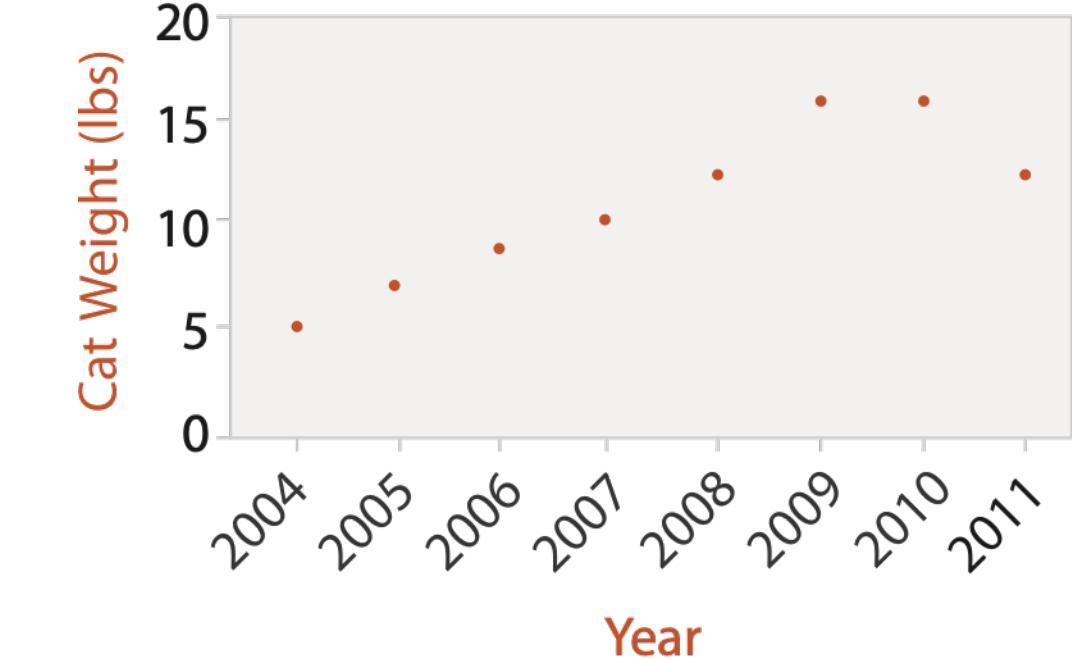
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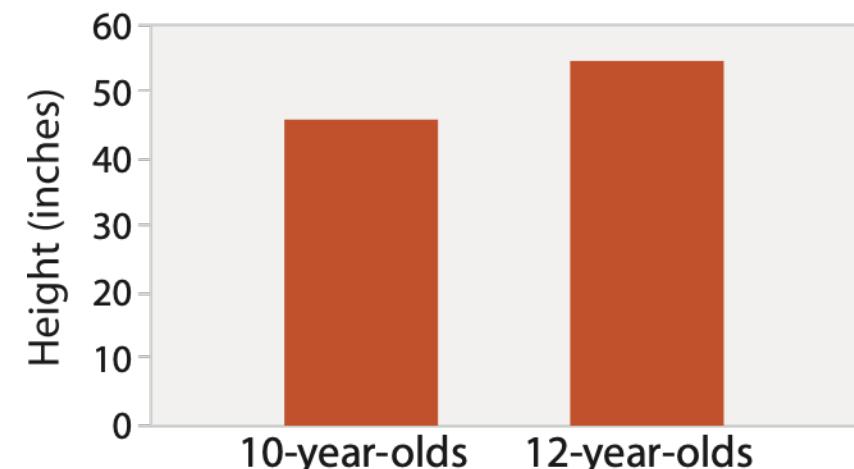
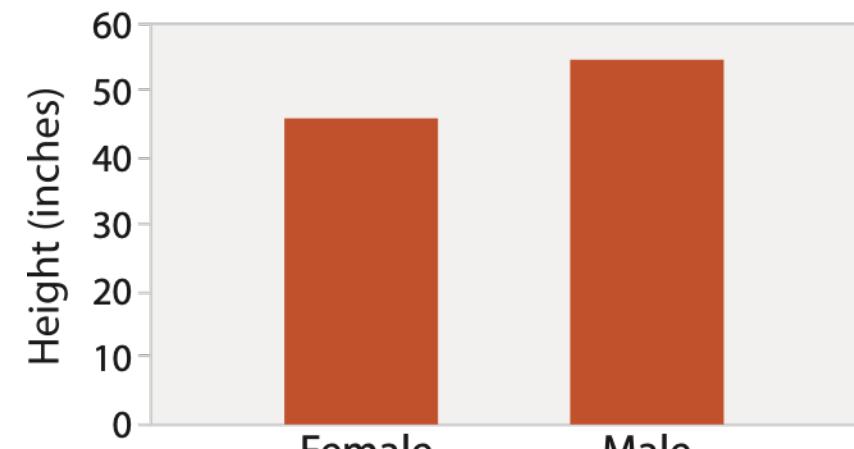
Idiom: dot / line chart

- one key, one value
 - data
 - 2 quant attrs
 - mark: points *AND* *line connection marks between them*
 - channels
 - aligned lengths to express quant value
 - separated and ordered by key attrib into horizontal regions
 - task
 - find trend
 - connection marks emphasize ordering of items along key axis by explicitly showing relationship between one item and the next
 - scalability
 - hundreds of key levels, hundreds of value levels



Choosing bar vs line charts

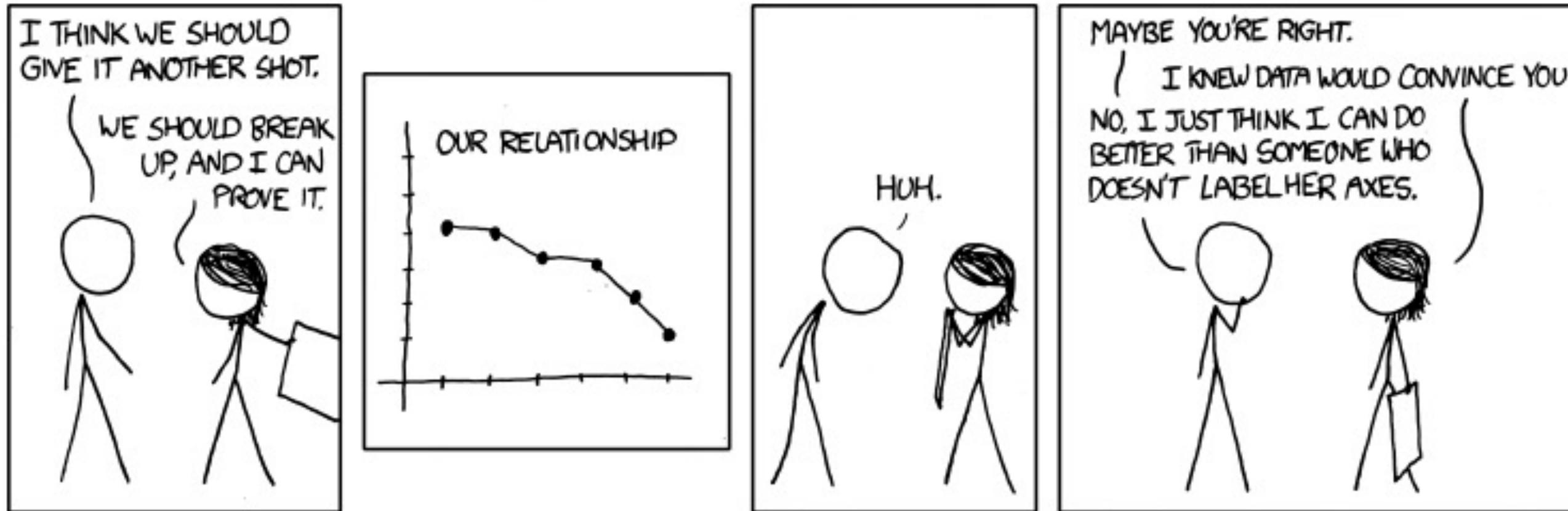
- depends on type of key attrib
 - bar charts if categorical
 - line charts if ordered
- do not use line charts for categorical key attrs
 - violates expressiveness principle
 - implication of trend so strong that it overrides semantics!
 - “The more male a person is, the taller he/she is”



after [Bars and Lines: A Study of Graphic Communication.
Zacks and Tversky. *Memory and Cognition* 27:6 (1999),
1073–1079.]

Chart axes: label them!

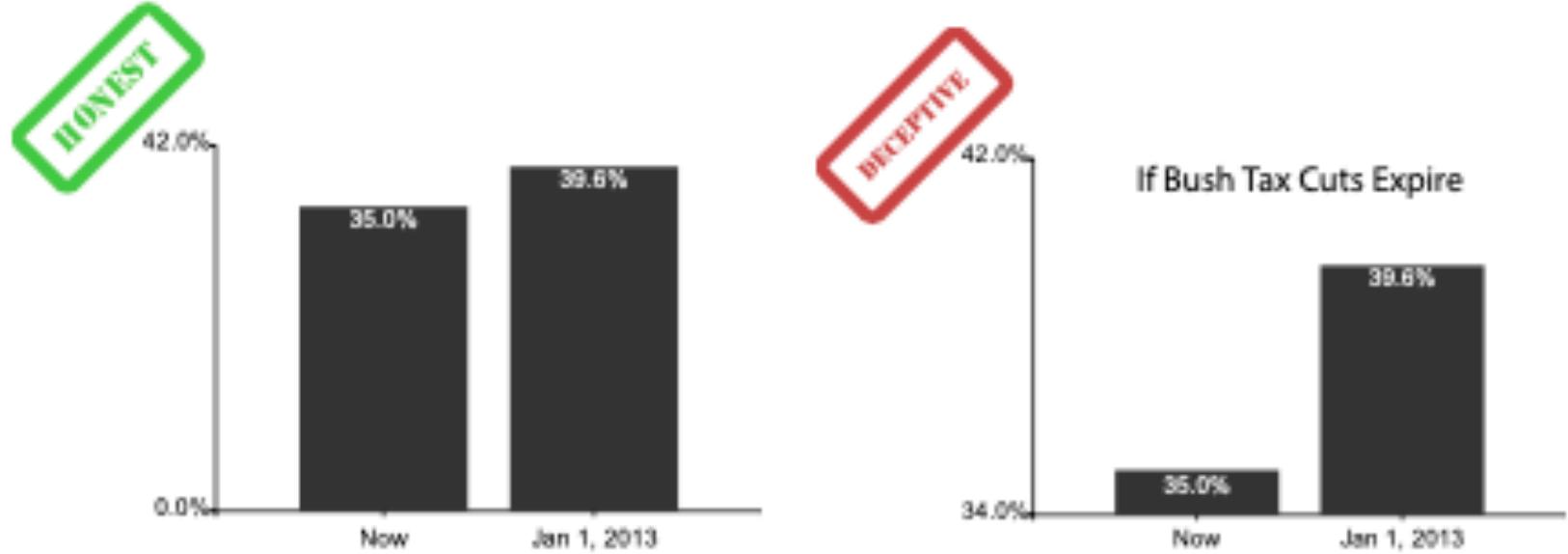
- best practice to label
 - few exceptions: individual small multiple views could share axis label



<https://xkcd.com/833/>

Chart axes: avoid cropping y axis

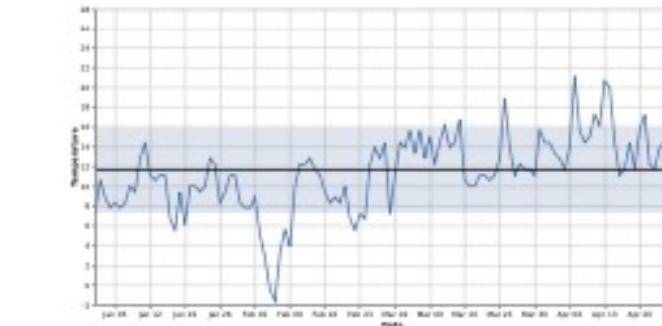
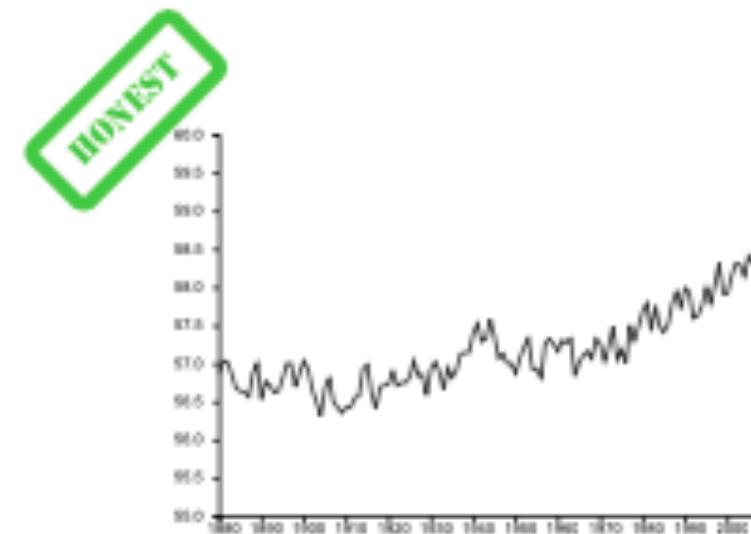
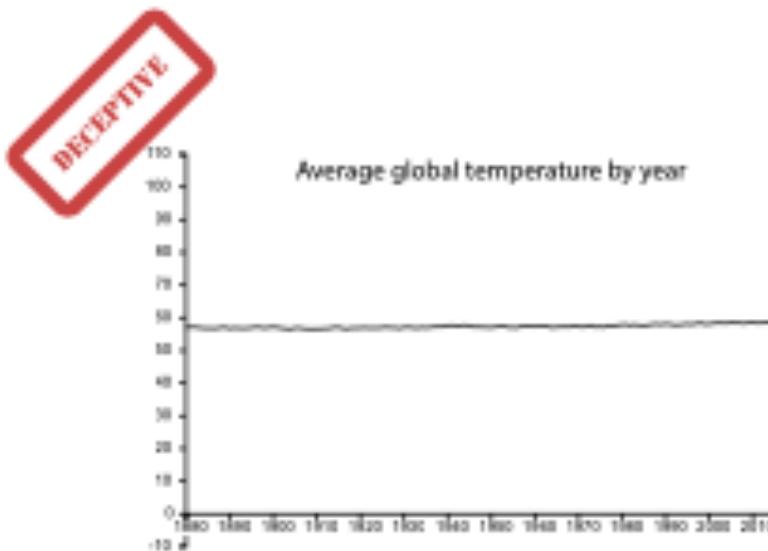
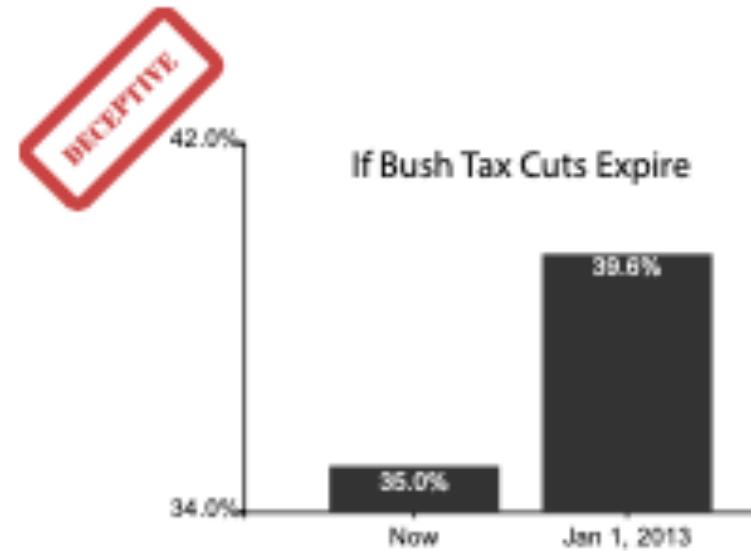
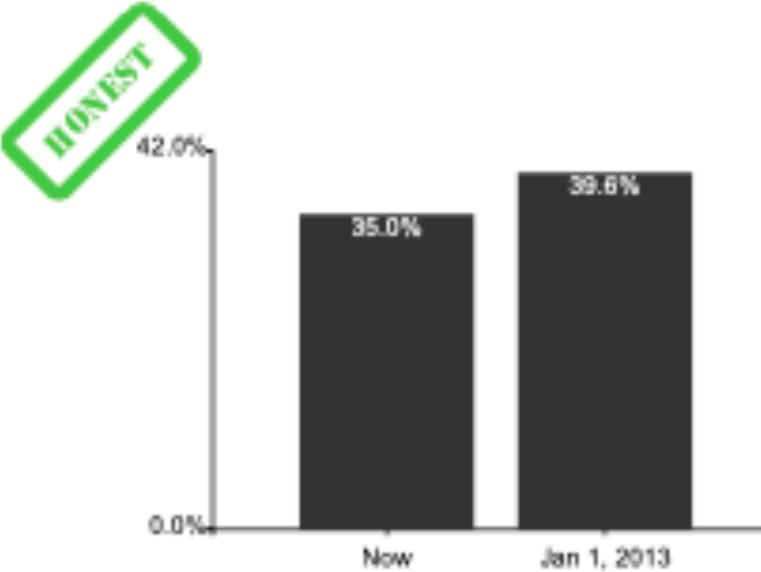
- include 0 at bottom left or slope misleads



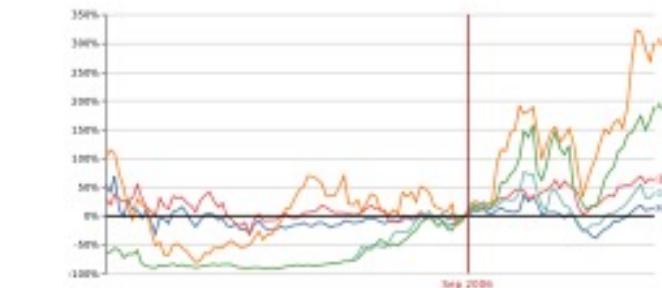
[Truncating the Y-Axis: Threat or Menace?
Correll, Bertini, & Franconeri, CHI 2020.]

Chart axes: avoid cropping y axis

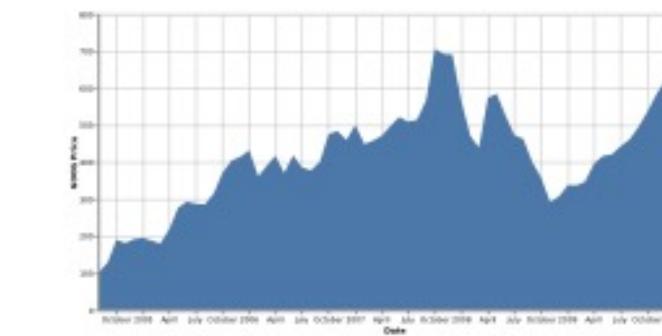
- include 0 at bottom left or slope misleads
 - some exceptions (arbitrary 0, small change matters)



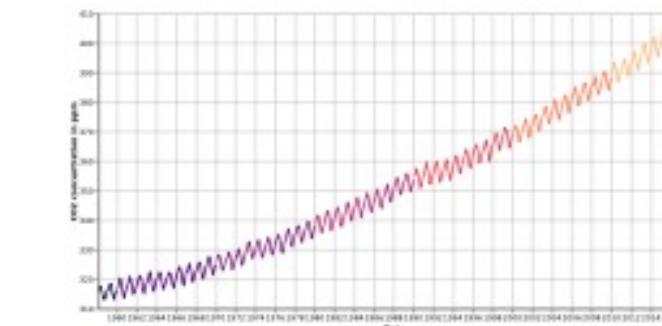
(a) Statistical process charts rely on comparison to an expected value, and so deviations from that value, not from zero, are important



(b) Index charts compare to an indexed value rather than zero.



(c) Stock charts must show small differences in stock value, as these can translate to enormous monetary gains or losses.



