# Spatial Layout: Arrange Tables

# How?

## Encode

- Arrange
  - Express
  - Separate
  - Order
  - Align
  - Use

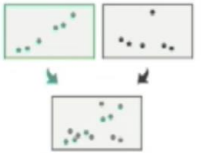
- Map
  from categorical and ordered attributes
  - Color
    - Hue
    - Saturation
    - Luminance
  - Size, Angle, Curvature, ...
  - Shape
  - Motion
    *Direction, Rate, Frequency, ...*

## Manipulate

- Change
- Select
- Navigate

## Facet

- Juxtapose
- Partition
- Superimpose



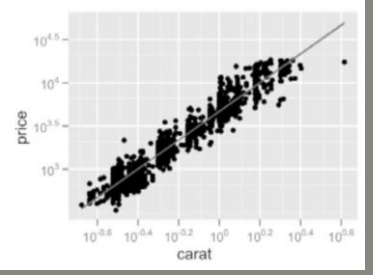
## Reduce

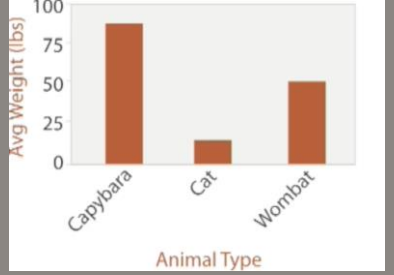
- Filter
- Aggregate
- Embed

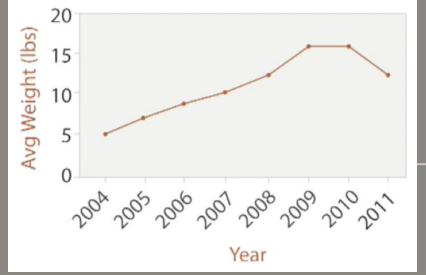
What?

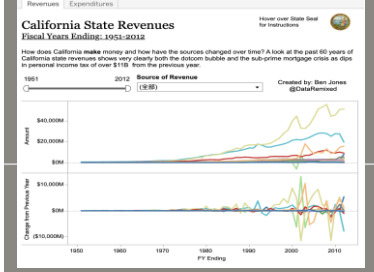
Why?

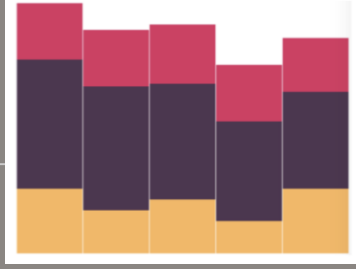
How?

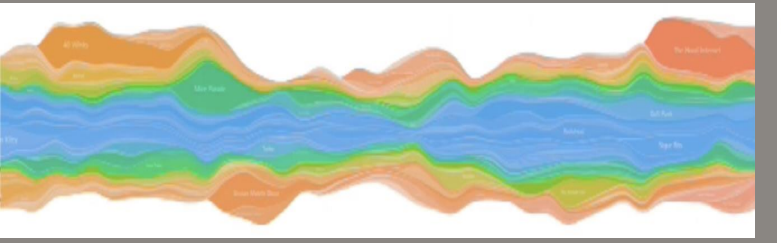

price
carat

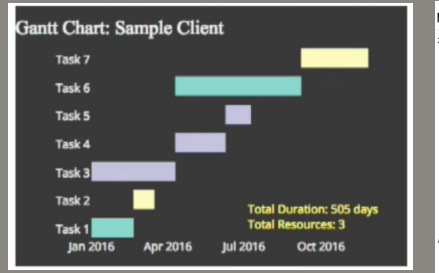

Avg Weight (lbs)
Capybara
Cat
Wombat
Animal Type

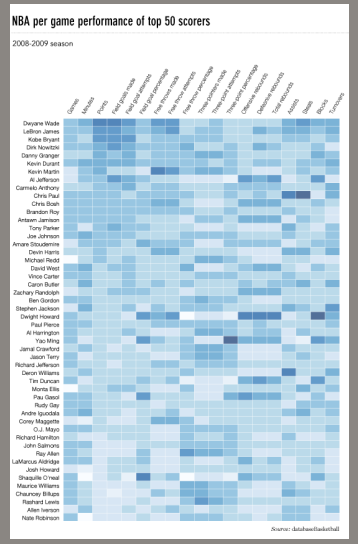

Avg Weight (lbs)
Year

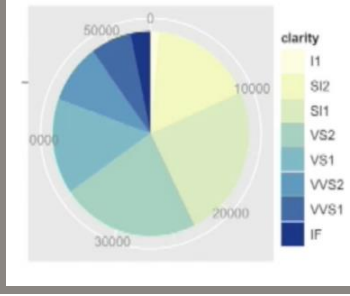

California State Revenues
Fiscal Years Ending: 1951-2012

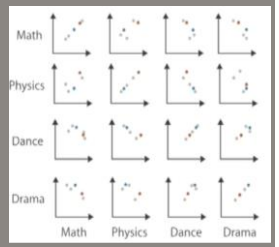


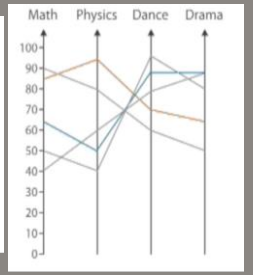


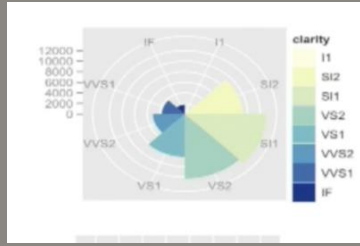

Gantt Chart: Sample Client
Task 7
Task 6
Task 5
Task 4
Task 3
Task 2
Task 1
Total Duration: 505 days
Total Resources: 3
Jan 2016
Apr 2016
Jul 2016
Oct 2016

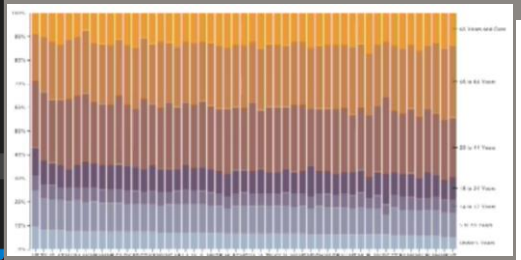

NBA per game performance of top 50 scorers
2008-2009 season

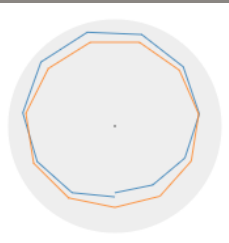

clarity
I1
SI2
SI1
VS2
VS1
VVS2
VVS1
IF

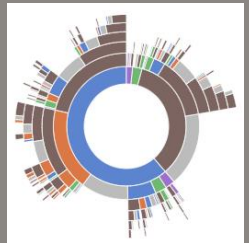

Math
Physics
Dance
Drama

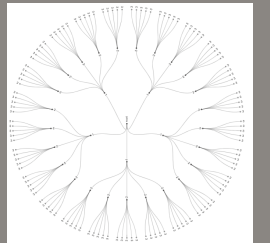

Math
Physics
Dance
Drama

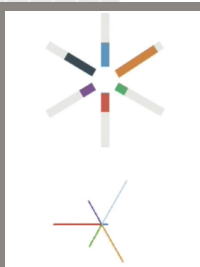

clarity
I1
SI2
SI1
VS2
VS1
VVS2
VVS1
IF











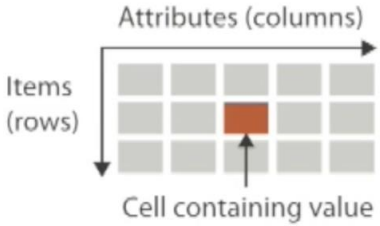
# Key and Value

- In visualization
  - Value:
    - dependent variables
    - Value you want to show in the visualization
  - Key: independent variables
    - To index a value (Usually, categorical or ordinal)

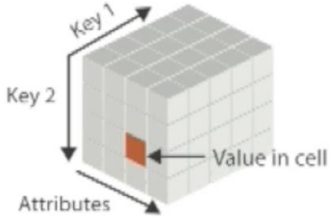
| | day | apricot | blueberry | cherry |
|---|---|---|---|---|
| 2 | Mon | 120 | 180 | 100 |
| 3 | Tue | 60 | 185 | 105 |
| 4 | Wed | 100 | 215 | 110 |
| 5 | Thu | 80 | 230 | 105 |
| 6 | Fri | 120 | 240 | 105 |