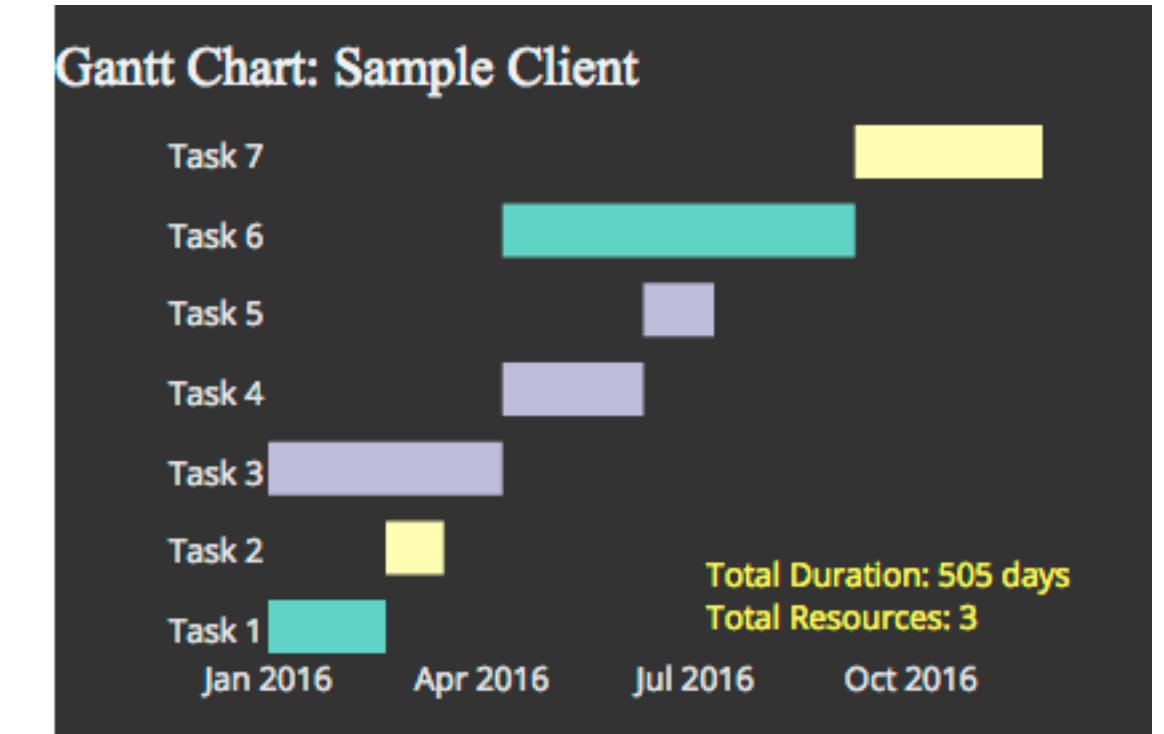
(d) Climate Anomaly charts rely on both highlighting deviation from a non-zero expected value but also emphasize the potentially disastrous impact of even minute changes in climate.

[Truncating the Y-Axis: Threat or Menace?

Correll, Bertini, & Franconeri, CHI 2020.]

Idiom: Gantt charts

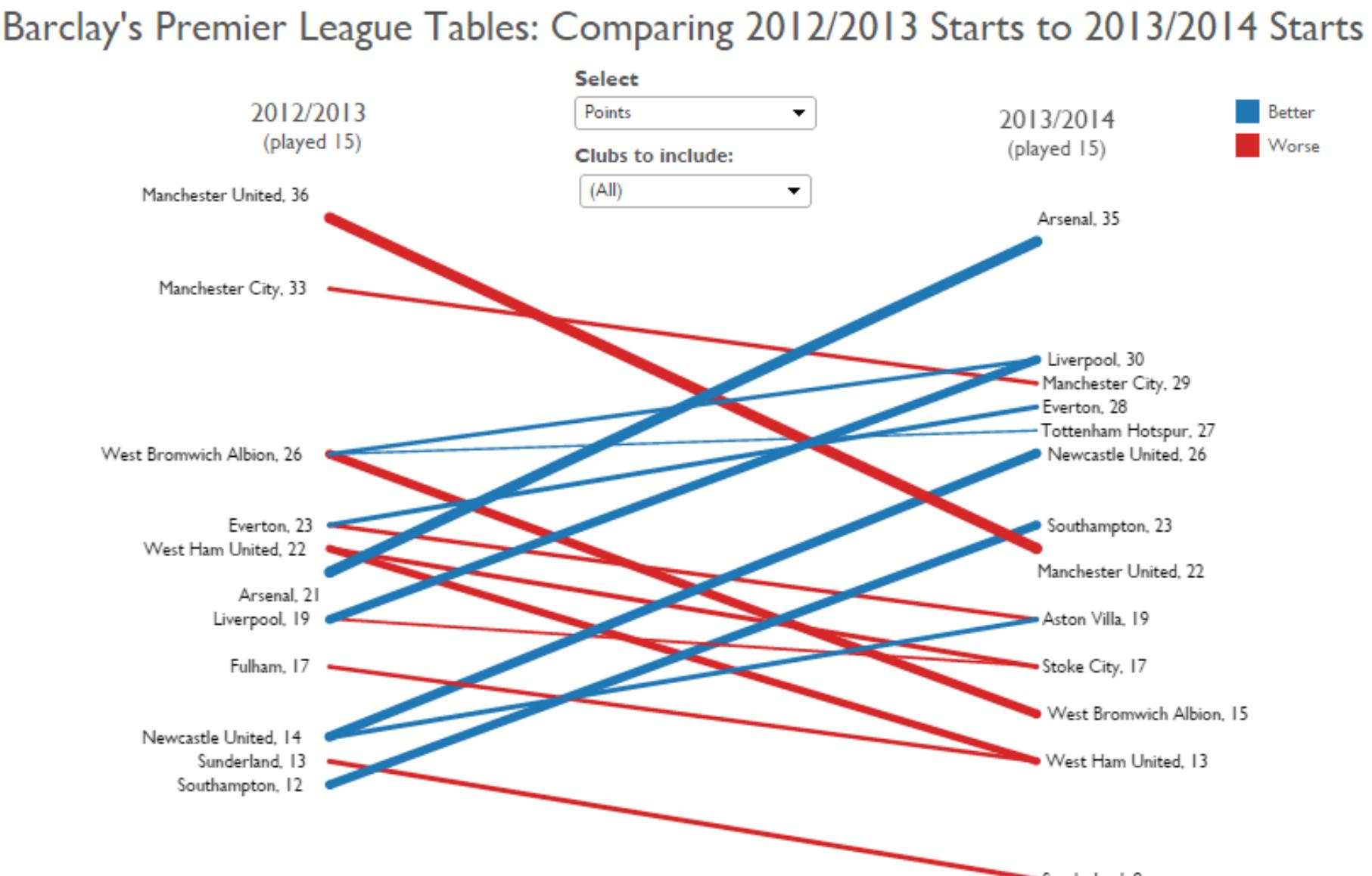
- one key, two (related) values
 - data
 - 1 categ attrib, 2 quant attrs
 - mark: line
 - length: duration
 - channels
 - horiz position: start time
(+end from duration)
 - task
 - emphasize temporal overlaps & start/end dependencies between items
 - scalability
 - dozens of key levels [bars]
 - hundreds of value levels [durations]



<https://www.r-bloggers.com/gantt-charts-in-r-using-plotly/>

Idiom: Slopegraphs

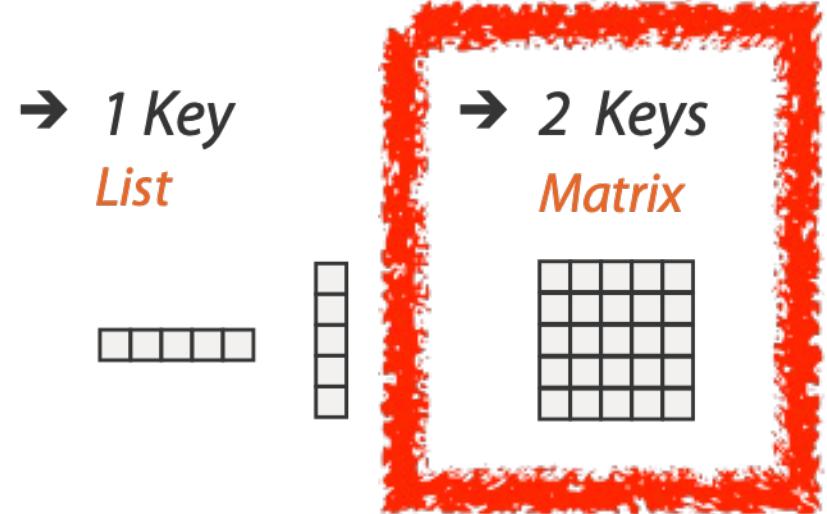
- two values
 - data
 - 2 quant value attrs
 - (1 derived attrib: change magnitude)
 - mark: point + line
 - line connecting mark between pts
 - channels
 - 2 vertical pos: express attrib value
 - (linewidth/size, color)
 - task
 - emphasize changes in rank/value
 - scalability
 - hundreds of value levels
 - dozens of items



<https://public.tableau.com/profile/ben.jones#/vizhome/Slopegraphs/Slopegraphs>

2 Keys

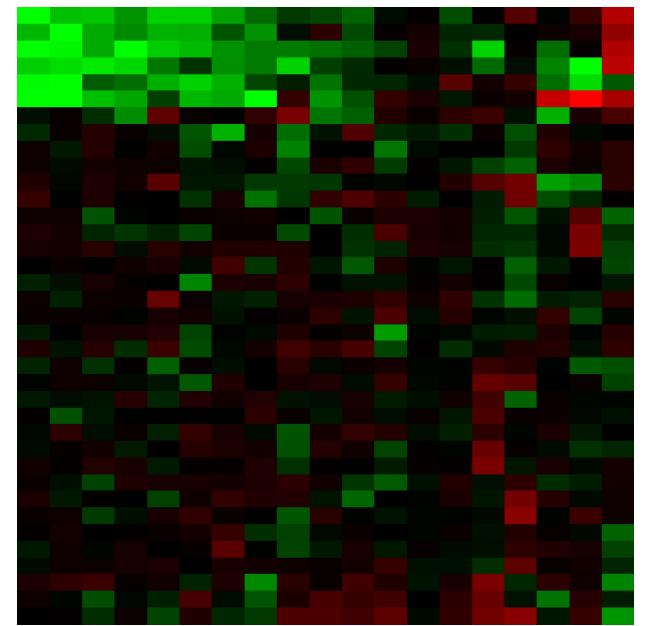
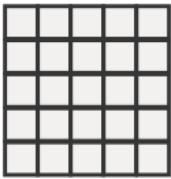
→ 0 Keys
→ Express Values



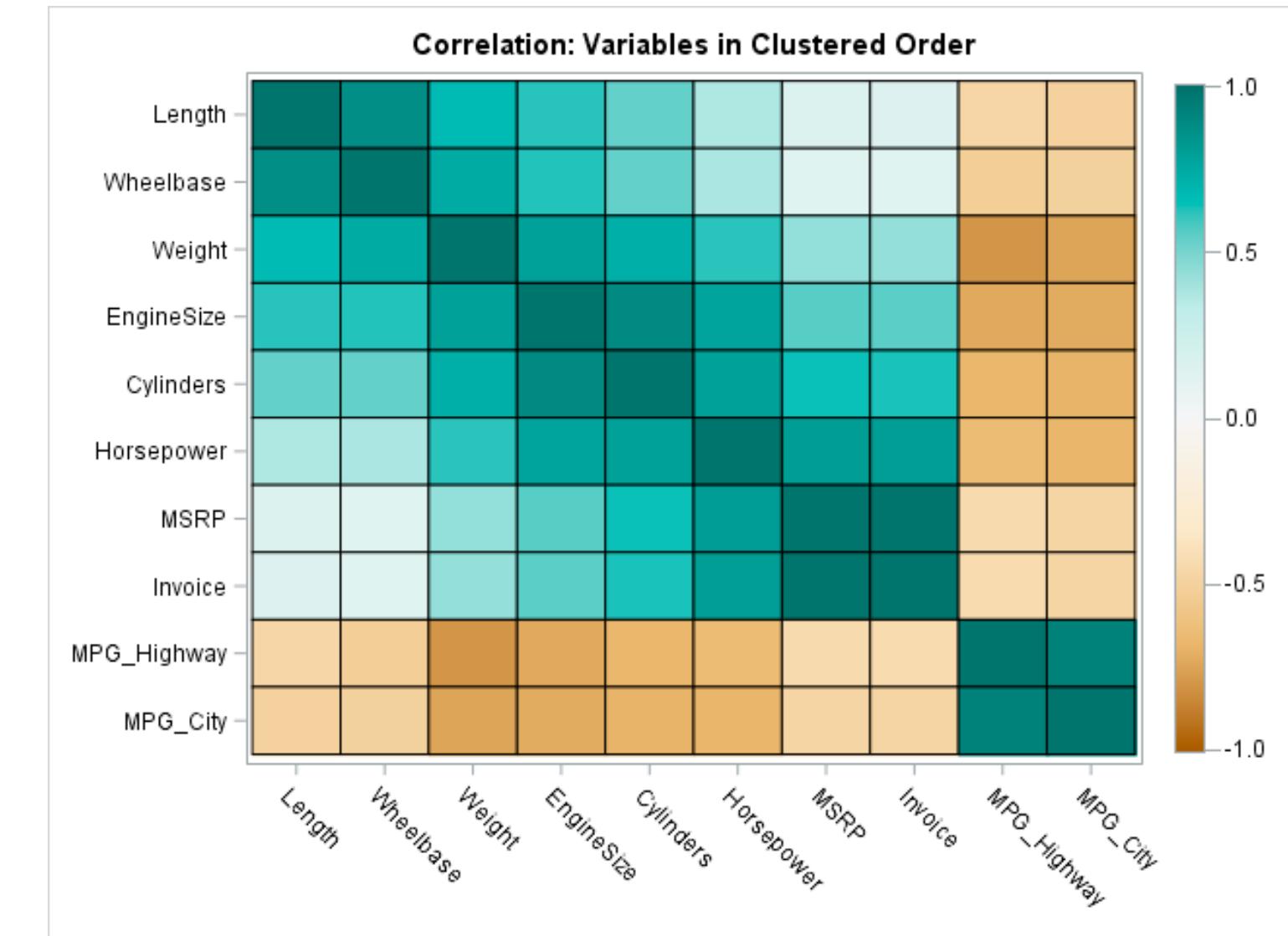
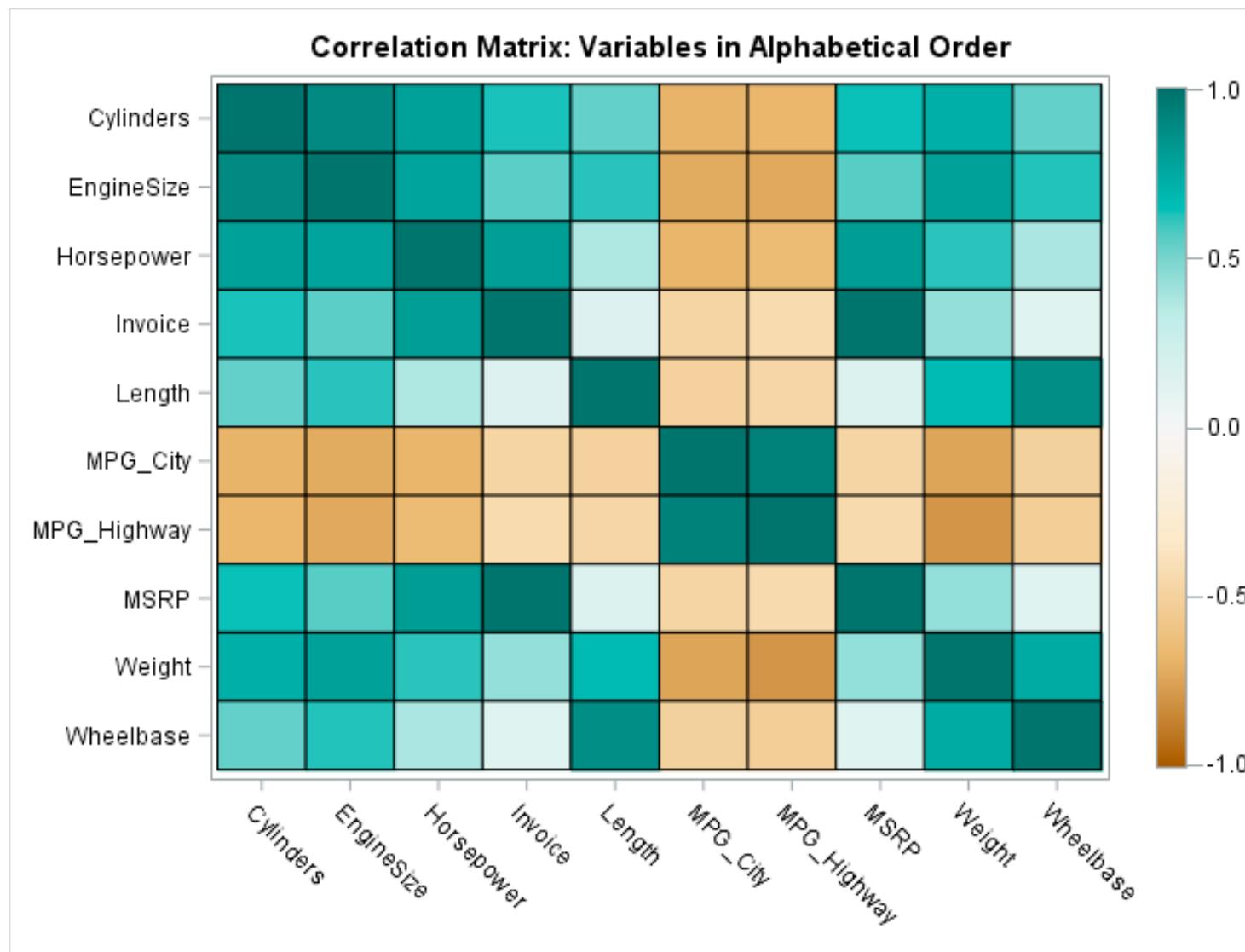
Idiom: heatmap

- two keys, one value
 - data
 - 2 categ attrs (gene, experimental condition)
 - 1 quant attrib (expression levels)
 - marks: point
 - separate and align in 2D matrix
 - indexed by 2 categorical attributes
 - channels
 - color by quant attrib
 - (ordered diverging colormap)
 - task
 - find clusters, outliers
 - scalability
 - 1M items, 100s of categ levels, ~10 quant attrib levels