2 keys (2D): combination of (day, fruitName) can point to a value

## → Tables



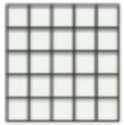

## → *Multidimensional Table*




## → Express Values

## → *1 Key* *List*

## → *2 Keys* *Matrix*



## → *3 Keys* *Volume*

## → *Many Keys* *Recursive Subdivision*

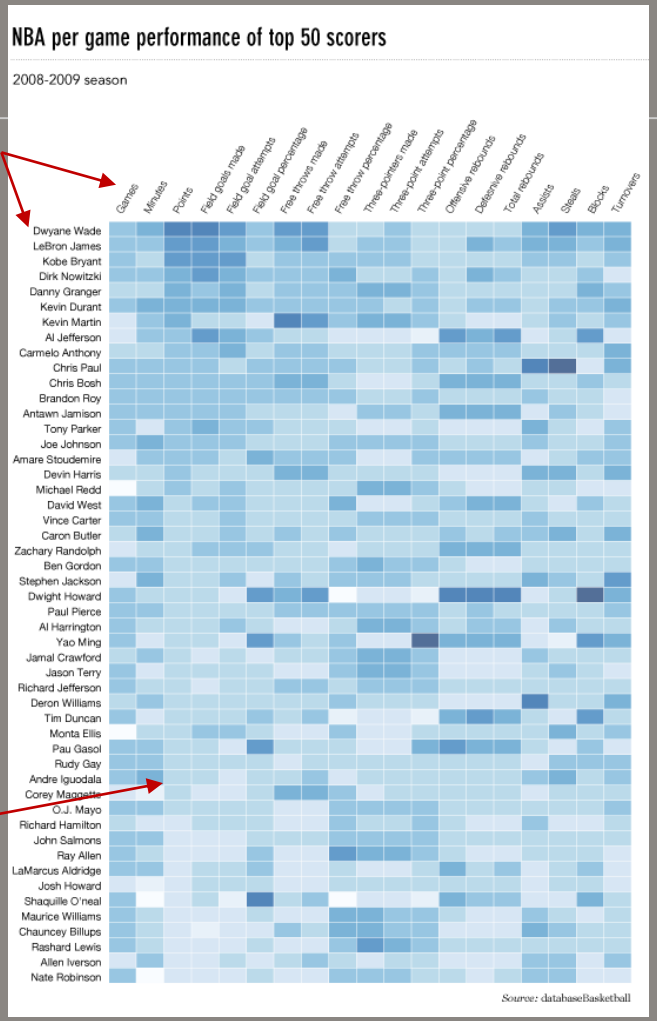
# Key and Value

- In visualization
  - Value:
    - dependent variables
    - Value you want to show in the visualization
  - Key: independent variables
    - To index a value (Usually, categorical or ordinal)

| Player | Games | Minutes | Points | Rebounds | …… |
|---|---|---|---|---|---|
| James | 80 | 44 | 28 | 9 | … |
| Wade | 75 | 32 | 25 | 6 | … |
| … | … | … | … | … | … |

2 keys

values



# S05-01

# Arrange Table Data

## Express Values

## Separate, Order, Align Regions

- Separate

- Order

- Align

- *1 Key*
  *List*

- *2 Keys*
  *Matrix*

- *3 Keys*
  *Volume*

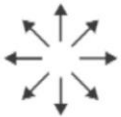
- *Many Keys*
  *Recursive Subdivision*

## Axis Orientation

- Rectilinear

- Parallel

- Radial

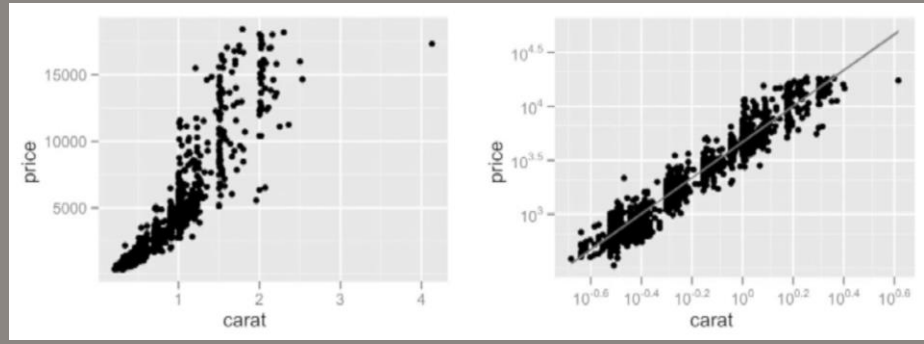


## Layout Density

- Dense

- Space-Filling

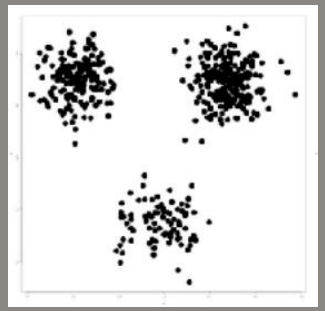
# Idiom: scatterplot




- Express values
  - Quantitative attribute
- No keys, only values
  - Data
    - 2 quantitative attributes
  - Mark:
    - points
  - Channels
    - Horizontal + vertical position
  - Tasks
    - Find trends, outliers, distribution, correlation, clusters
  - Scalability
    - Hundreds of items

you do not care which date of the data points,
But correlation, outlier…..

| date | carat | price |
|---|---|---|
| Jan-20 | 1 | 100 |
| Jan-20 | 2 | 250 |
| Jan-20 | 3 | 400 |
| Jan-20 | 4 | 800 |
| 20-Feb | 1 | 125 |
| 20-Feb | 2 | 250 |
| 20-Feb | 3 | 700 |
| 20-Feb | 4 | 1200 |
| … | … | … |



**Scalability**: how many data you can show before this visualization is ineffective

D3: https://www.d3-graph-gallery.com/graph/scatter_basic.html

# Idiom: scatterplot

- Express values
  - Quantitative attribute
- No keys, only values
  - Data
    - 2 quantitative attributes
  - Mark:
    - points
  - Channels
    - Horizontal + vertical position
  - Tasks
    - Find trends, outliers, distribution, correlation, clusters
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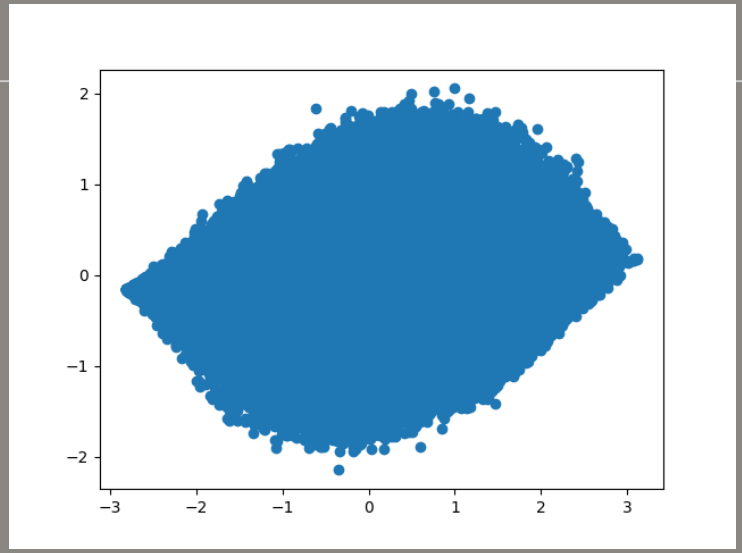
    - Hundreds of items

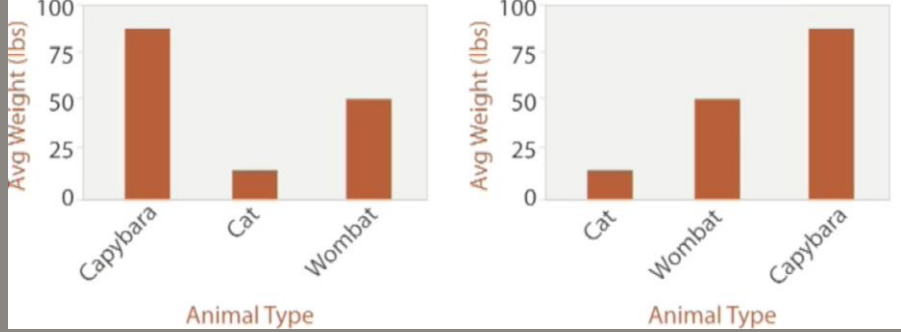



Too many points. It can not show more details

**Scalability**: how many data you can show before this visualization is ineffective

D3: https://www.d3-graph-gallery.com/graph/scatter_basic.html

# Idiom: bar chart

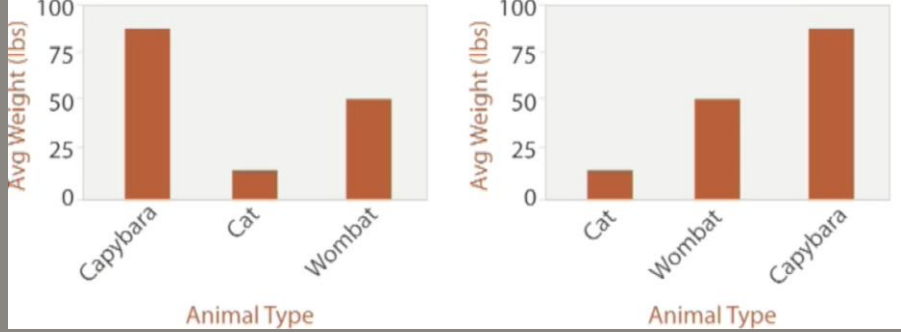



- One key, one value
  - Data
    - 1 categorical attribute (key), 1 quantitative attribute
  - Mark: lines
  - Channels
    - Length to express quantitative value
    - Spatial region: one per mark
      - Separated horizontally, aligned vertically
      - Ordered by quantitative attribute
        - By label (alphabetical) , by length attribute(data-driven)
  - Task
    - Compare, lookup values
  - Scalability
    - Dozens to hundreds of levels for key attribute