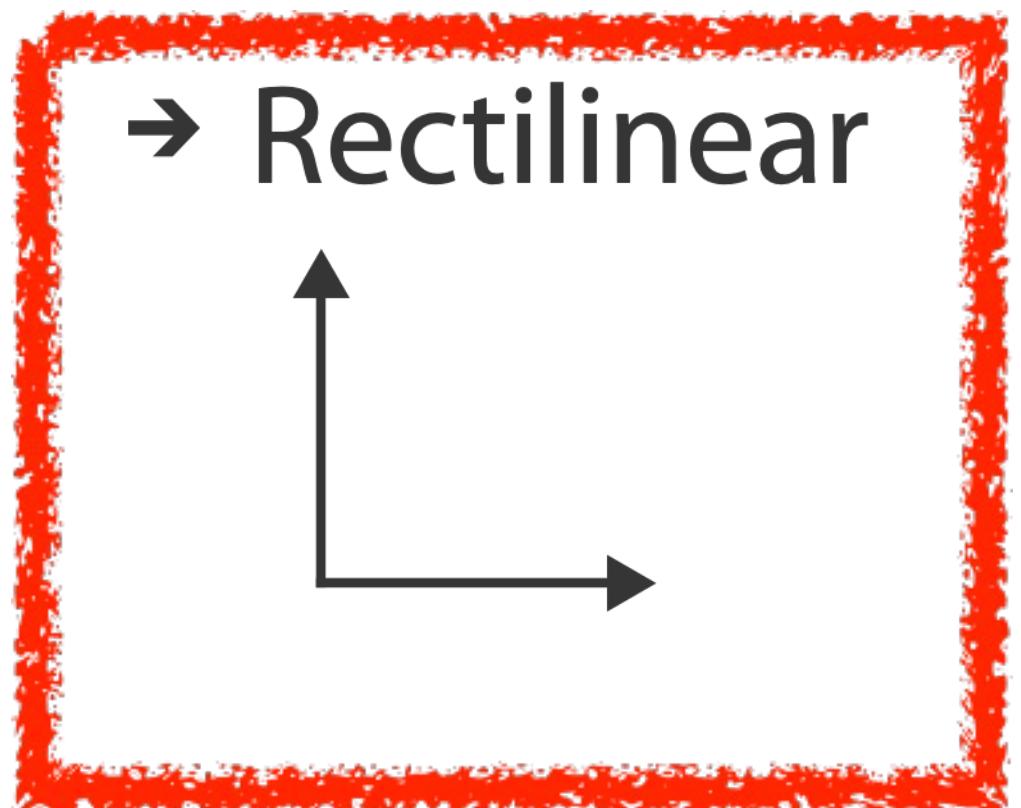
→ 2 Keys
Matrix



Heatmap reordering

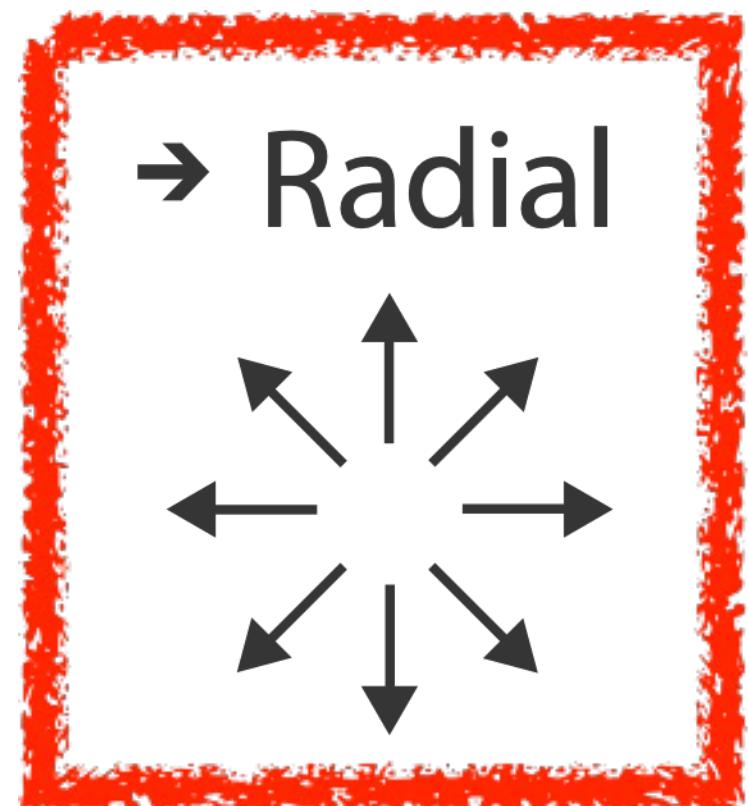


→ Axis Orientation



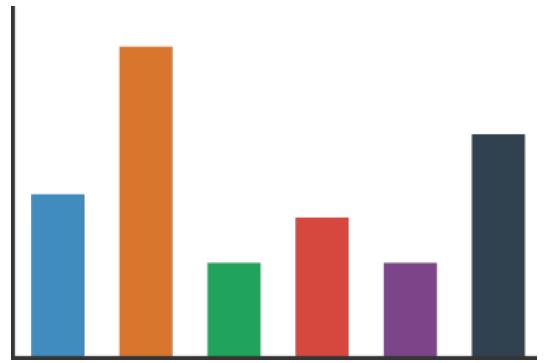
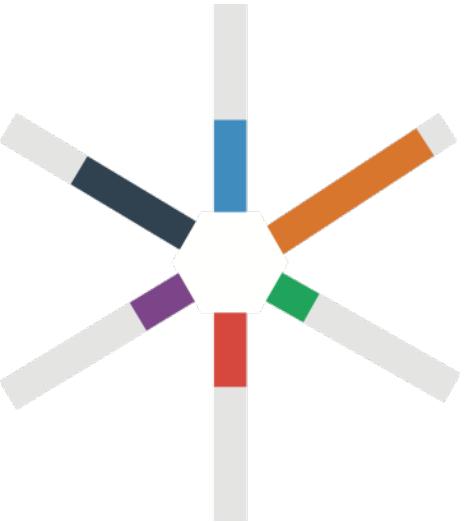
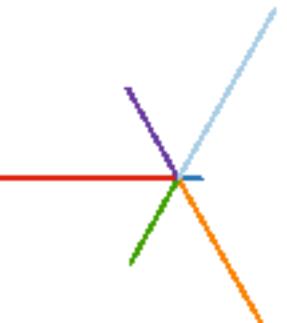
→ Parallel

A diagram showing three black arrows pointing upwards, spaced evenly apart horizontally.



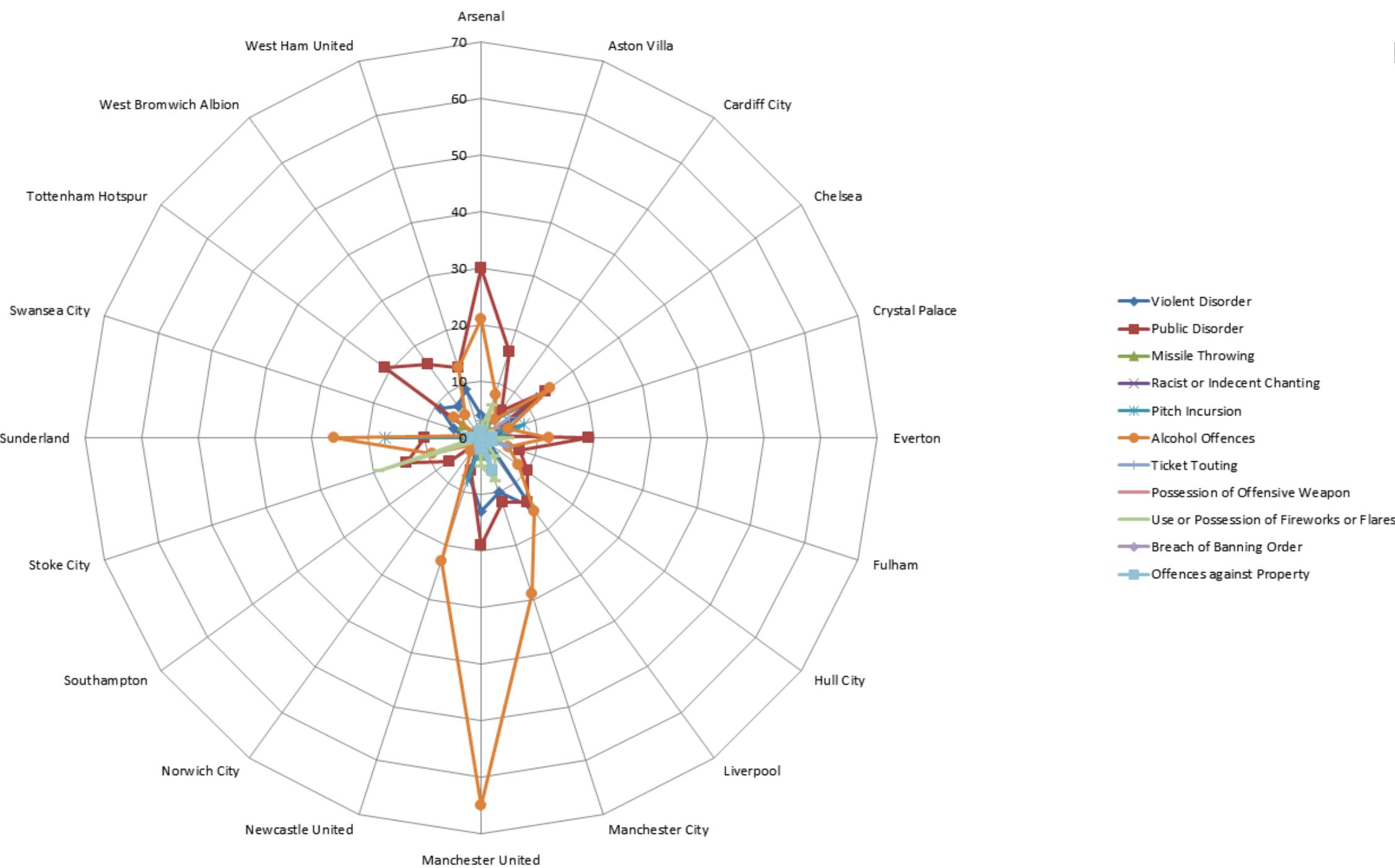
Idioms: radial bar chart, star plot

- star plot
 - line mark, radial axes meet at central point
- radial bar chart
 - line mark, radial axes meet at central ring
 - channels: length, angle/orientation
- bar chart
 - rectilinear axes, aligned vertically
- accuracy
 - length not aligned with radial layouts
 - less accurately perceived than rectilinear aligned



Idiom: radar plot

- radial line chart
 - point marks,
radial layout
 - connecting line
marks
- avoid unless data
is cyclic



“Radar graphs: Avoid them (99.9% of the time)”



Os sinais da bússola eleitoral

Disputa de 2010 foi parecida com a de 2006.

Alberto Cairo, Alexandre Matsur, Carlos Eduardo Cruz Garcia, Eliseu Barreira Junior, Marco Vergolfi e Ricardo Mendoza

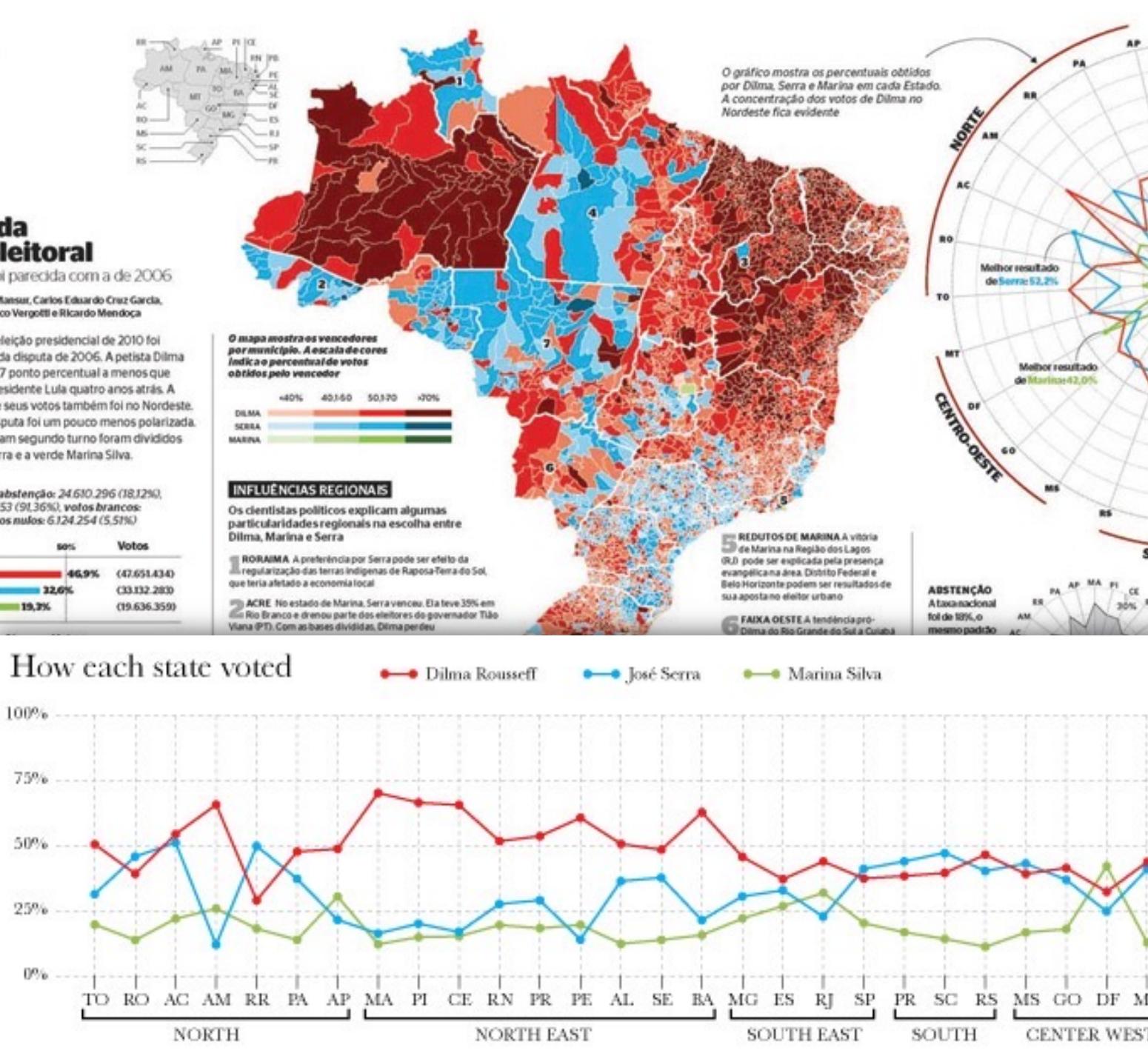
O PRIMEIRO TURNO da eleição presidencial de 2010 foi muito parecido com o da disputa de 2006. A petista Dilma Rousseff teve apenas 1,7 ponto percentual a menos que o índice obtido pelo presidente Lula quatro anos atrás. A concentração maior de seus votos também foi no Nordeste. Dessa vez, porém, a disputa foi um pouco menos polarizada. Os votos que provocaram segundo turno foram divididos entre o tucano José Serra e a verde Marina Silva.

Eleitores: 135.804.433, abstenção: 24.610.296 (18,12%), votos válidos: 110.590.153 (91,36%), votos brancos: 3.479.340 (3,13%) e votos nulos: 6.124.254 (5,51%).

Candidatos	sos	Votos
Dilma Rousseff PT	46,9%	(47.651.434)
José Serra PSDB	32,6%	(33.132.283)
Marina Silva PV	19,3%	(19.636.359)

Outros vencedores

Plínio (PSOL)
José Maria Eymael (DC)
Zé Maria (PSTB)
Levy Fidélis (PRB)
Ivan Pinheiro (PCB)
Rui Costa Pimenta (PSC)



original
difficult to interpret

redesign for
rectilinear

Idioms: pie chart, coxcomb chart

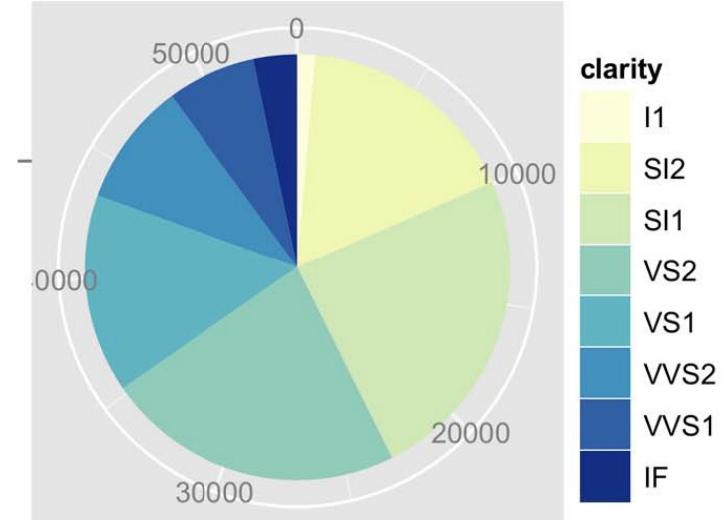
- pie chart

- interlocking area marks with angle channel: 2D area varies

- separated & ordered radially, uniform height

- accuracy: area less accurate than rectilinear aligned line length

- task: part-to-whole judgements



- coxcomb chart

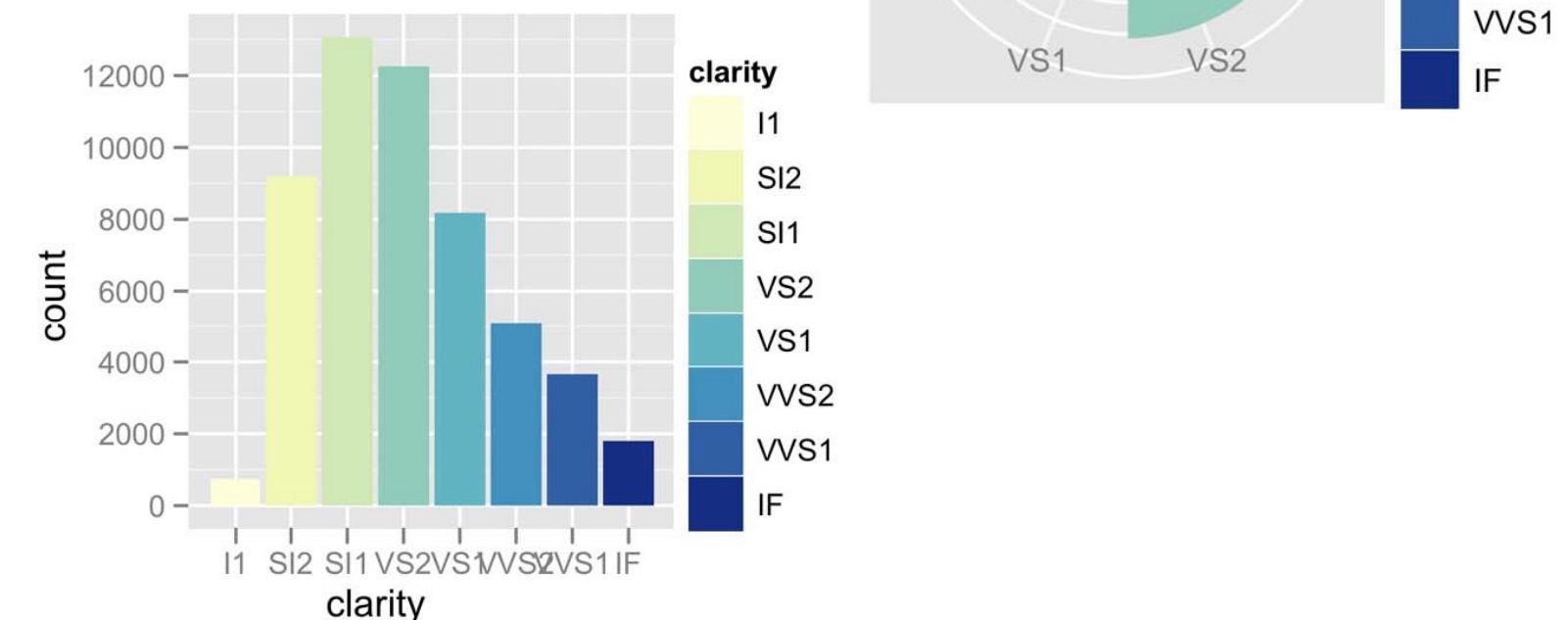
- line marks with length channel: 1D length varies

- separated & ordered radially, uniform width

- direct analog to radial bar charts

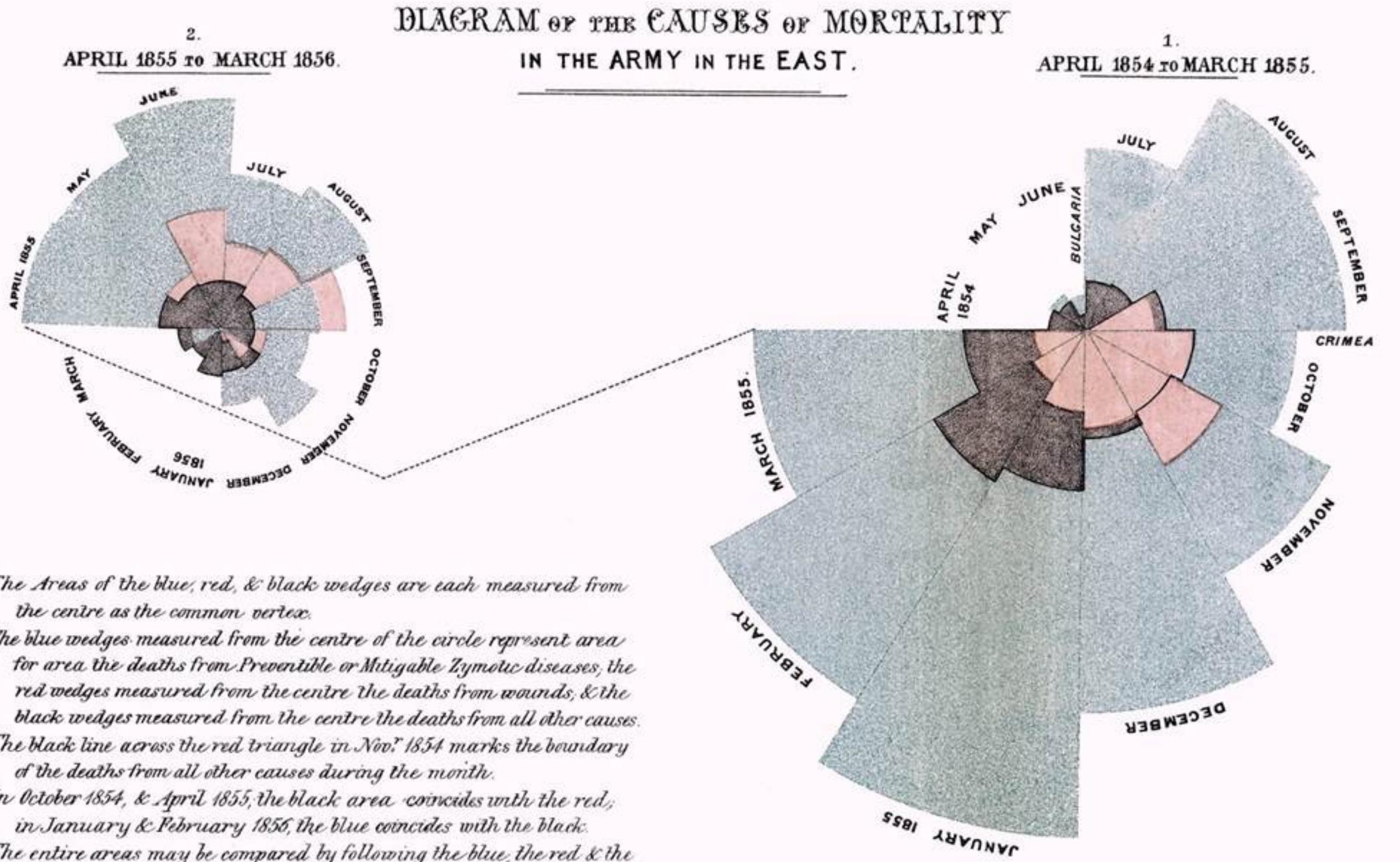
- data

- 1 categ key attrib, 1 quant value attrib



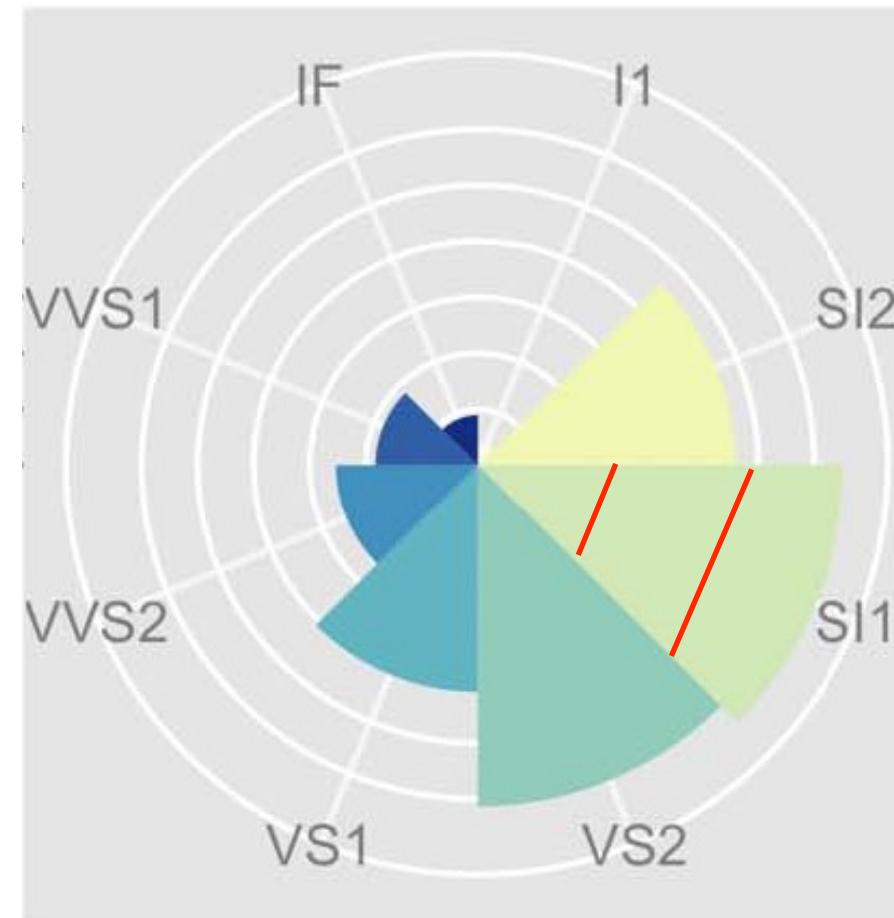
Coxcomb / nightingale rose / polar area chart

invented by Florence Nightingale: Diagram of the Causes of Mortality in the Army in the East

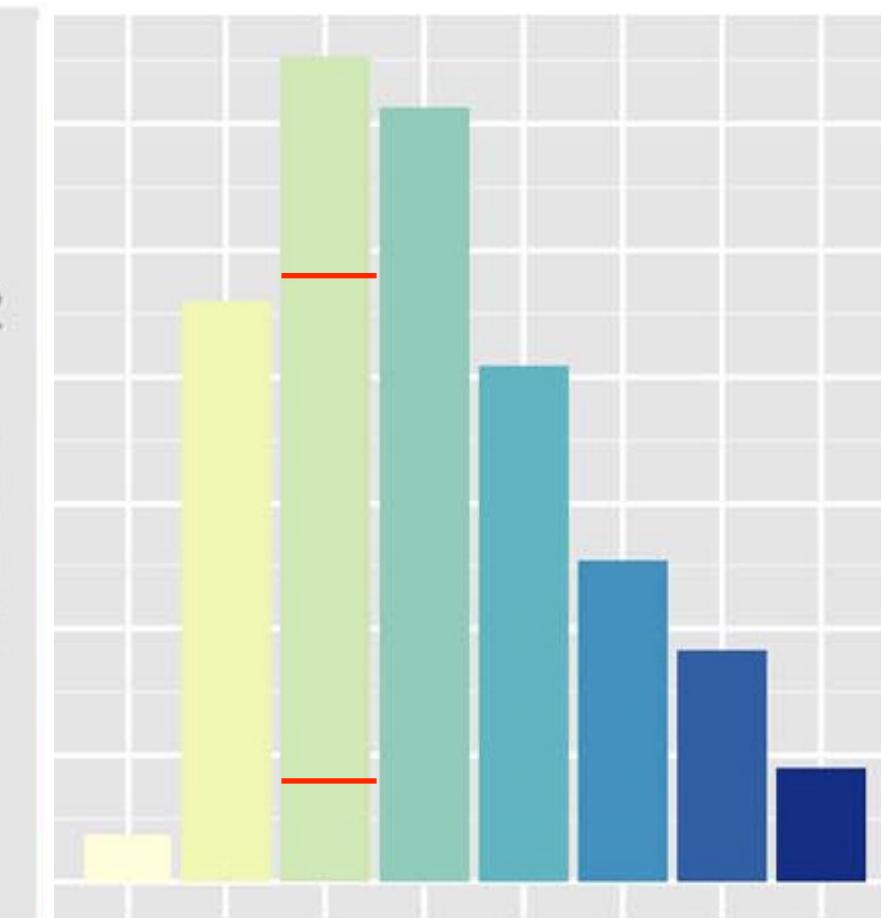


Coxcomb: perception

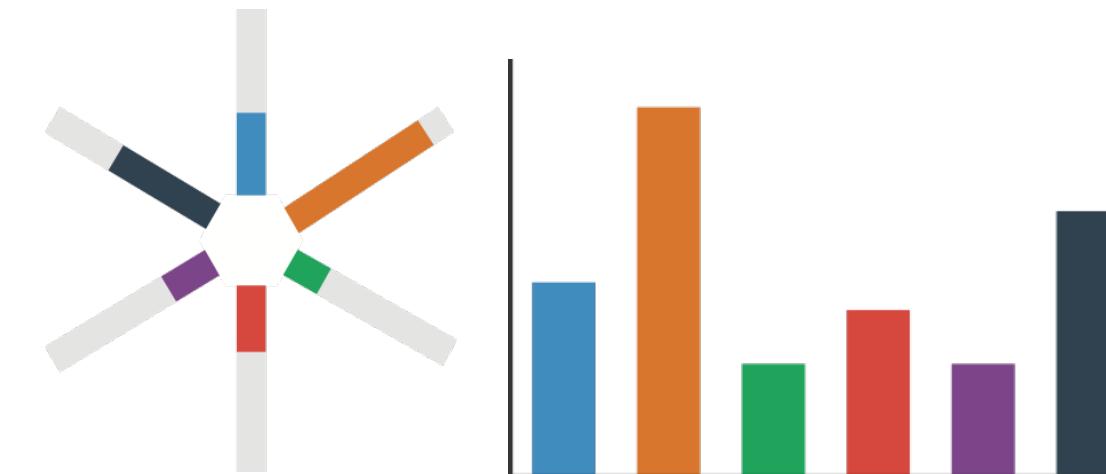
- encode: **1D length**
- decode/perceive: **2D area**
- nonuniform line/sector width as length increases
 - so area variation is nonlinear wrt line mark length!
- bar chart safer: uniform width, so area is linear with line mark length
 - both radial & rectilinear cases



nonuniform width as length increases



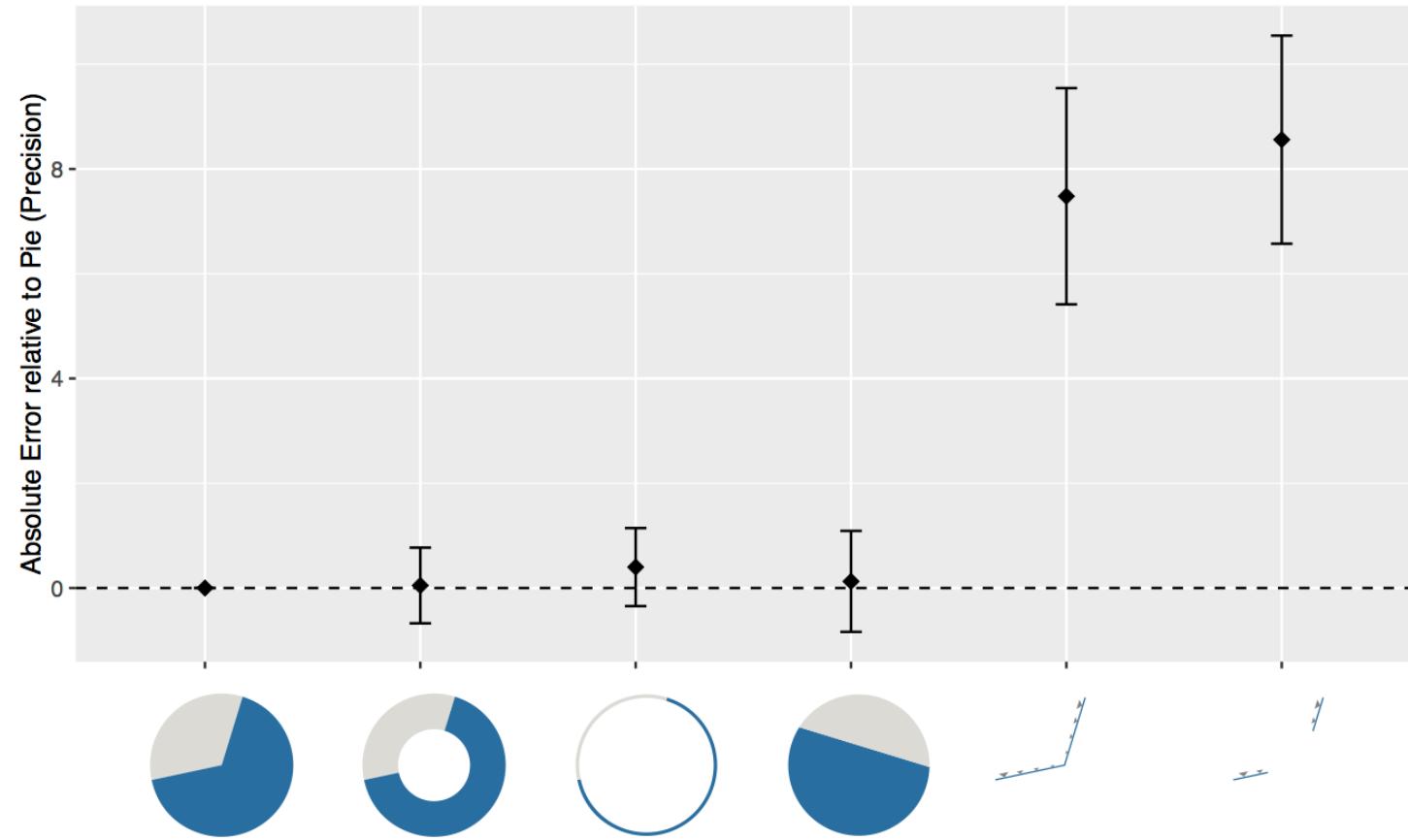
uniform width as length increases



radial & rectilinear bars: uniform width as length increases

Pie charts: perception

- some empirical evidence that people respond to arc length
 - decode/perceive: not angles
 - maybe also areas?...
- donut charts no worse than pie charts

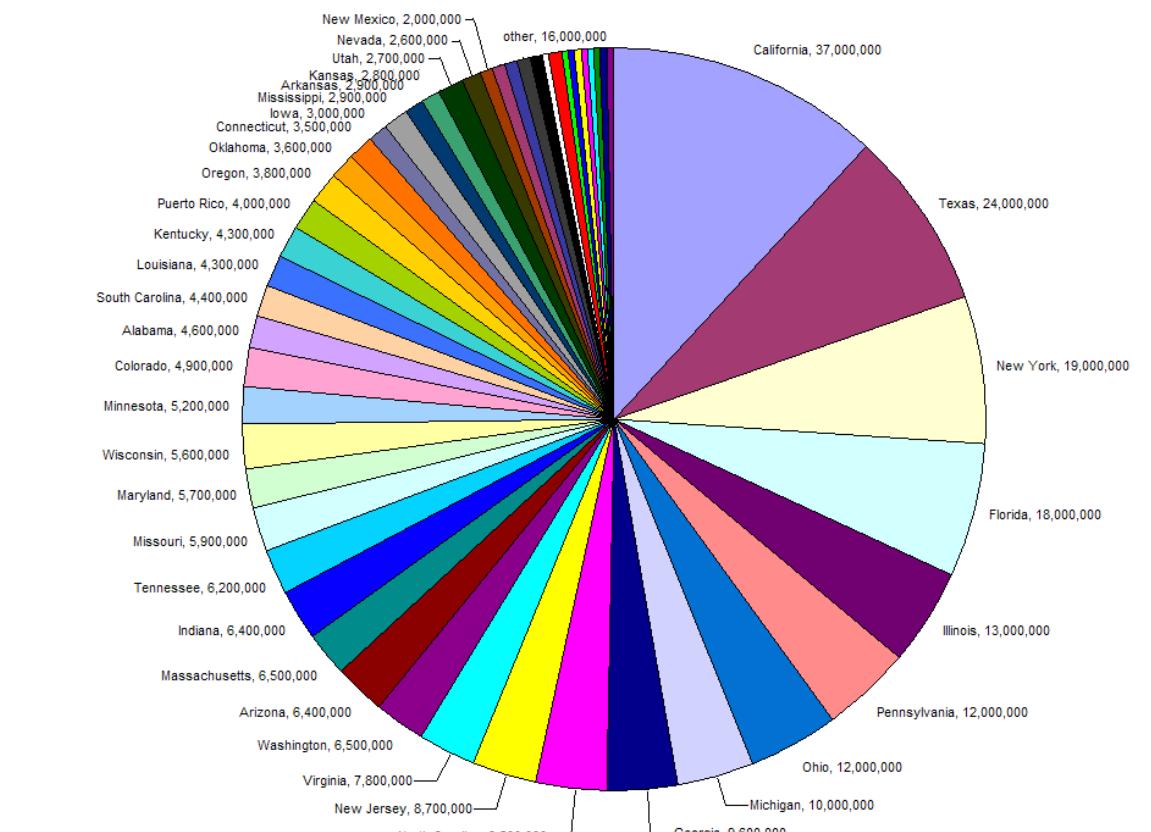
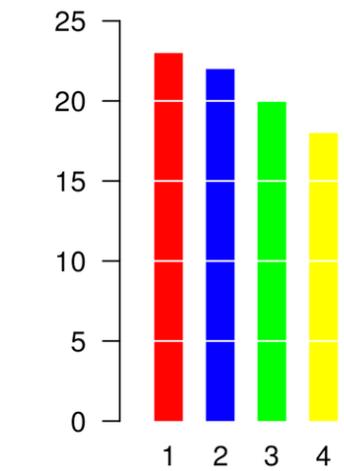
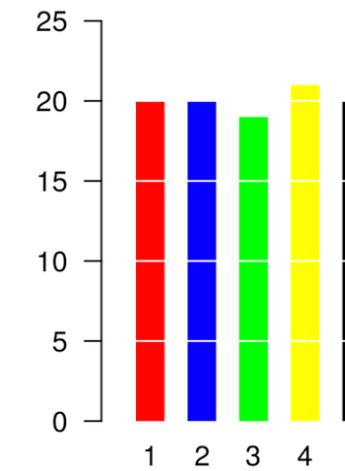
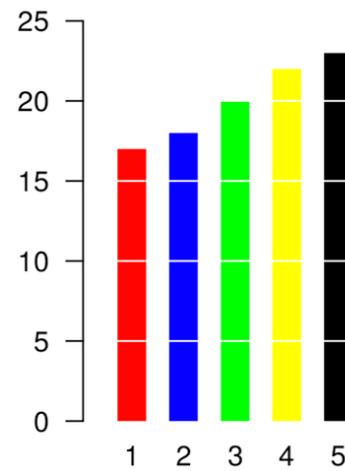
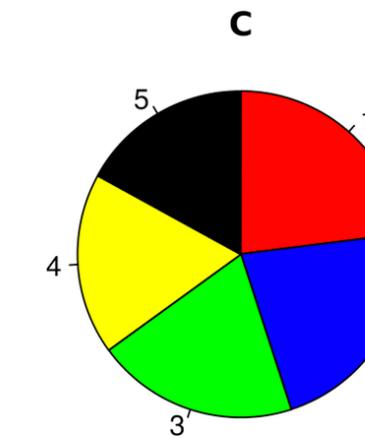
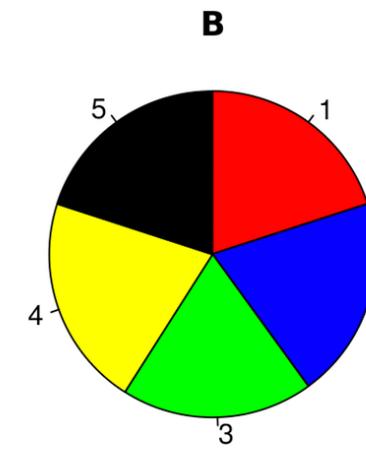
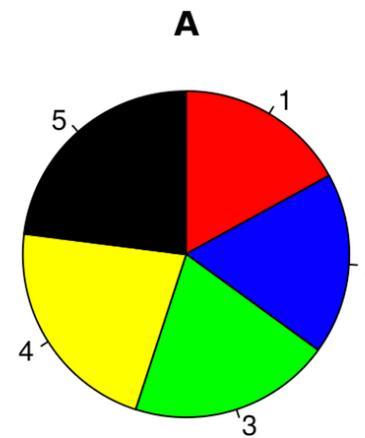


[*Arcs, Angles, or Areas: Individual Data Encodings in Pie and Donut Charts.*
Skau and Kosara. Proc. EuroVis 2016.]