D3: https://bl.ocks.org/d3noob/8952219

**How do we order the x-axis??**
Visual channel x-axis: magnitude channel
Data attribute on x-axis: categorical

# Idiom: bar chart

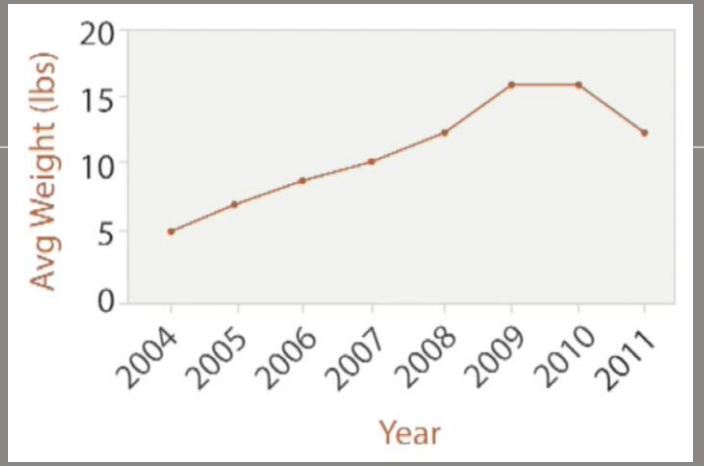



- One key, one value
  - Data
    - 1 categorical attribute (key), 1 quantitative attribute
  - Mark: lines
  - Channels
    - Length to express quantitative value
    - Spatial region: one per mark
      - Separated horizontally, aligned vertically
      - Ordered by quantitative attribute
        - By label (alphabetical), by length attribute(data-driven)
  - Task
    - Compare, lookup values
  - Scalability
    - Dozens to hundreds of levels for key attribute

D3: https://bl.ocks.org/d3noob/8952219

# S05-02

# Idiom: line chart/ dot plot

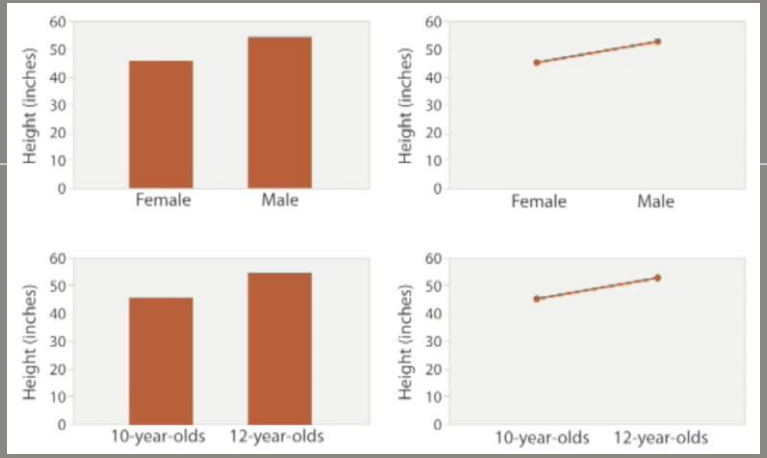



- One key, one value
  - Data
    - **2 quantitative attributes**
  - Mark:
    - points
    - Line connection marks between them
  - Channels
    - Aligned lengths to express quantitative value
    - Separated and ordered by key attribute into horizontal regions
  - Task
    - Find trend:  connection marks (perceptually) **emphasize** ordering of items along key axis by explicitly showing relationship one item and the next
  - Scalability
    - Hundreds of key levels, hundreds of value levels

D3: https://www.d3-graph-gallery.com/line

# Bar Chart vs Line Chart

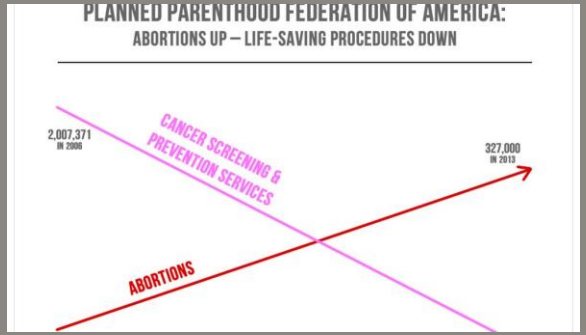
- Depends on type of key attribute
  - **Bar charts if categorical**
  - **Line chart if ordered**
- Do not use line charts for categorical key attributes
  - Violates expressiveness principle
    - Implication of trend so strong that it overrides semantics
    - The more male a person is, the taller he/she is??

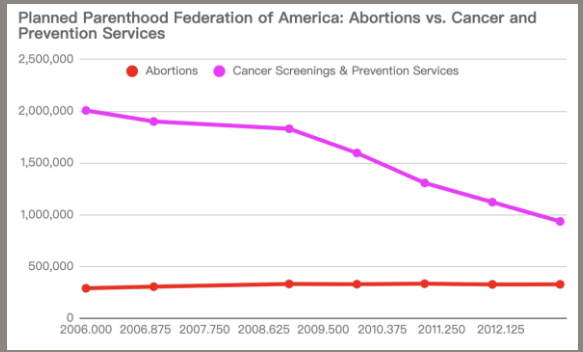


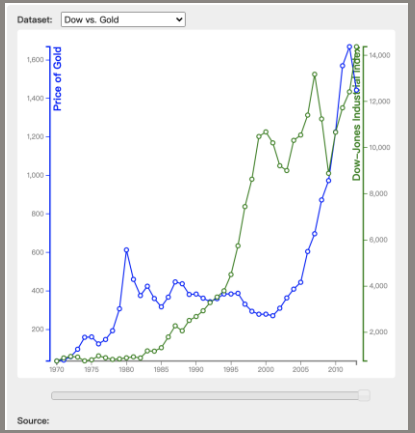

The line char implicitly interpolate the values between two points

# Dual Axis Line Chart

- Axes are critical!!!



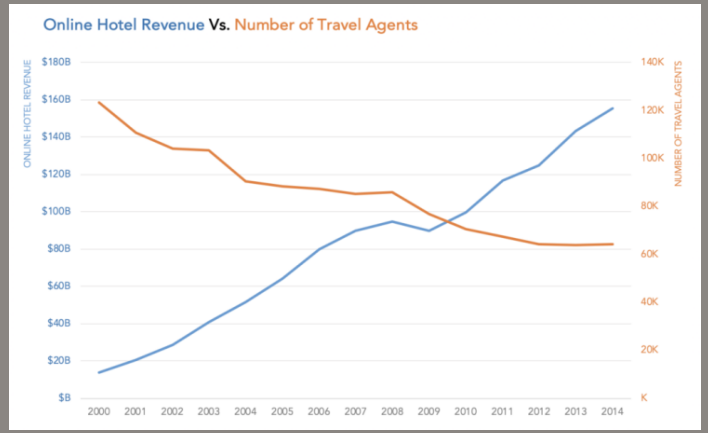



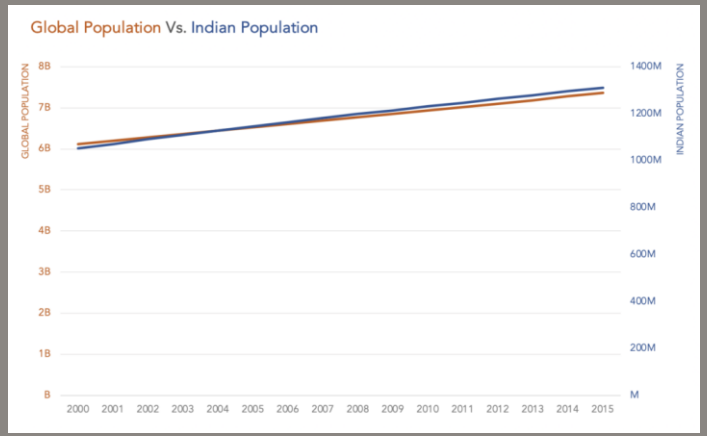




Reference: http://daydreamingnumbers.com/blog/dual-axis-charts/

# Dual Axis Line Chart

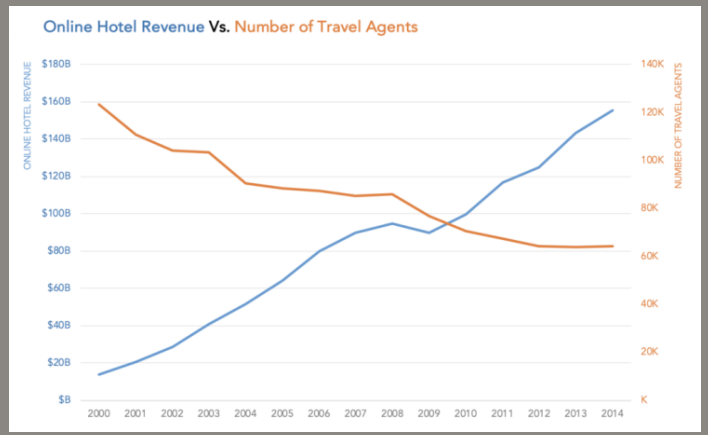
- Axes are critical!!!
- For the axes
  - Same unit?
  - Same scale?