<https://eagereyes.org/blog/2016/an-illustrated-tour-of-the-pie-chart-study-results>

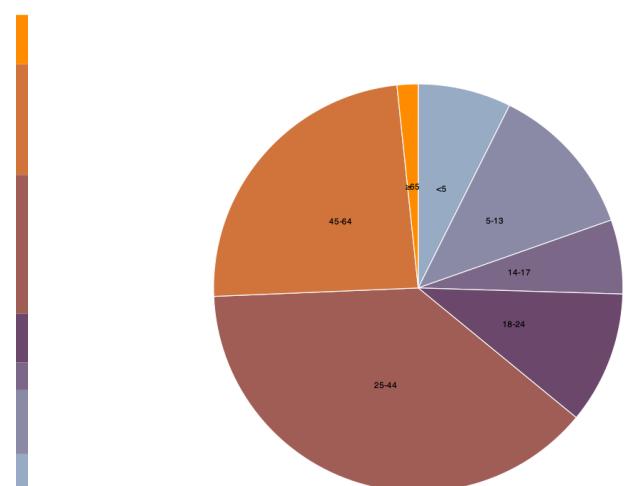
Pie charts: best practices

- not so bad for two (or few) levels, for part-to-whole task
- dubious for several levels if details matter
- terrible for many levels



Idioms: normalized stacked bar chart

- task
 - part-to-whole judgements
- normalized stacked bar chart
 - stacked bar chart, normalized to full vert height
 - single stacked bar equivalent to full pie
 - high information density: requires narrow rectangle
- pie chart
 - information density: requires large circle

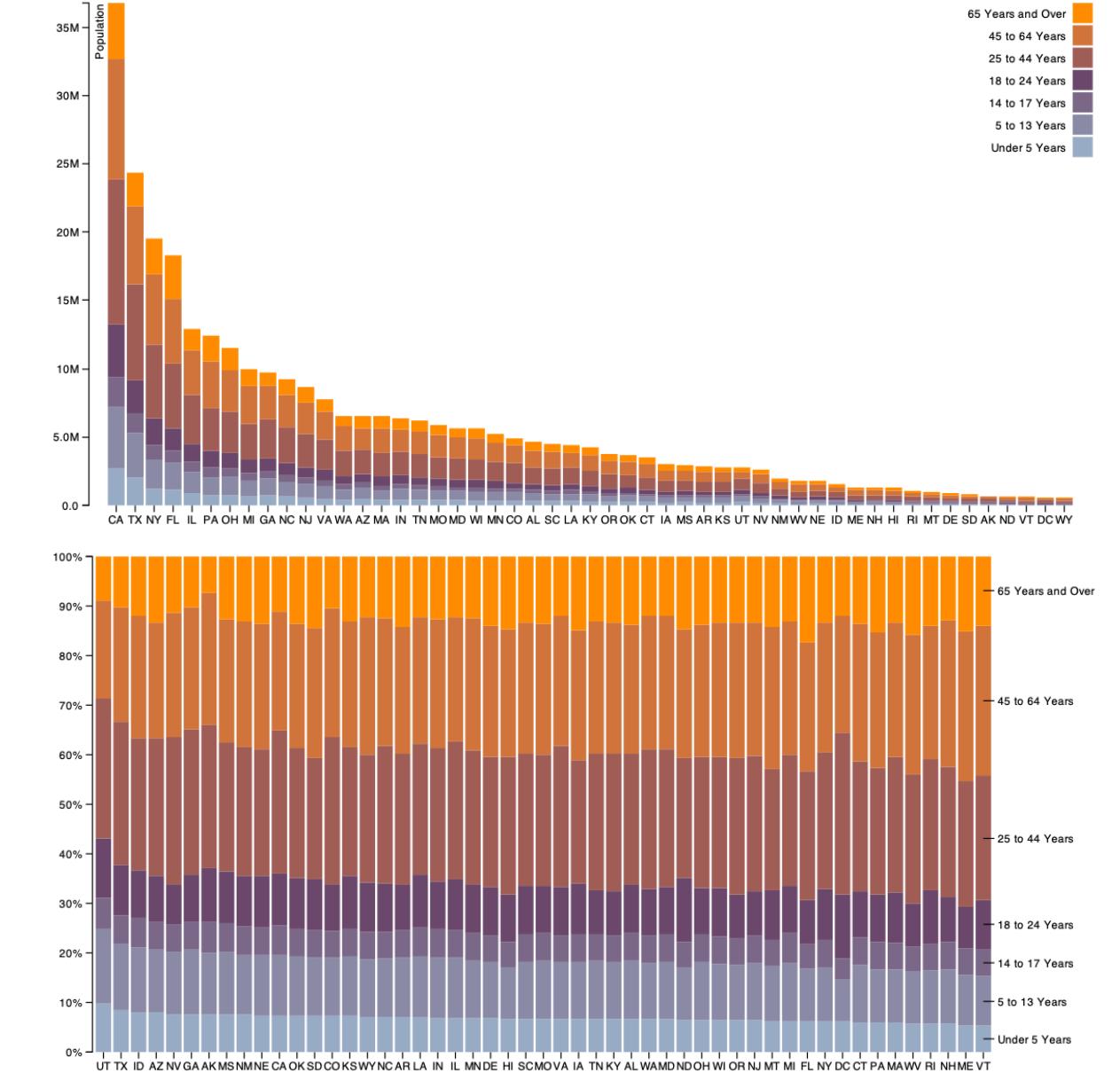


<http://bl.ocks.org/mbostock/388620>

8

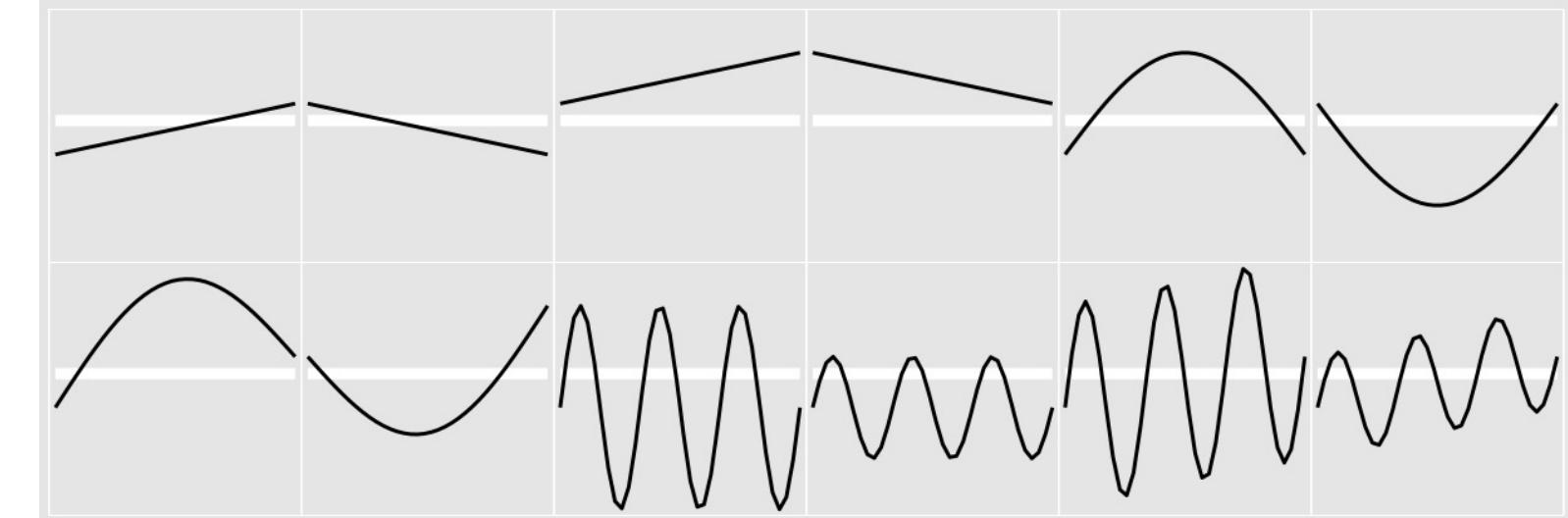
<http://bl.ocks.org/mbostock/388723>

E

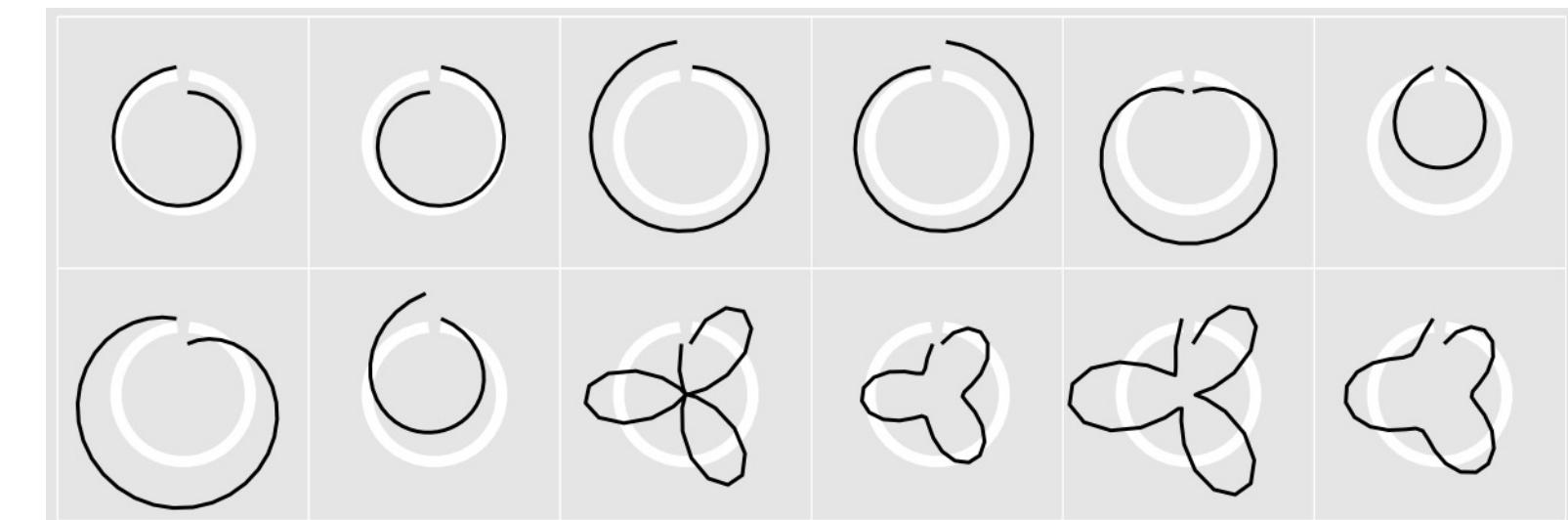


Idiom: glyphmaps

- rectilinear good for linear vs nonlinear trends

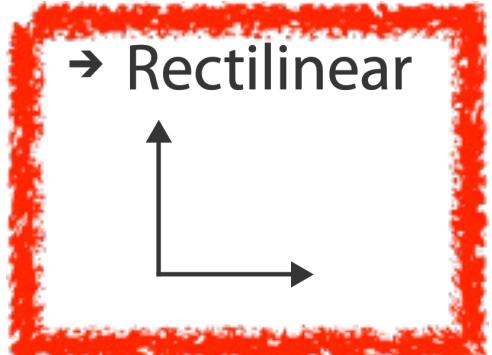


- radial good for cyclic patterns
– evaluating periodicity



[*Glyph-maps for Visually Exploring Temporal Patterns in Climate Data and Models.*
Wickham, Hofmann, Wickham, and Cook. *Environmetrics* 23:5 (2012), 382–393.]

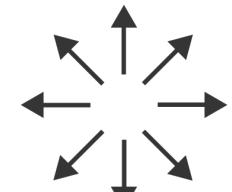
→ Axis Orientation



→ Parallel



→ Radial



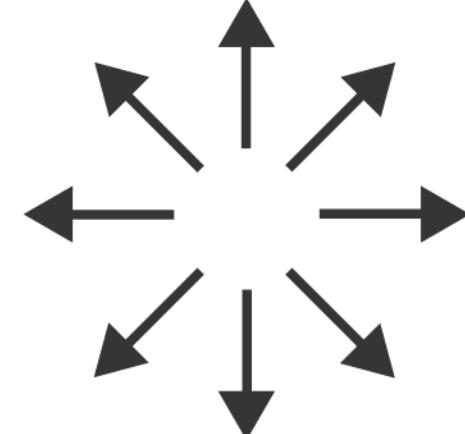
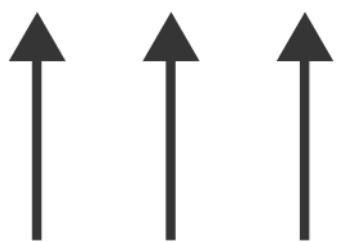
→ Axis Orientation



→ Rectilinear

→ Parallel

→ Radial



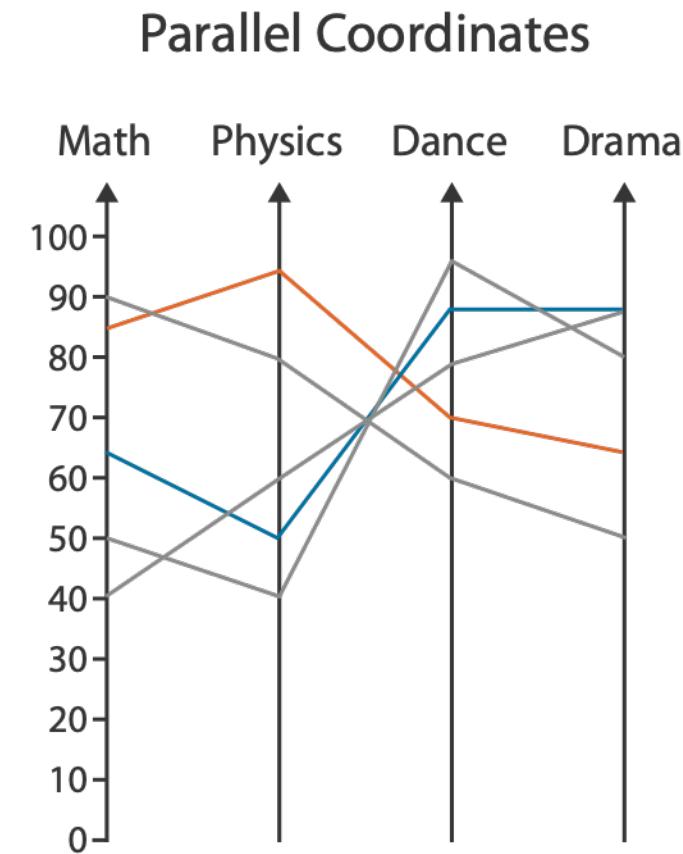
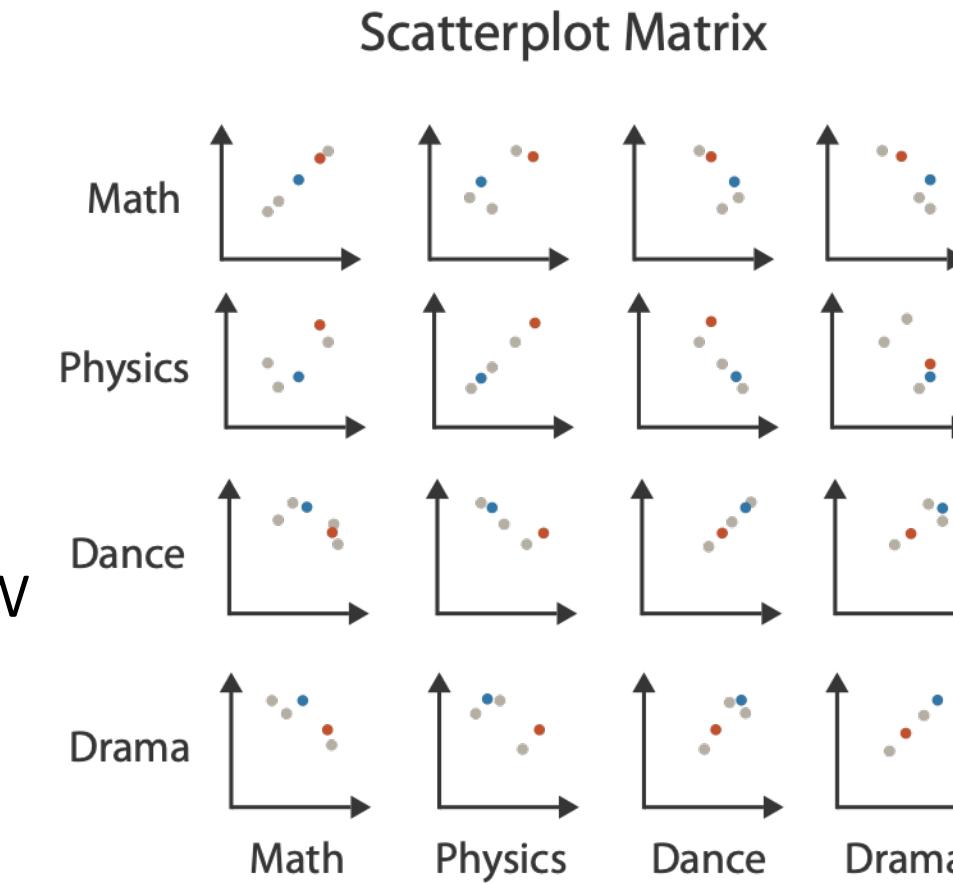
Idiom: SPLOM

- scatterplot matrix (SPLOM)
 - rectilinear axes, point mark
 - all possible pairs of axes
 - scalability
 - one dozen attrs
 - dozens to hundreds of items



Idioms: parallel coordinates

- scatterplot limitation
 - visual representation with orthogonal axes
 - can show only two attributes with spatial position channel
- alternative: line up axes in parallel to show many attributes with position
 - item encoded with a line with n segments
 - n is the number of attributes shown
- parallel coordinates
 - parallel axes, jagged line for item
 - rectilinear axes, item as point
 - axis ordering is major challenge
 - scalability
 - dozens of attrs
 - hundreds of items



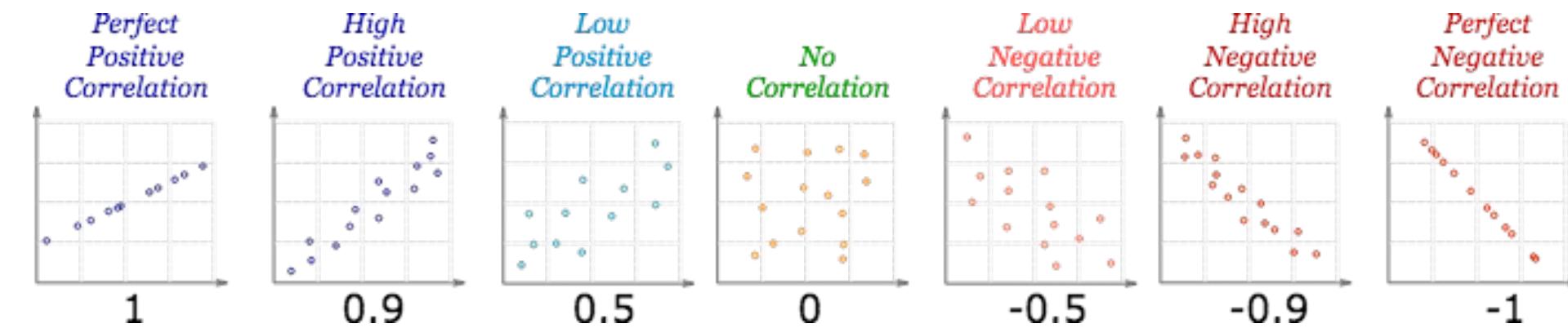
Table

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

after [Visualization Course Figures. McGuffin, 2014.
<http://www.michaelmcguffin.com/courses/vis/>]

Task: Correlation

- scatterplot matrix
 - positive correlation
 - diagonal low-to-high
 - negative correlation
 - diagonal high-to-low
 - uncorrelated: spread out
- parallel coordinates
 - positive correlation
 - parallel line segments
 - negative correlation
 - all segments cross at halfway point
 - uncorrelated
 - scattered crossings