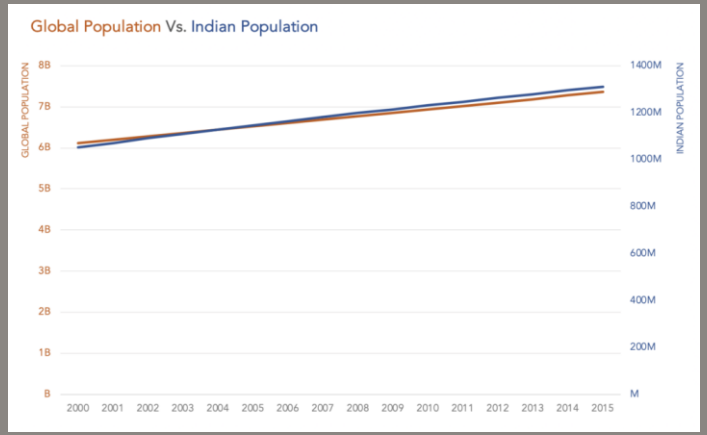


# Dual Axis Line Chart

- What users may focus on when they look at 2 lines in a line chart?
  - Crossing point
  - Correlation/trend/rate

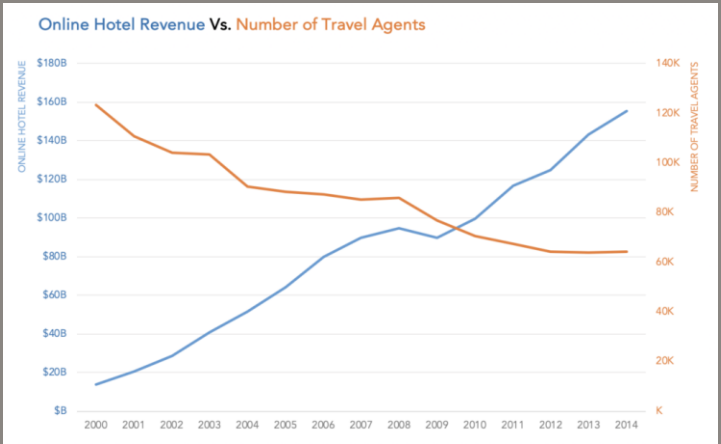


# S05-03

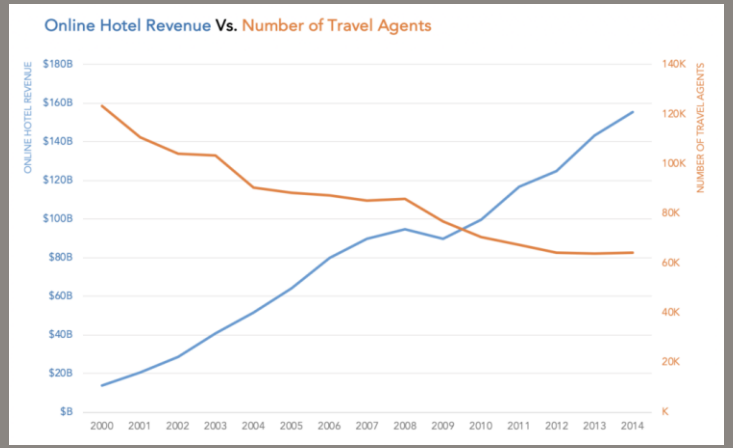
# Dual Axis Line Chart

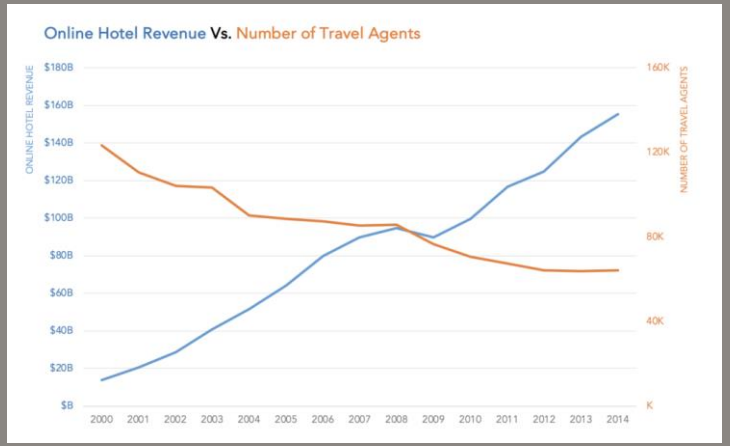
- What users may focus on when they look at 2 lines in a line chart?
  - **Crossing point**
  - Correlation/trend/rate



# Dual Axis Line Chart

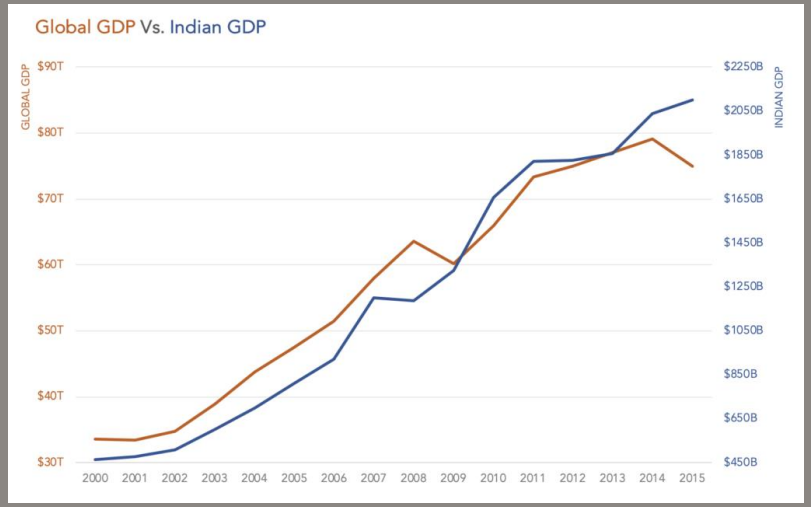
- What users may focus on when they look at 2 lines in a line chart?
  - **Crossing point:** we can simply change the scale of axis to get different crossing point (because unit/scale are different in this case)
  - Correlation/trend/rate



# Dual Axis Line Chart

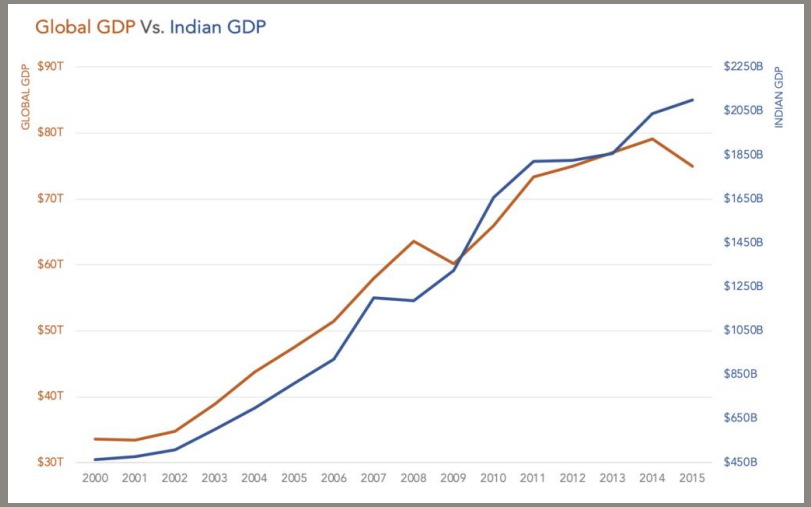
- What users may focus on when they look at 2 lines in a line chart?
  - Crossing point
  - **Correlation/trend/rate**




Global GDP and Indian GDP have almost same growing rate?

# Dual Axis Line Chart

- What users may focus on when they look at 2 lines in a line chart?
  - Crossing point
  - **Correlation/trend/rate**



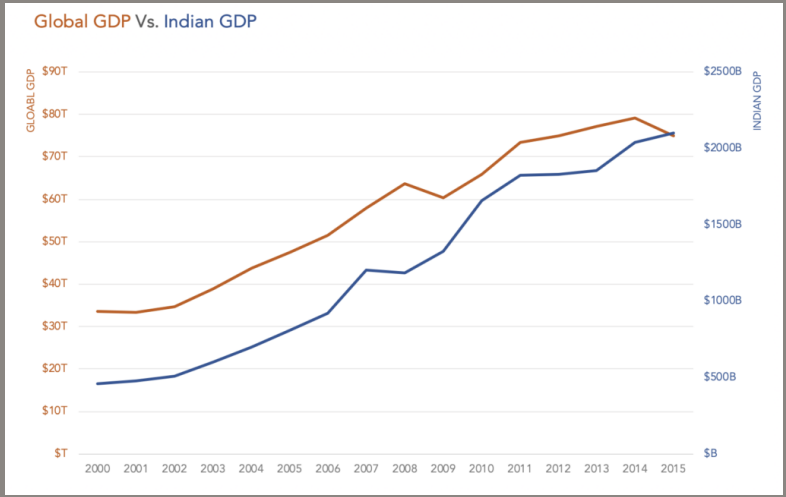

Global GDP and Indian GDP have almost same growing rate?

No, Indian has a much higher growing rate

Note: the baselines are not zero

# Dual Axis Line Chart

- What users may focus on when they look at 2 lines in a line chart?
  - **Crossing point**
  - Correlation/trend/rate



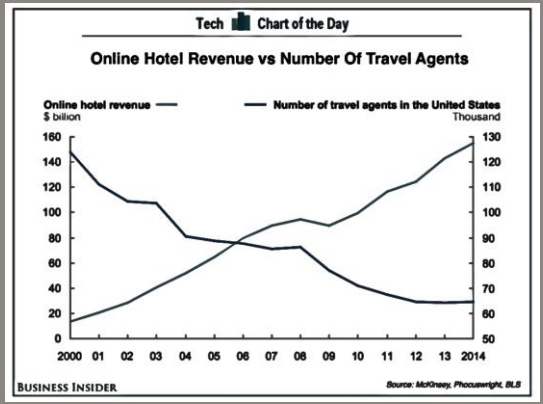

Zero baseline?

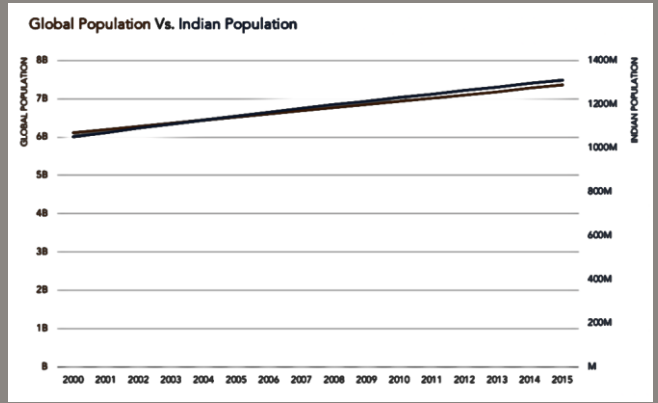
Does the crossing point mean anything?
Indian GDP catches up global GDP in 2015?

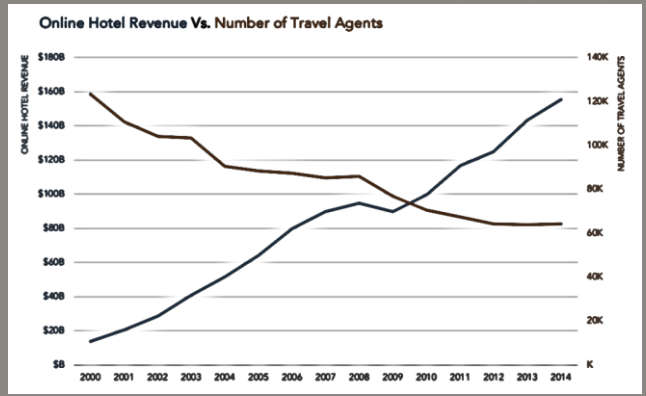
Log scale on y-axis?

# Dual Axis Line Chart

- Not intuitive to know a line belongs to which axis?
- We could use different color to pair them

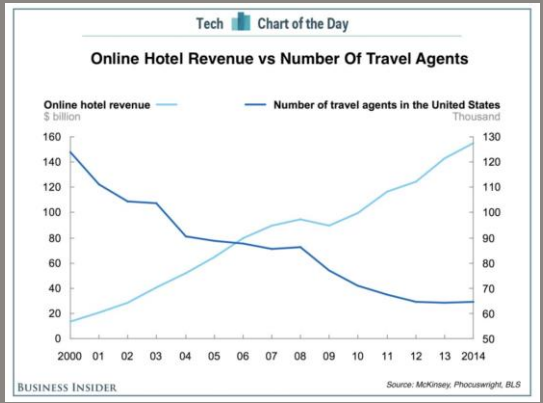


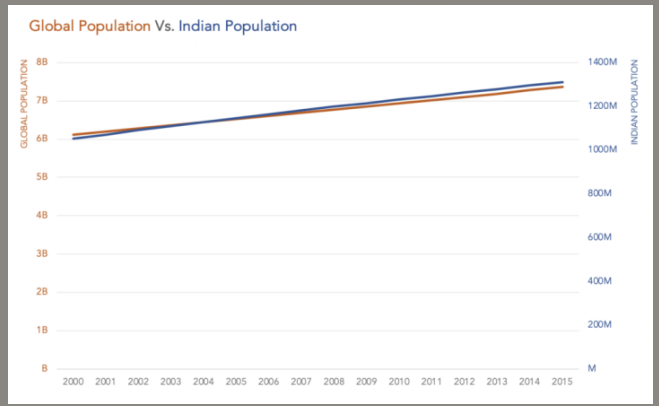



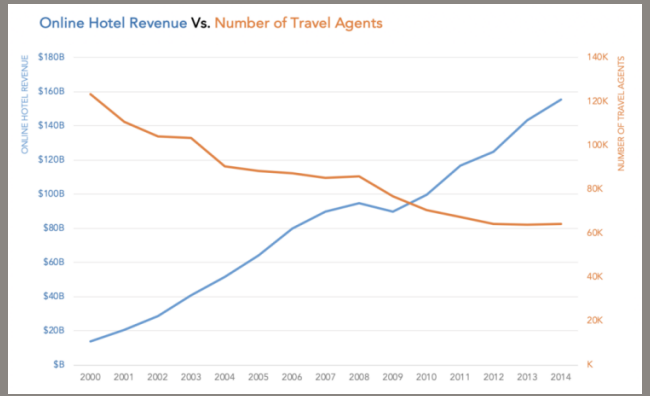



# Dual Axis Line Chart

- Not intuitive to know a line belongs to which axis?
- We could use different color to pair them



# Dual Axis Line Chart

- When you look at a dual axis line chart
  - Too many ways to mislead you (un/intentionally)
  - Check the axes first: unit, scale, zero baseline or not

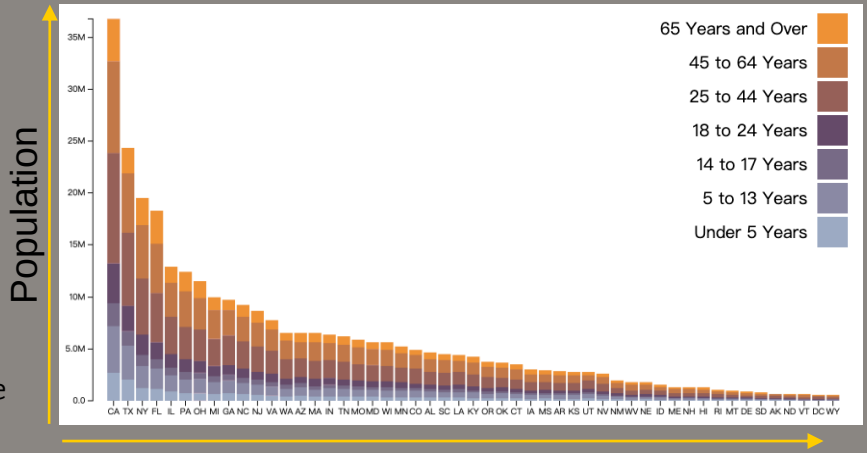
- When you draw a dual axis line chart
  - Too many ways to mislead users
  - If a crossing point exist, does the crossing points convey the proper information
  - If the line chart shows a special pattern (e.g. correlation), is that what you want?
  - Visually pair the line to the corresponding axis