<https://www.mathsisfun.com/data/scatter-x-y-plots.html>

A

B

C

D

E

F

G

H

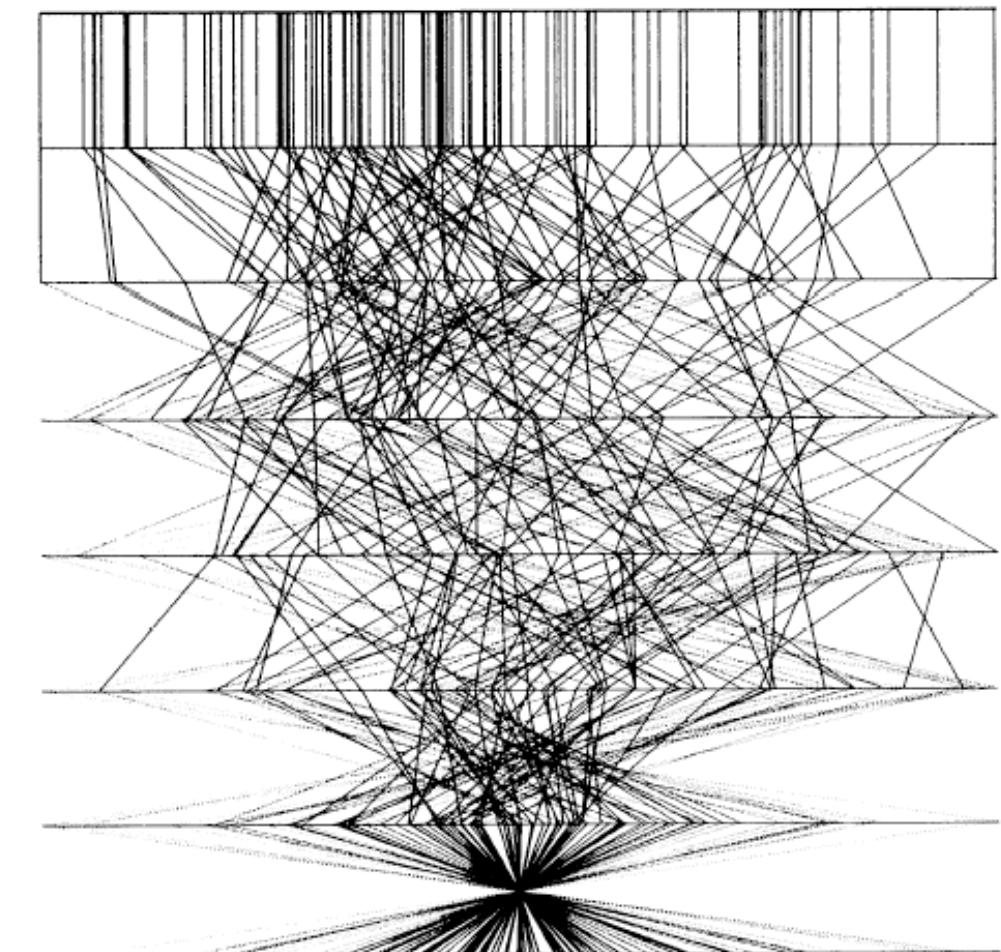
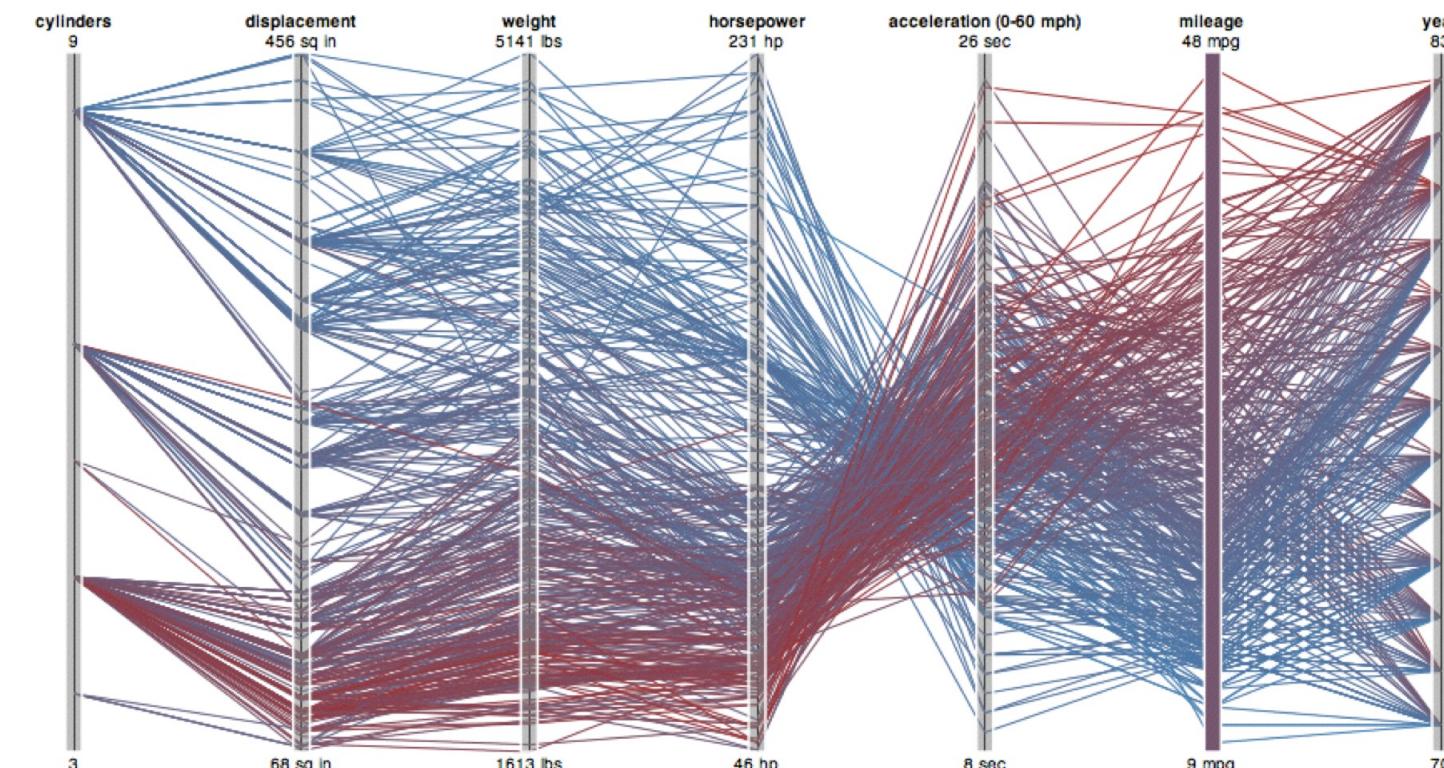


Figure 3. Parallel Coordinate Plot of Six-Dimensional Data Illustrating Correlations of $\rho = 1, .8, .2, 0, -.2, -.8, \text{ and } -1$.

[Hyperdimensional Data Analysis Using Parallel Coordinates. Wegman. Journ. American Statistical Association 85:411 (1990), 664–675.]

Parallel coordinates, limitations

- visible patterns only between neighboring axis pairs
- how to pick axis order?
 - usual solution: reorderable axes, interactive exploration
 - same weakness as many other techniques
 - downside of interaction: human-powered search
 - some algorithms proposed, none fully solve

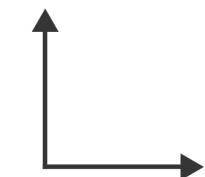


Orientation limitations

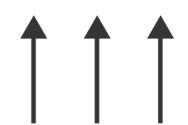
- rectilinear: scalability wrt #axes
 - 2 axes best, 3 problematic, 4+ impossible
- parallel: unfamiliarity, training time
- radial: perceptual limits
 - polar coordinate asymmetry
 - angles lower precision than length
 - nonuniform sector width/size depending on radial distance
 - frequently problematic
 - but sometimes can be deliberately exploited!
 - for 2 attrs of very unequal importance

⇒ Axis Orientation

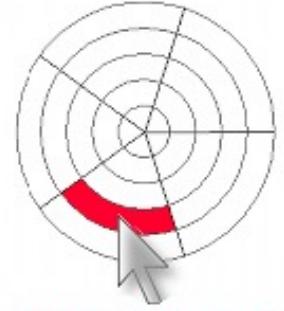
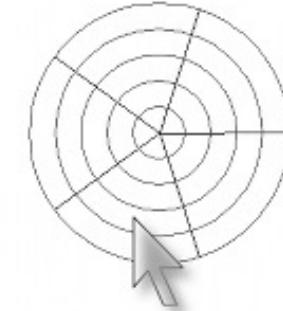
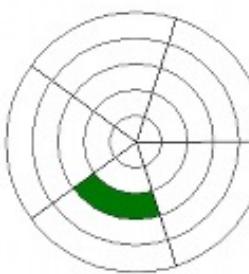
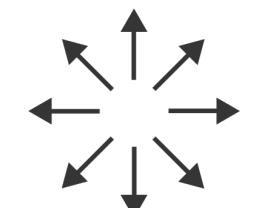
→ Rectilinear



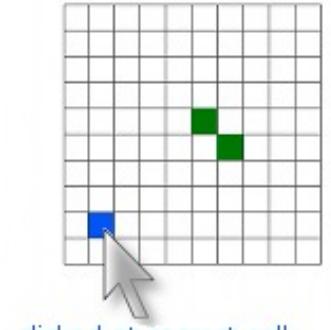
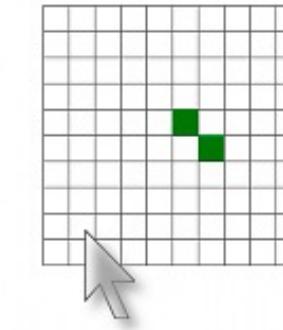
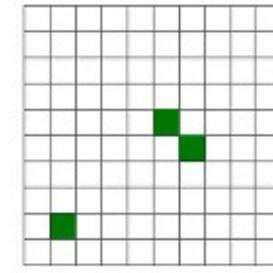
→ Parallel



→ Radial



clicked at wrong cell



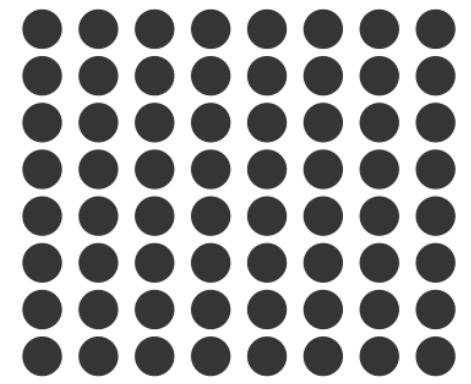
clicked at correct cell

Layout density



Layout Density

→ Dense



→ Space-Filling

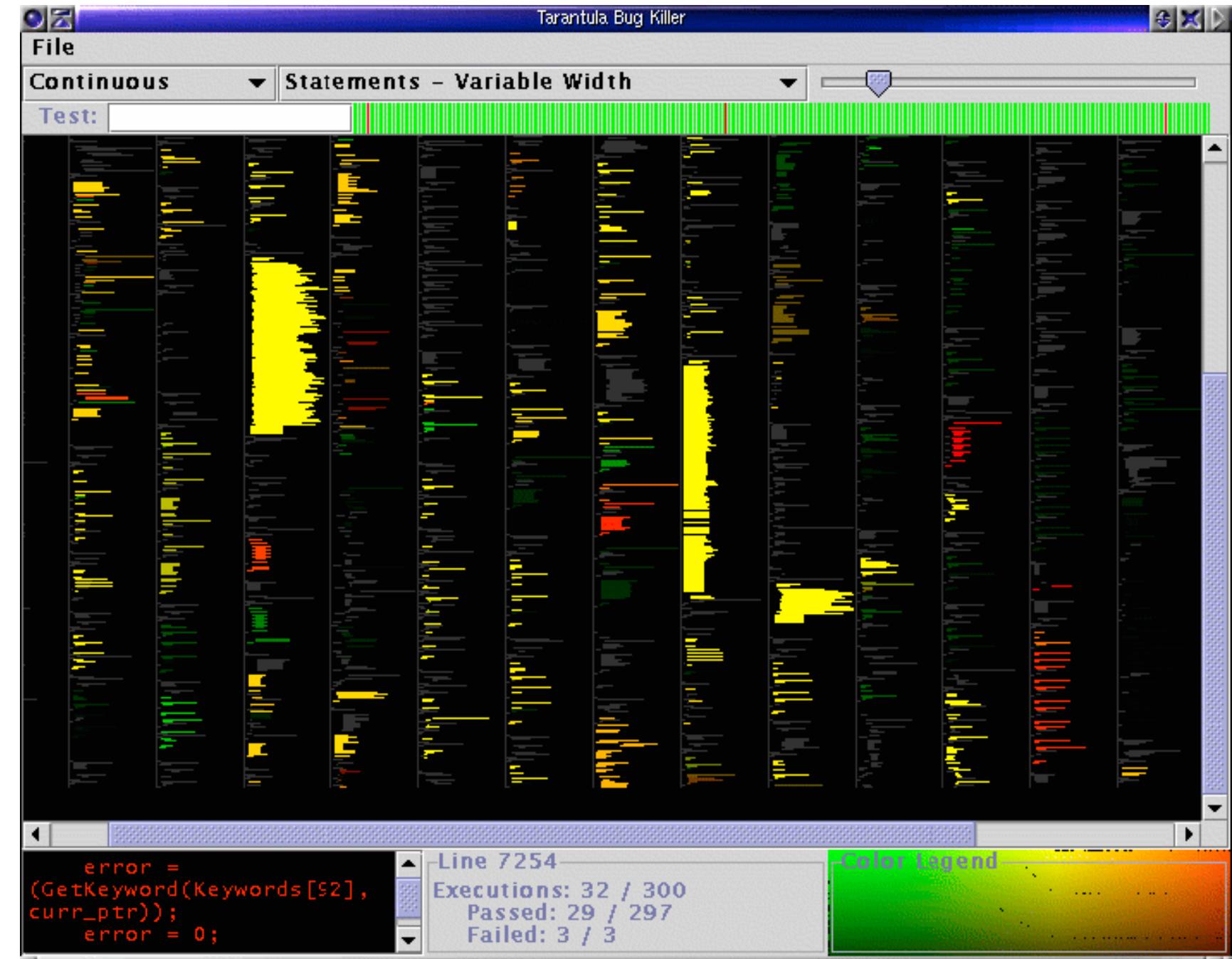
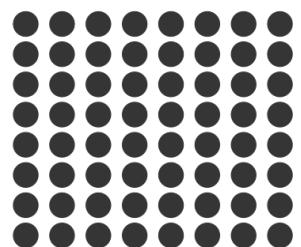


Idiom: Dense software overviews

- data: text
 - text + 1 quant attrib per line
- derived data:
 - one pixel high line
 - length according to original
- color line by attrib
- scalability
 - 10K+ lines

➔ Layout Density

➔ Dense



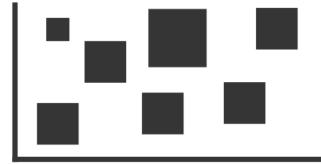
Arrange tables

→ Express Values

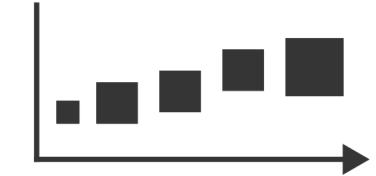


→ Separate, Order, Align Regions

→ Separate



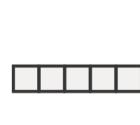
→ Order



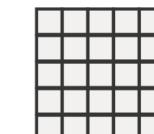
→ Align



→ 1 Key
List

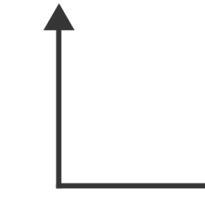


→ 2 Keys
Matrix



→ Axis Orientation

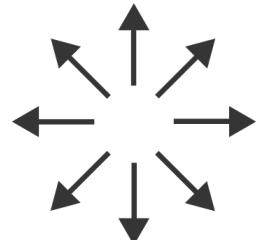
→ Rectilinear



→ Parallel

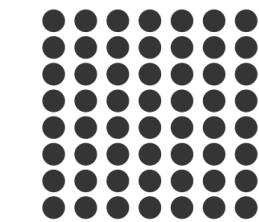


→ Radial



→ Layout Density

→ Dense



How?

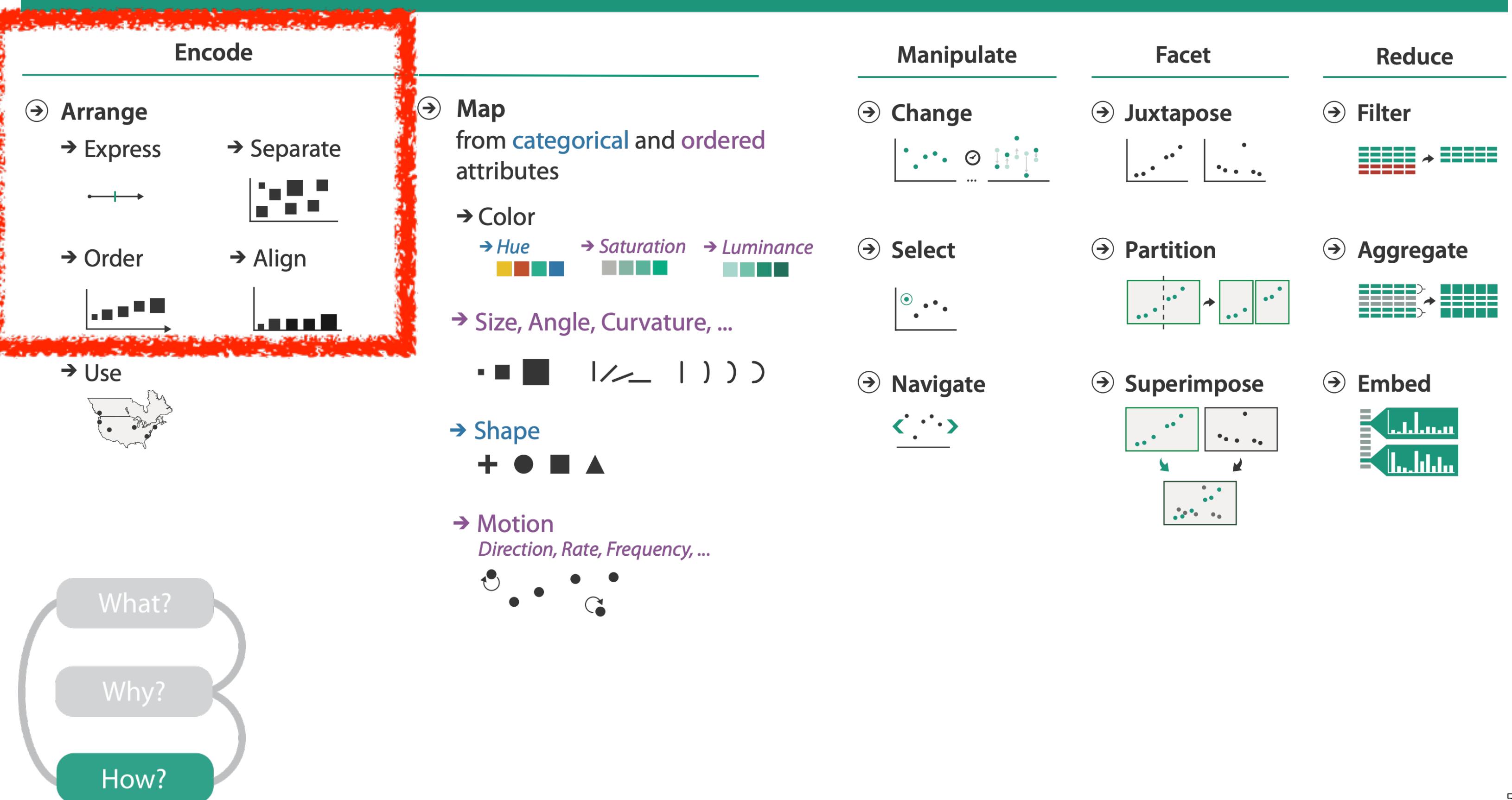
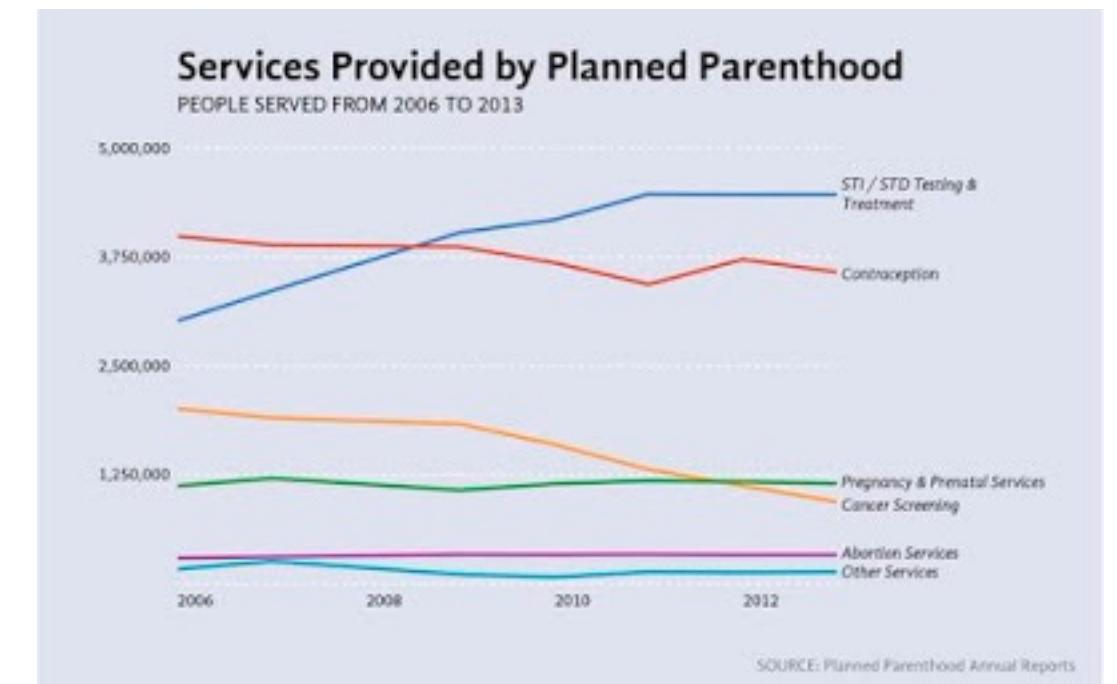
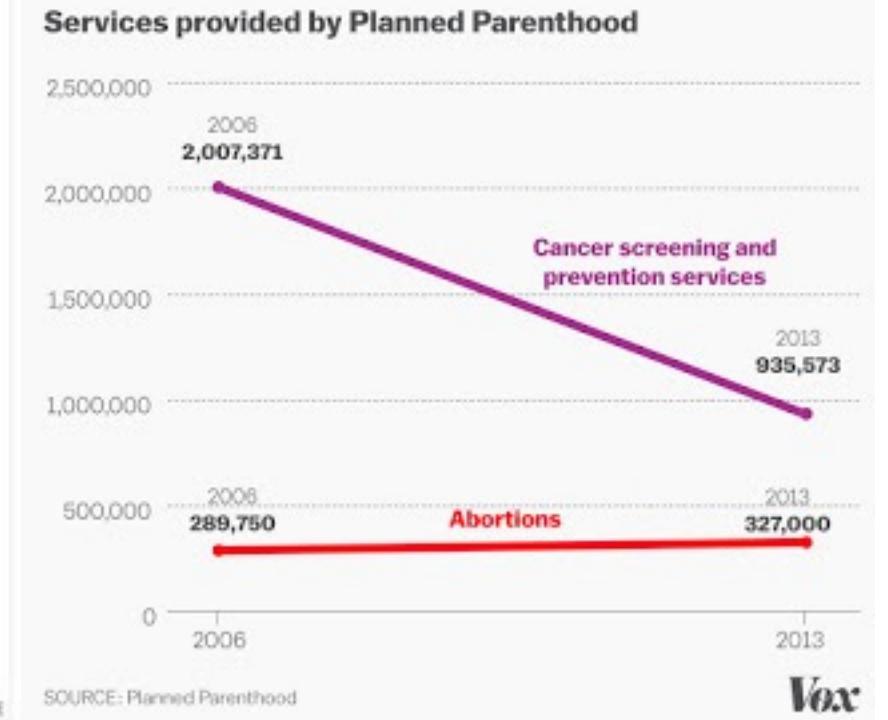
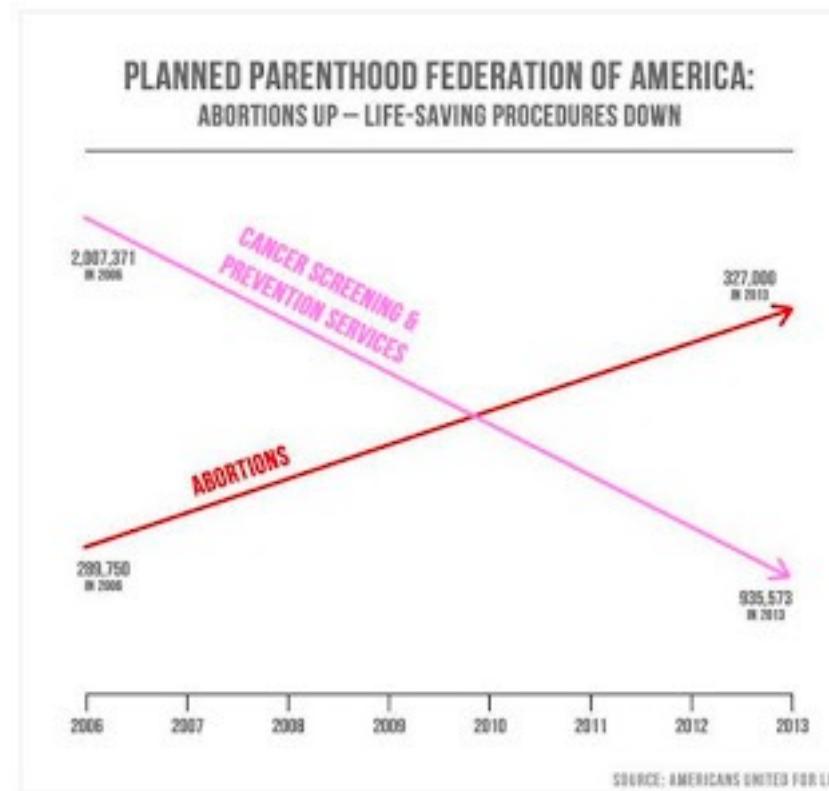