# Idiom: Stacked bar chart

- One more key
  - Data
    - 2 categorical/ordinal attr, 1 quantitative attr
  - 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
    - Compare bars at bottom (close to the baseline)
  - Scalability
    - Several to one dozen levels for stacked attribute

| | < 5 | 5 - 13 | 14 - 17 | … |
|---|---|---|---|---|
| AZ | … | … | … | … |
| CA | … | … | … | … |
| TX | … | … | … | … |
| … | …… | …… | … | … |

Different color bars: age group




D3: http://bl.ocks.org/KatiRG/5f168b5c884b1f9c36a5

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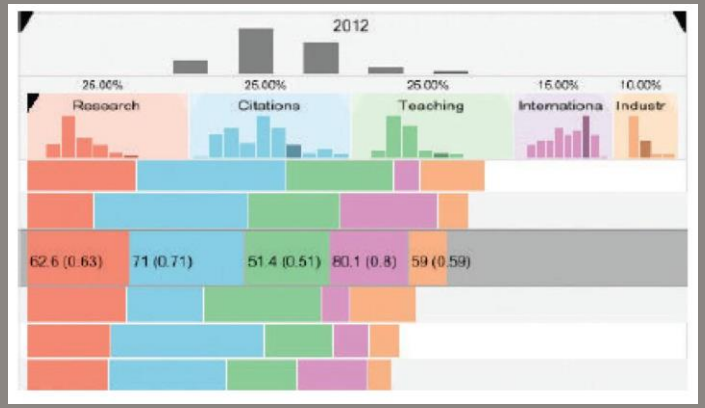
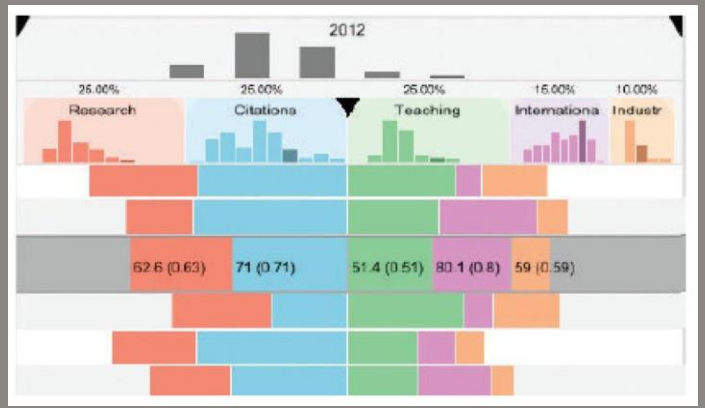
  - Scalability
    - Several to one dozen levels for stacked attribute

Choice of the baseline?

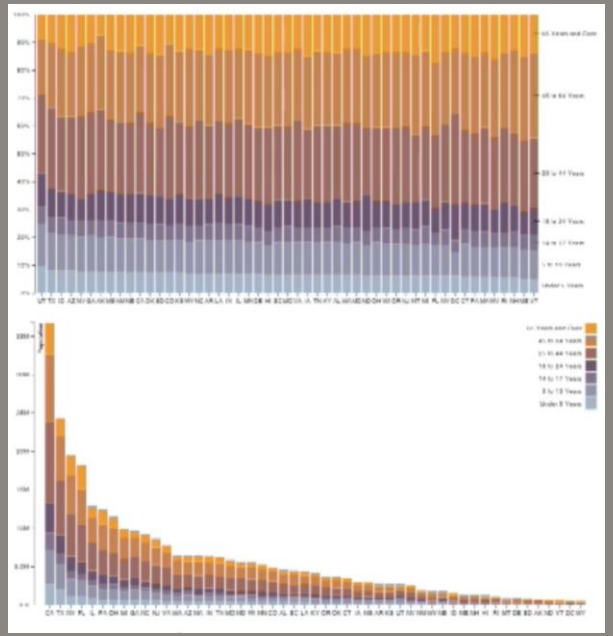



D3: http://bl.ocks.org/KatiRG/5f168b5c884b1f9c36a5

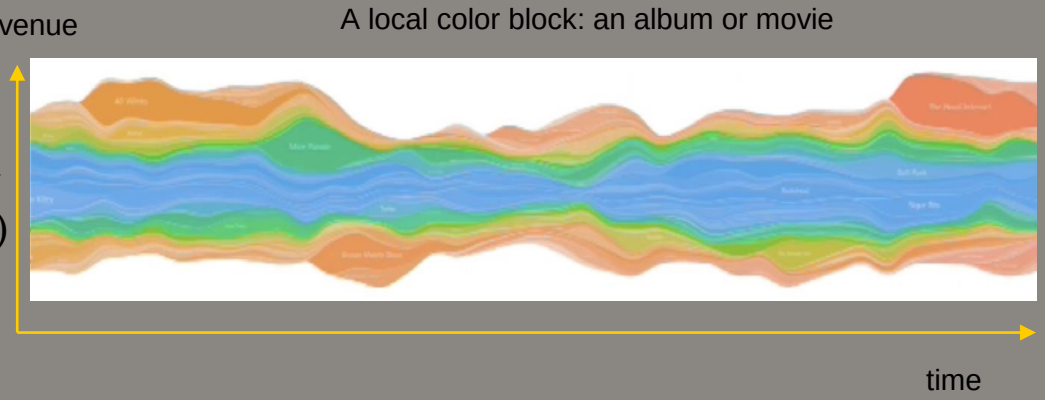
# Idiom: Normalized Stacked Barchart

- Task
  - Part-to-whole judgements
  - compare ratio among same categories
- Normalized stacked bar chart
  - Stacked bar chart, normalized to full vertical height



# Idiom: Streamgraph

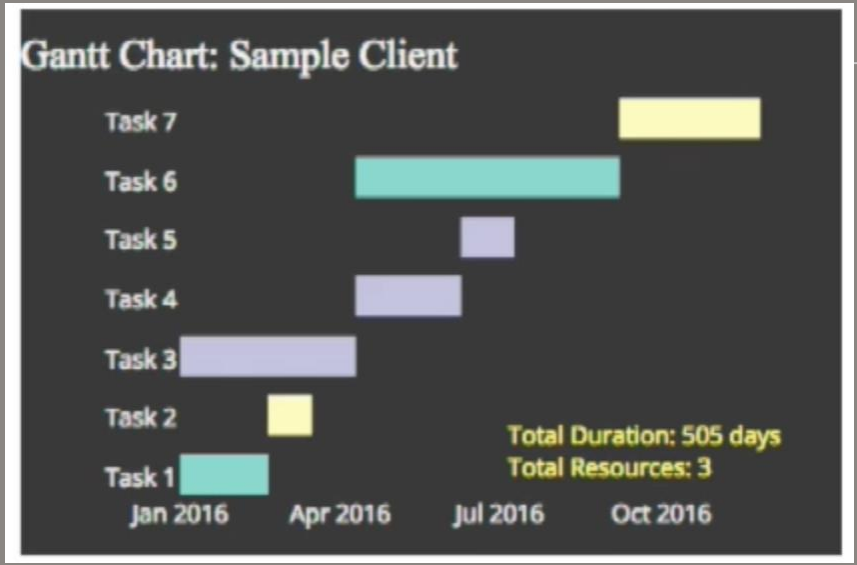
- Generalized stacked graph
  - Emphasizing horizontal continuity (create block size for comparison)
    - vs vertical item
  - Data
    - 1 categorical key attribute
    - 1 ordered key attribute
    - 1 quantitative value attribute
  - Task
    - Part-to-whole relationship over x-axis
  - Scalability
    - Hundreds of keys (x-axis direction)
    - Dozens to hundreds of keys (y-axis direction)
      - More than stacked bars, since most layers do not extend across whole chart




Connect to create the block size
to visualize the volume of a category

D3: https://www.d3-graph-gallery.com/streamgraph

# Idiom: Gantt charts

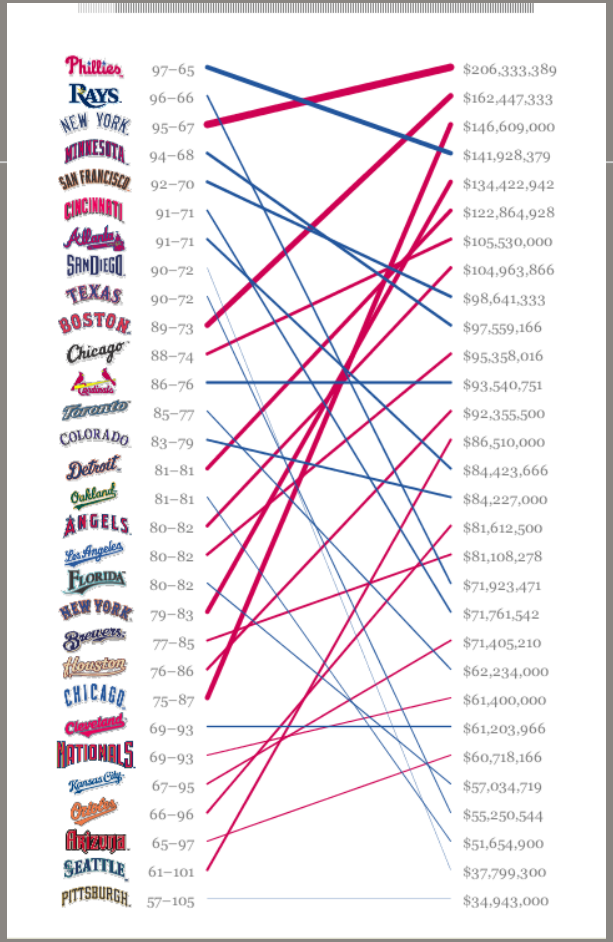



- One key, two (related) values
  - Data
    - 1 categorical attr, 2 quantitative attr
  - Mark: line
    - Length: duration
  - Channels
    - Horizontal position: start/end time
    - Horizontal length: duration
  - Task
    - Emphasize **temporal overlaps**, start/end dependencies between items
  - Scalability
    - Dozens of key levels
    - Hundreds of value levels

D3: http://bl.ocks.org/dk8996/5449641

# Idiom: Slopegraph

- Two values
  - Data
    - 2 quantitative values attributes
    - 1 derived attribute: change magnitude
  - Mark: point, line
    - Line connecting mark between points
  - Channels
    - 2 vertical position: express attribute value
    - linewidth/size, color
  - Task
    - Use the “slope” to emphasize changes in rank/value
  - Scalability
    - Hundreds of value levels




Use the slope of lines to emphasize the ranks difference of two attributes of the same item

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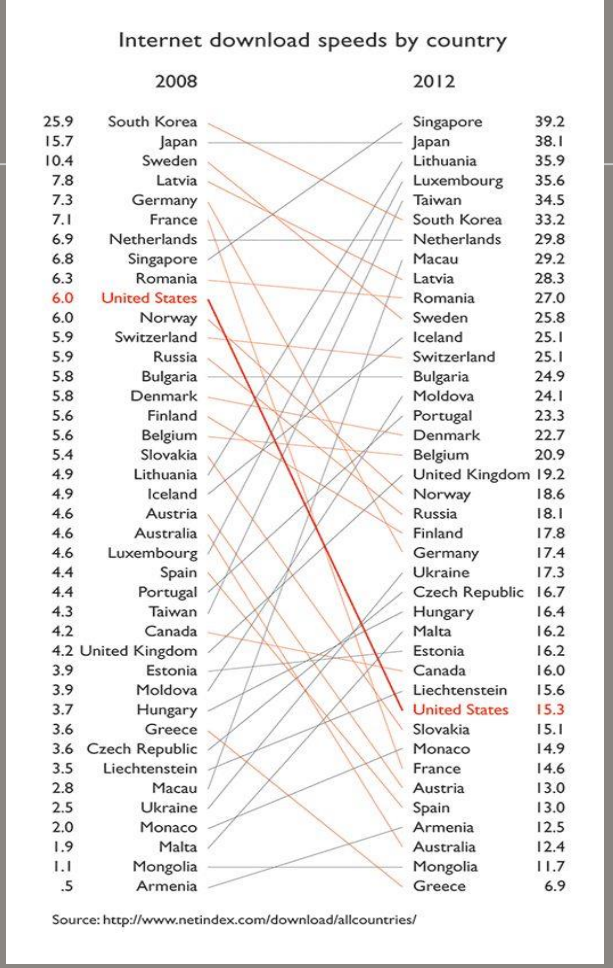
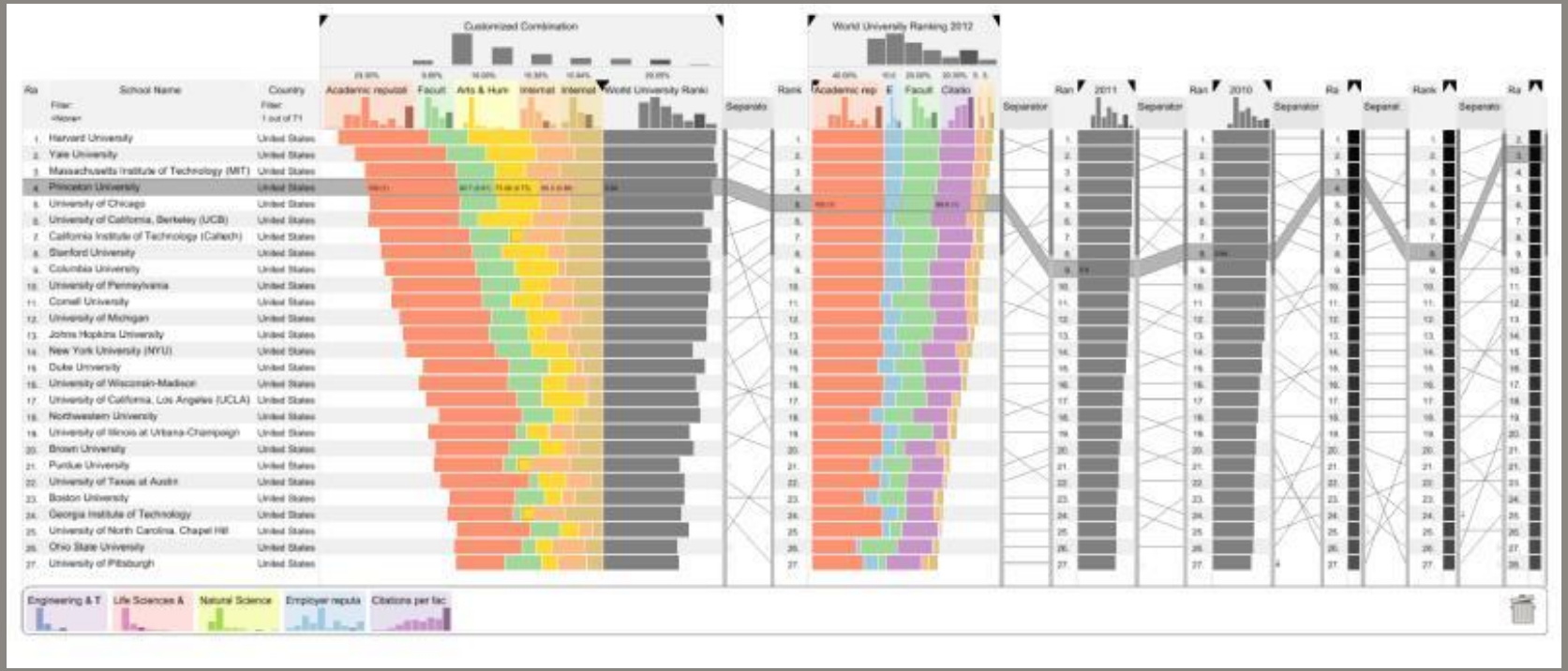



Use the slope of lines to emphasize the ranks difference of two attributes of the same item

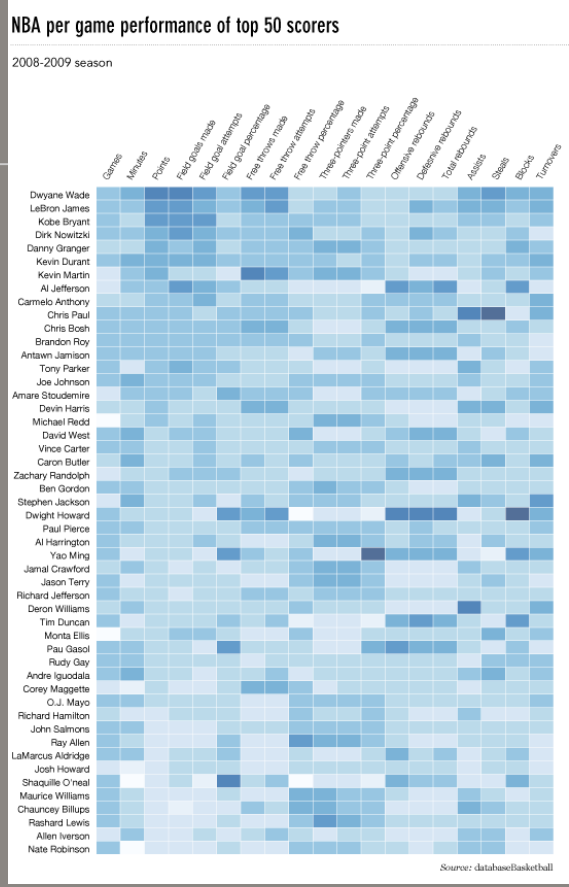
# Idiom: Slopegraph

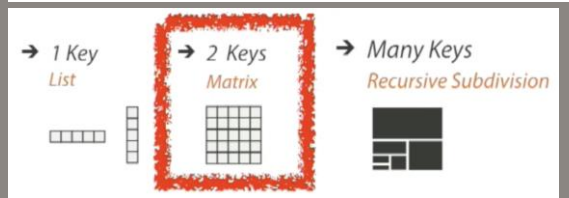
- Advanced application of slopegraph



# Idiom: heatmap

- Two keys, one value
  - Data
    - 2 categorical attributes
    - 1 quantitative attribute
  - marks: area
    - Separate and align in 2D matrix
    - Indexed by 2 categorical attributes
  - Channels
    - Color by quantitative value
  - Task
    - Find patterns, clusters, outlier
  - Scalability
    - 1M items, 100s of categorical levels, ~10 quantitative attribute levels