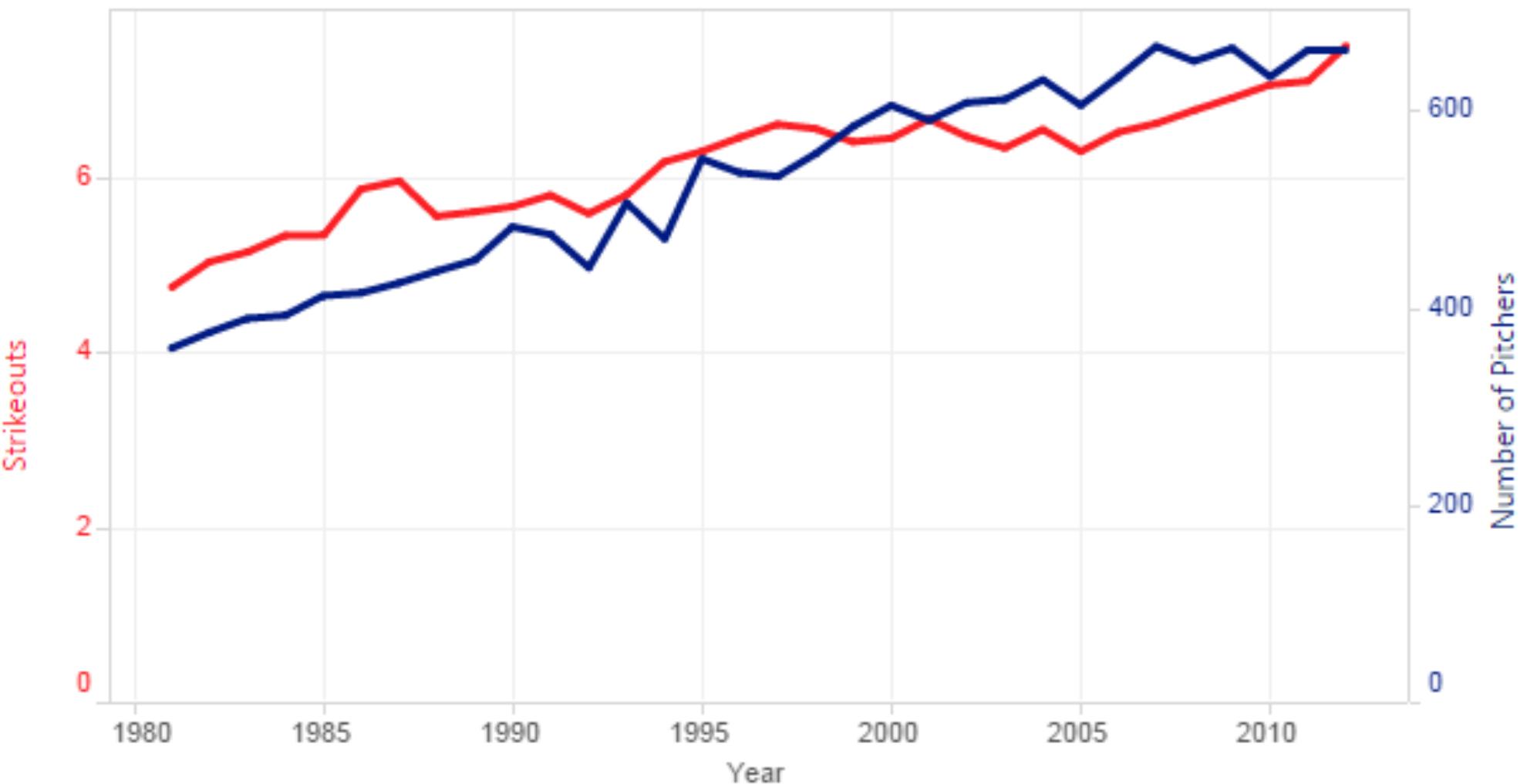
Chart axes

- labelled axis is critical
- avoid cropping y-axis
 - include 0 at bottom left
 - or slope misleads



Idiom: dual-axis line charts

- controversial
 - acceptable if commensurate
 - beware, very easy to mislead!

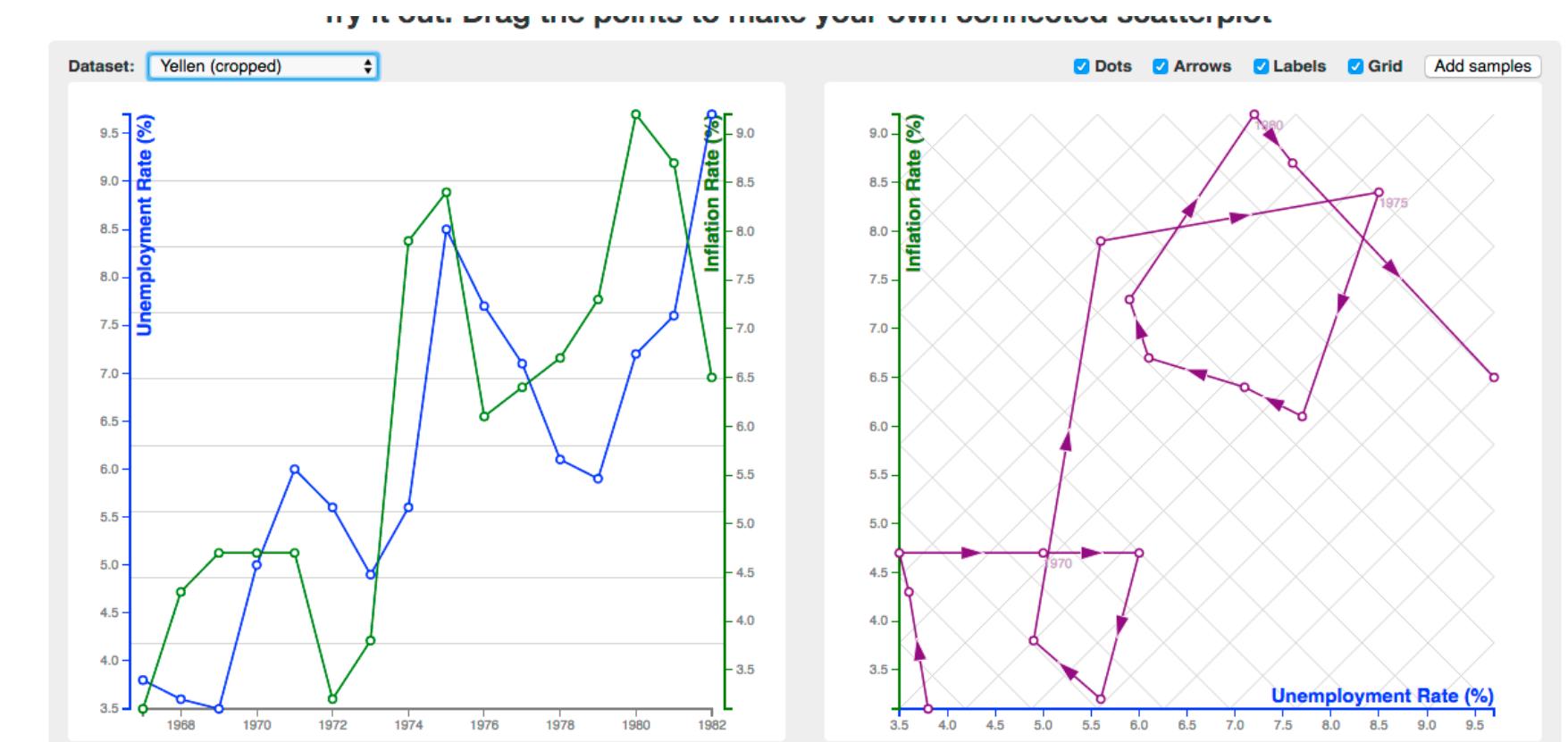
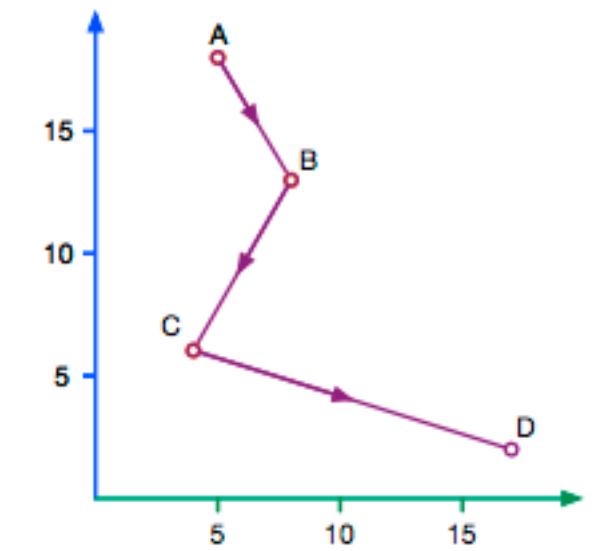
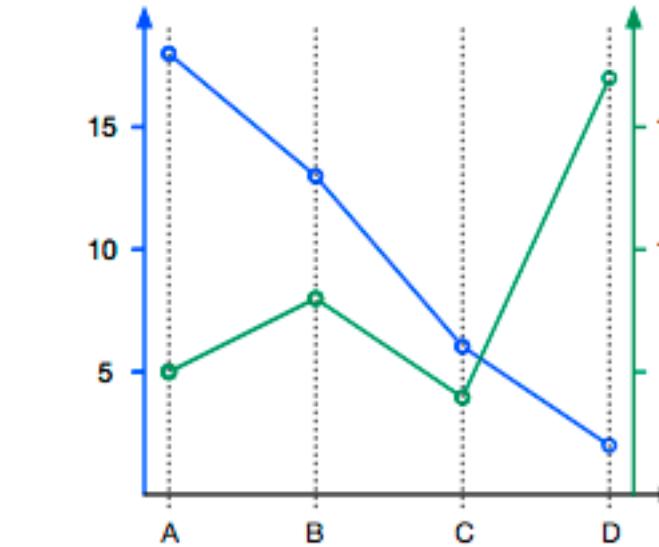
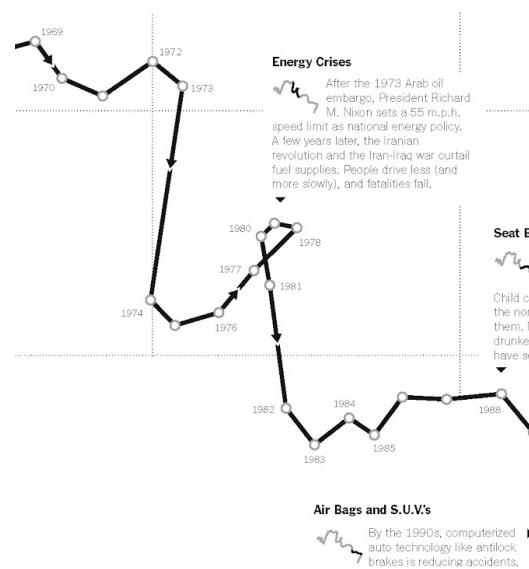


Source | <http://www.baseball-reference.com/leagues/MLB/pitch.shtml>

Ben Jones (@DataRemixed) | 5/4/2013

Idiom: connected scatterplots

- scatterplot with line connection marks
 - popular in journalism
 - horiz + vert axes: value attrs
 - line connection marks:
 - temporal order
 - alternative to dual-axis charts
 - horiz: time
 - vert: two value attrs
- empirical study
 - engaging, but correlation unclear



[The Connected Scatterplot for Presenting Paired Time Series.
Haroz, Kosara and Franconeri. IEEE TVCG 22(9):2174-86,
2016.]

http://steveharoz.com/research/connected_scatterplot/

Choosing line chart aspect ratios

- 1: banking to 45 (1980s)
 - Cleveland perceptual argument: most accurate angle judgement at 45

Fig 7.1 Sunspot Data: Aspect Ratio 1

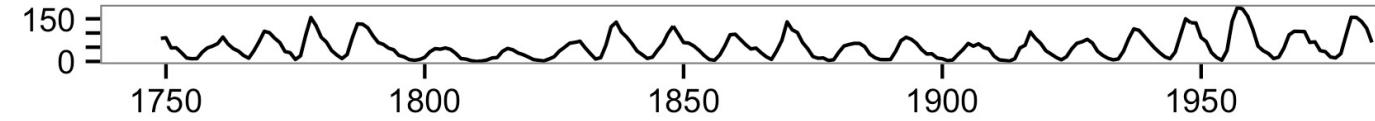
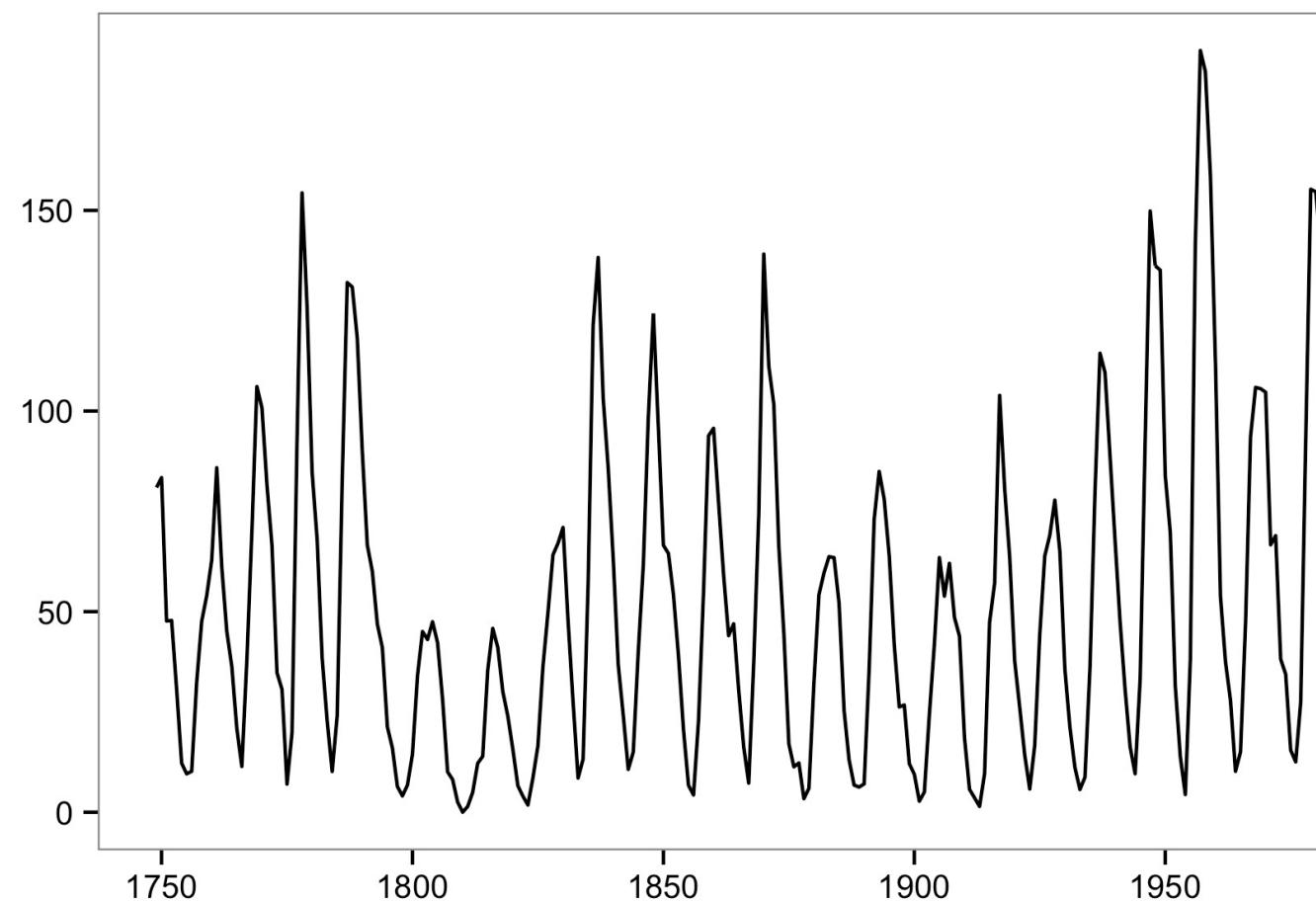
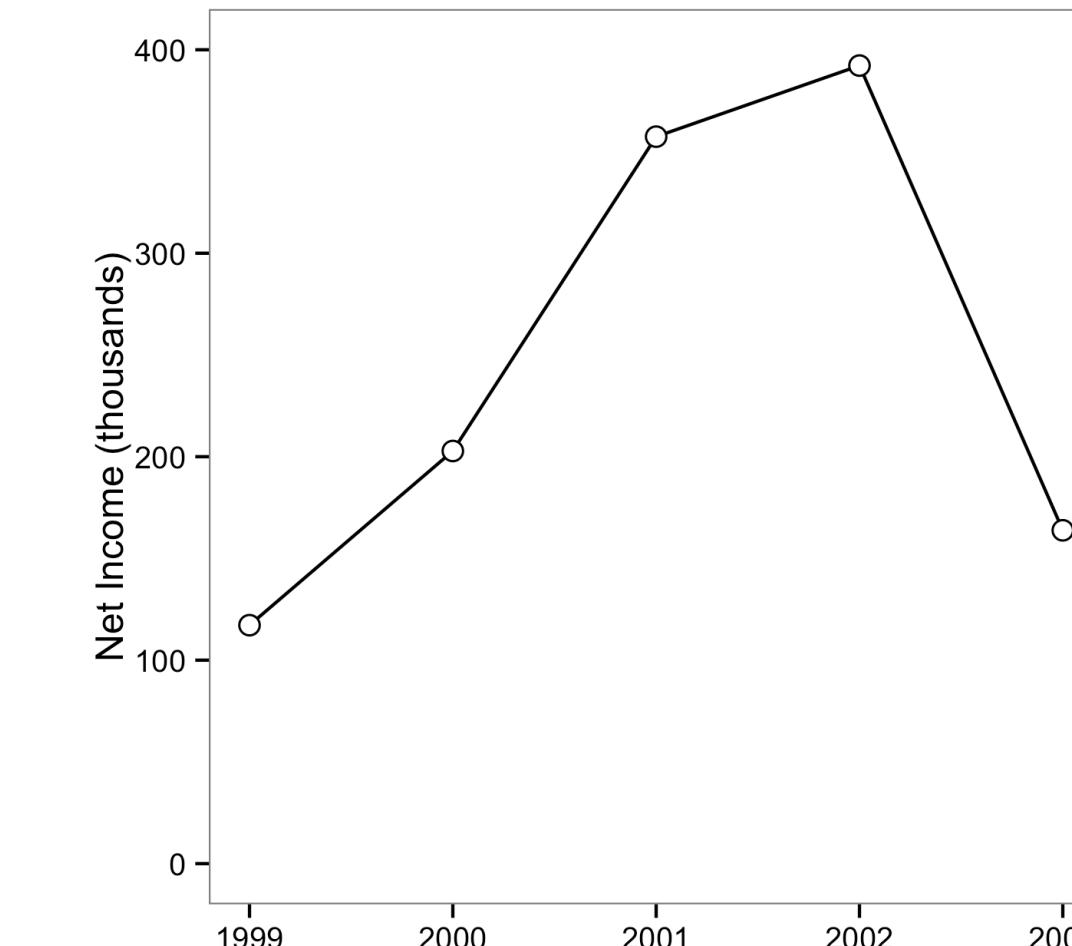
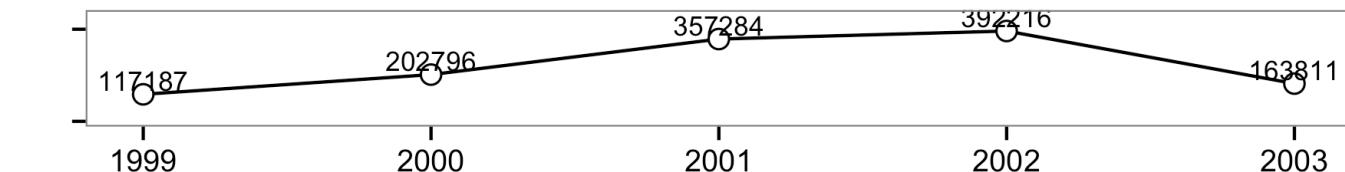
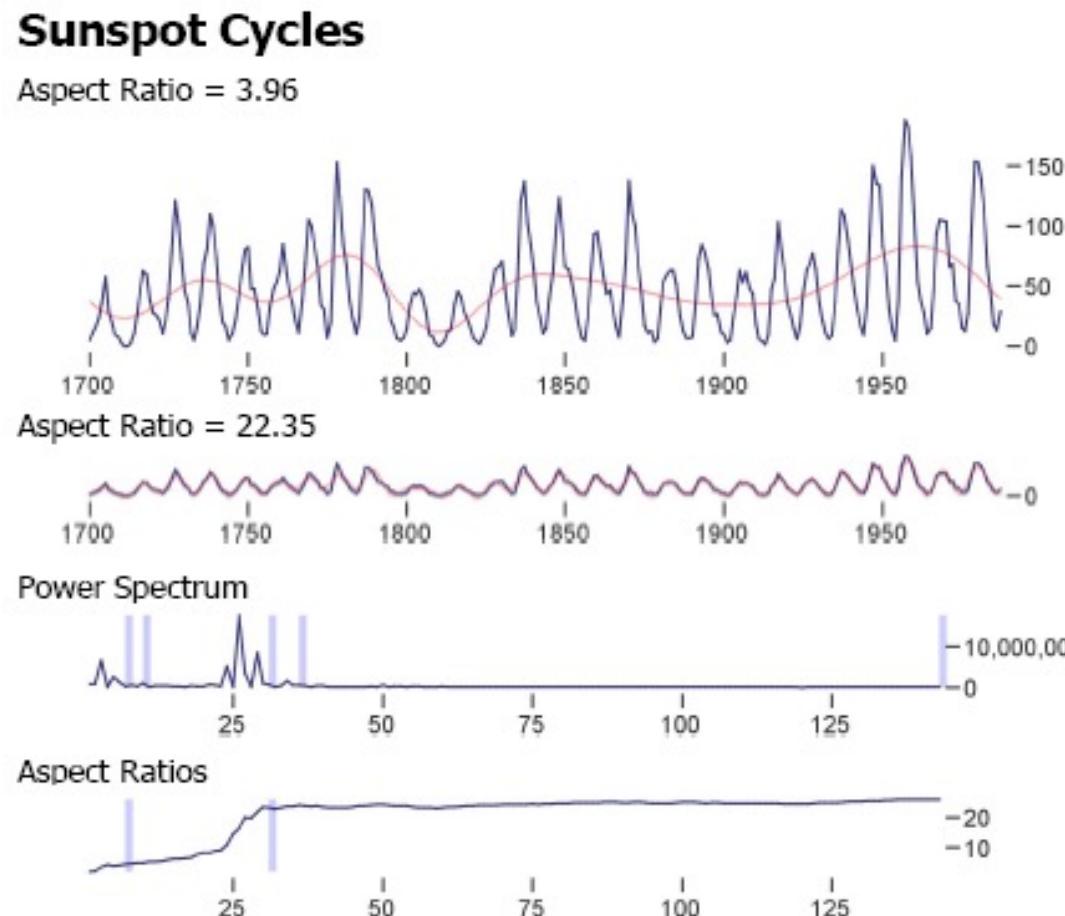


Fig 7.2 Annual Report: Aspect Ratio 2



Choosing line chart aspect ratios

- 2: multi scale banking to 45 (2006)
 - frequency domain analysis to find ratios
 - FFT the data, convolve with Gaussian to smooth
 - find interesting spikes/ranges in power spectrum
 - cull nearby regions if similar, ensure overview
 - create trend curves (red) for each aspect ratio



[\[Multi-Scale Banking to 45 Degrees.
Heer and Agrawala, Proc InfoVis
2006\]](#)

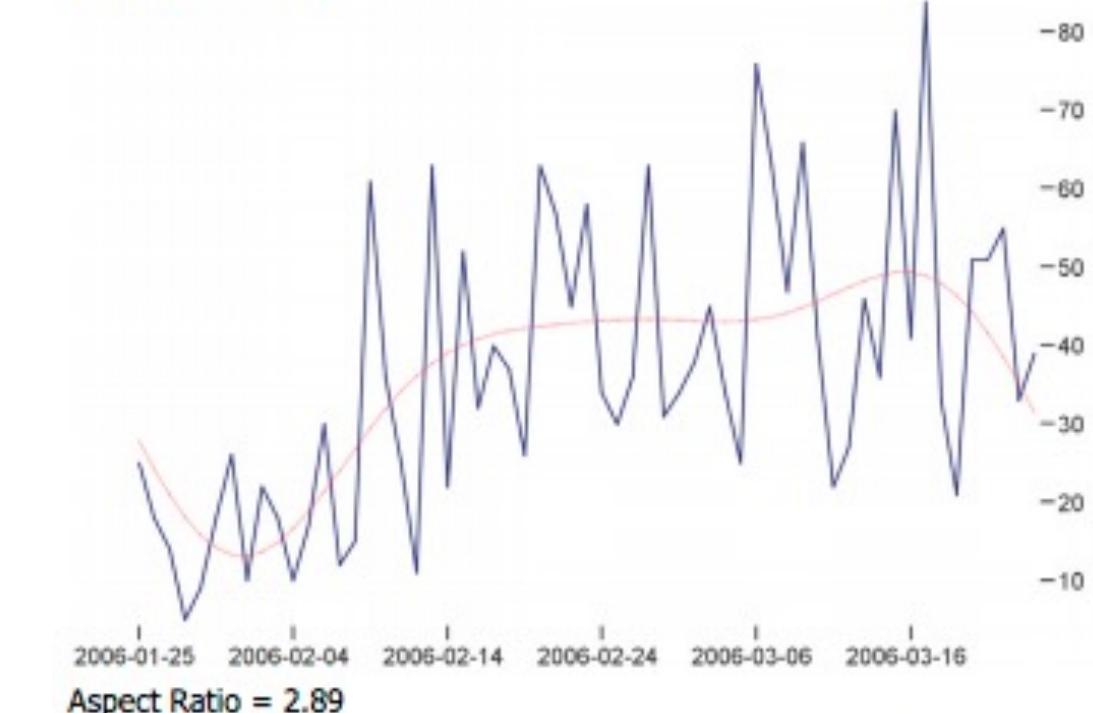
overall

weekly

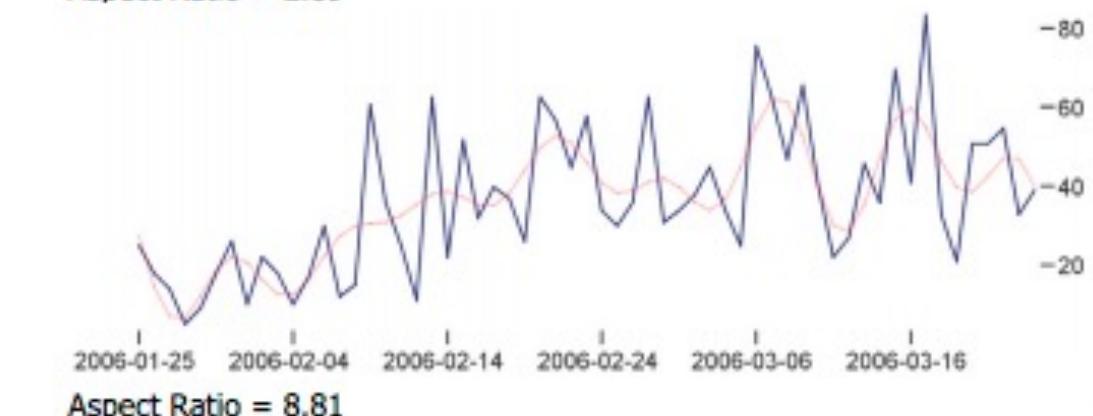
daily

Downloads of the prefuse toolkit

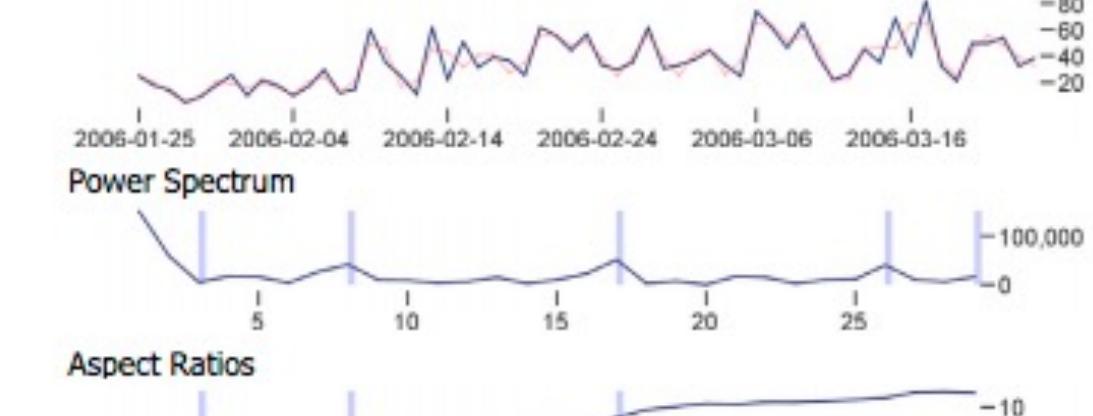
Aspect Ratio = 1.44



Aspect Ratio = 2.89



Aspect Ratio = 8.81

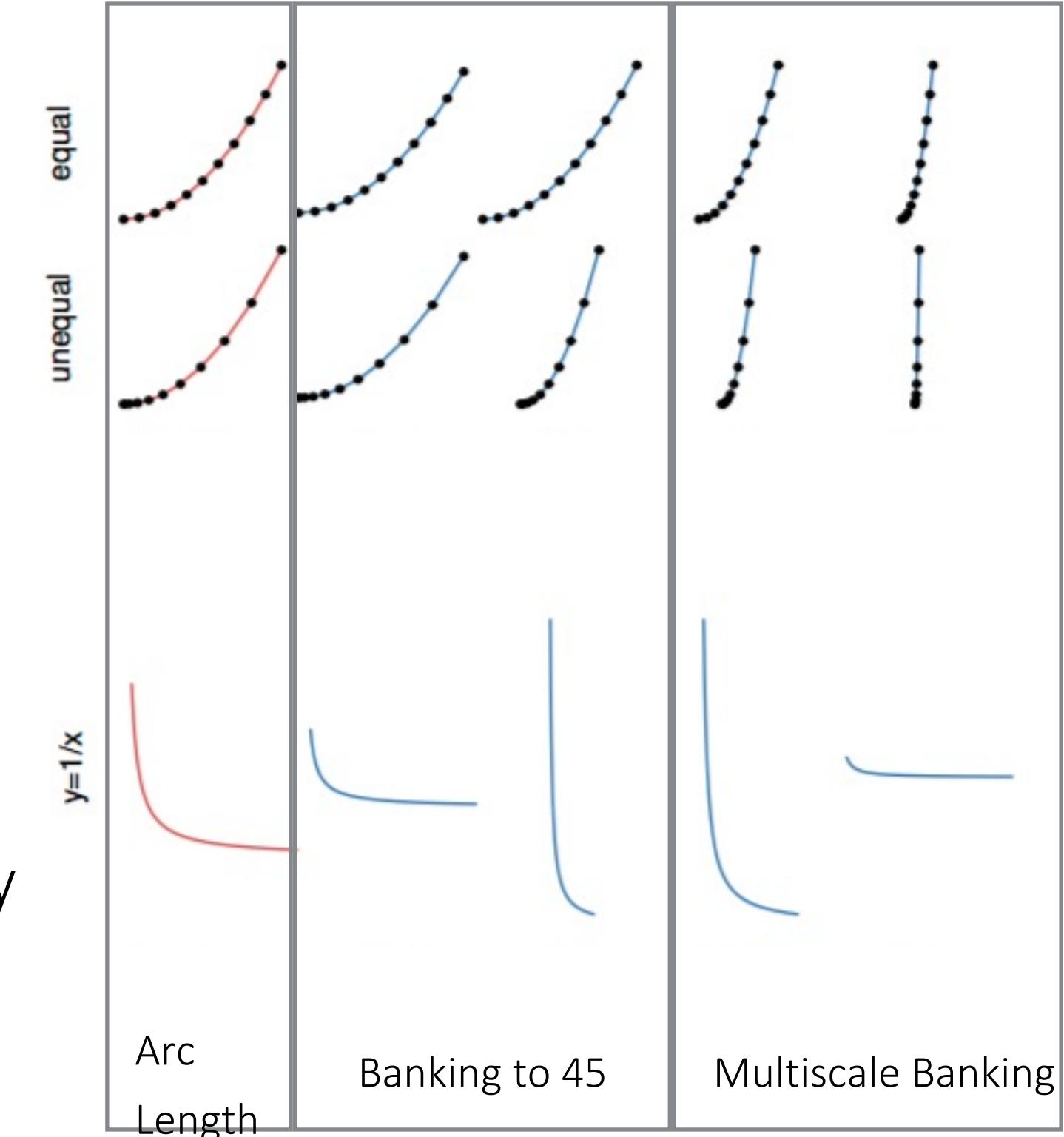


Power Spectrum

Aspect Ratios

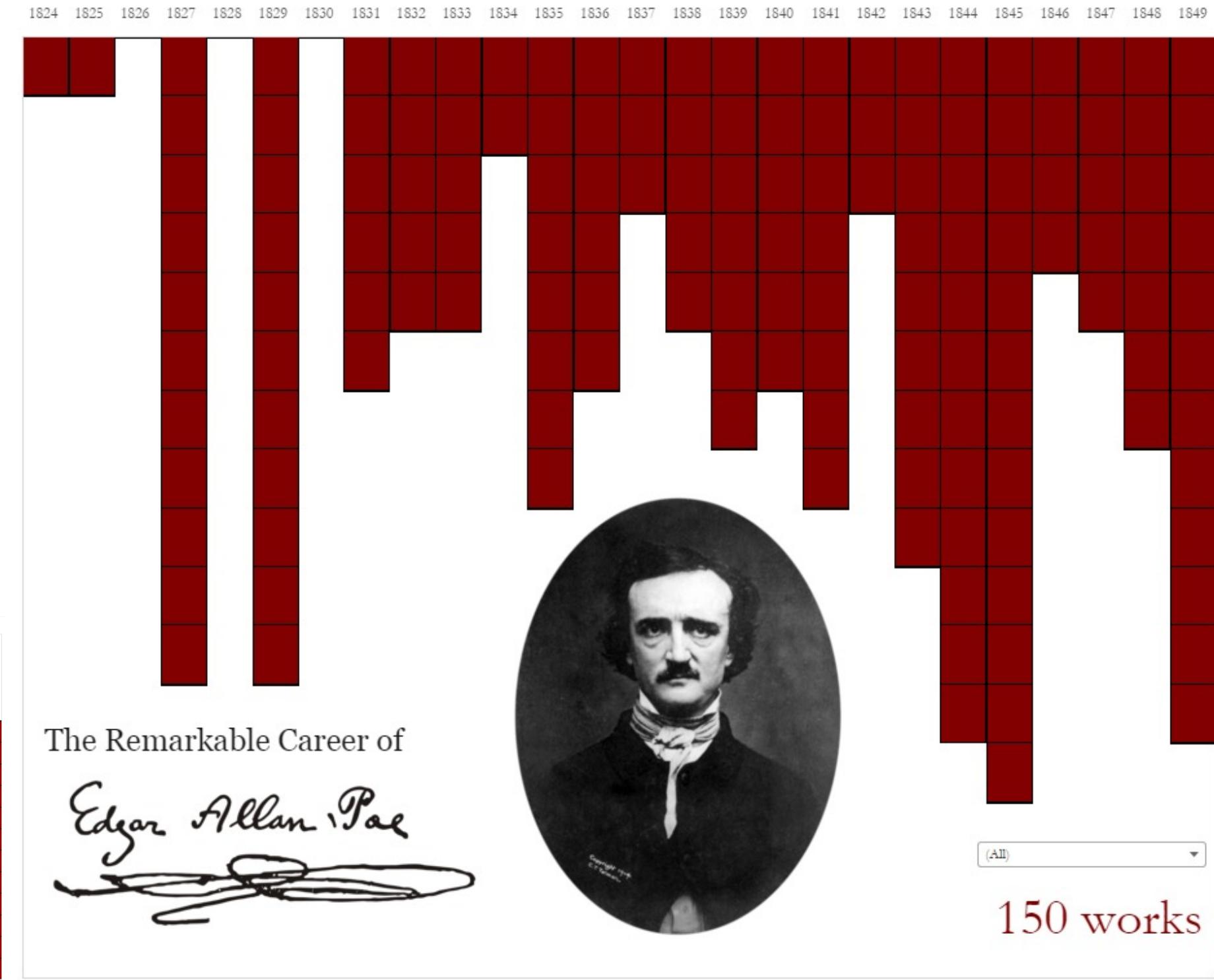
Choosing line chart aspect ratios

- 3: arc length based aspect ratio (2011)
 - minimize the arc length of curve while keeping the area of the plot constant
 - parametrization and scale invariant
 - symmetry preserving
 - robust & fast to compute
- meta-points from this progression
 - young field; prescriptive advice changes rapidly
 - reasonable defaults required deep dive into perception meets math



Breaking conventions

- presentation vs exploration
 - engaging/evocative
 - inverted y axis
 - blood drips down on Poe



<https://public.tableau.com/profile/ben.jones#!/vizhome/EdgarAllanPoeBoring/EdgarAllenPoeBoring>

<https://public.tableau.com/profile/ben.jones#!/vizhome/EdgarAllanPoeViz/EdgarAllanPoeViz>