Again! How to determine the order along x- and y axis

# Idiom: heatmap

- Two keys, one value
  - Data
    - 2 categorical attributes
    - 1 quantitative attribute
  - marks: area
    - Separate and align in 2D matrix
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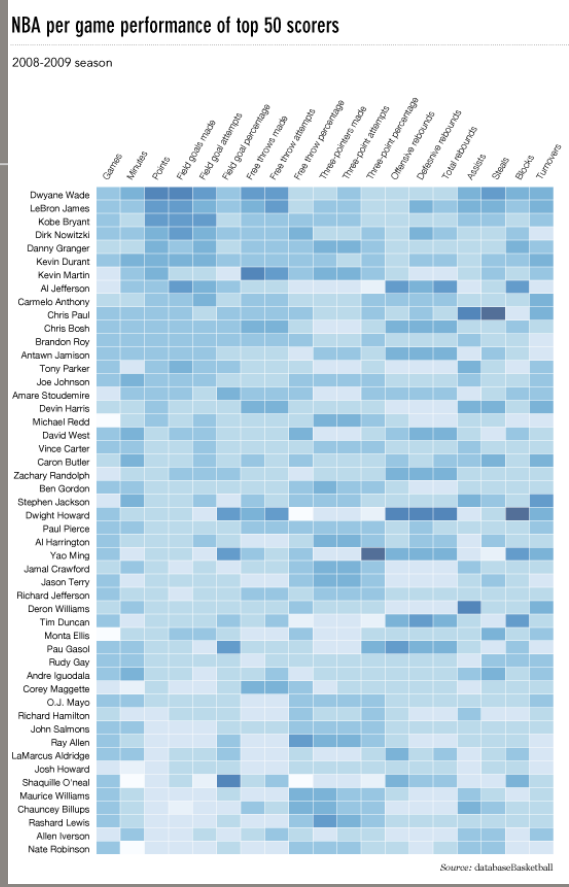
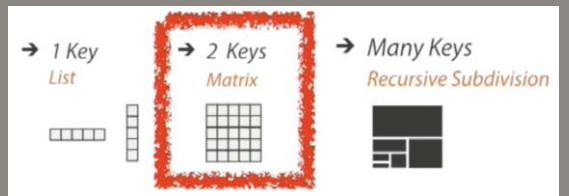
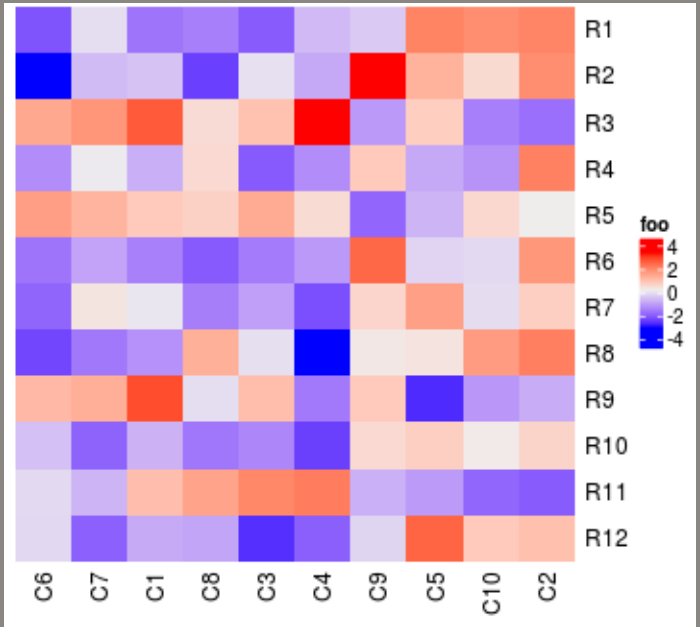
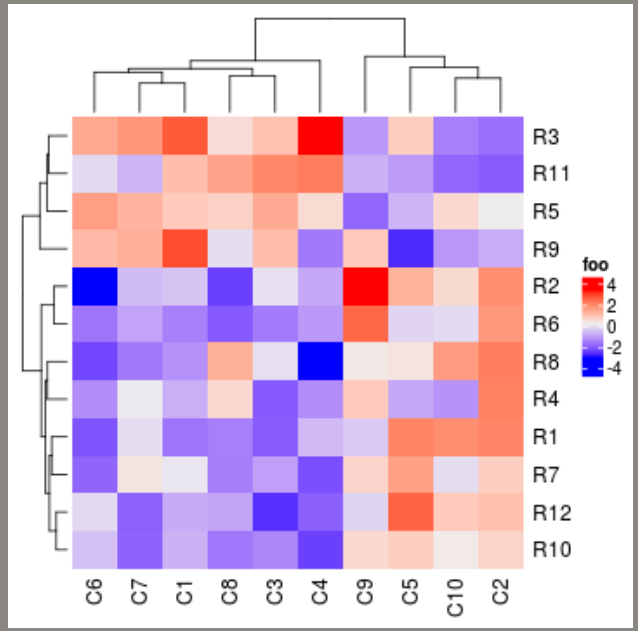


# Idiom: heatmap

- Clustering and reordering the axis by similarity could be the key to show the patterns in the dataset

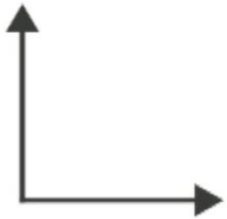



Reorder the row and column by hierarchical clustering

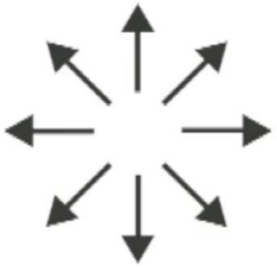
## Axis Orientation

- Rectilinear



- Parallel

- Radial



# Multi-variant Data Visualization

- Usually, we want show a visualization for users to discover the **correlation** among variables
- Multi-variant data

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 |

V1 V2 V3 V4

4 variables: each data item is described by 4 values

# Multi-variant Data Visualization

- Usually, we want show a visualization for users to discover the correlation among variables
- Multi-variant data
- Correlation between variables
  - Math vs. Math

Perfect positive correlation

Table

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| 85 | 95 | 70 | 65 |
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# Multi-variant Data Visualization

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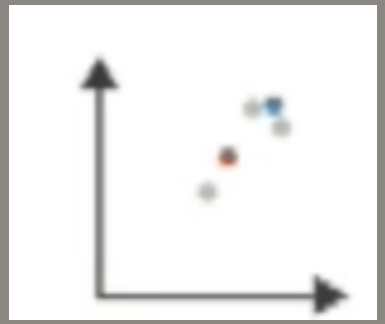
- Correlation between variables
  - Math vs. Physics
  - Dance vs. Drama



Positive correlation

Table

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|---|---|---|---|
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| 50 | 40 | 95 | 80 |
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| V1 | V2 | V3 | V4 |

4 variables: each data item is described by 4 values

# Multi-variant Data Visualization

- Usually, we want show a visualization for users to discover the correlation among variables
- Multi-variant data
- Correlation between variables
  - Physics vs. Dance

Negative correlation

Table

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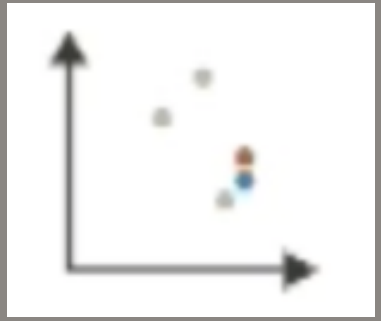

Uncorrelation?

Table

| Math | Physics | Dance | Drama |
|---|---|---|---|
| 85 | 95 | 70 | 65 |
| 90 | 80 | 60 | 50 |
| 65 | 50 | 90 | 90 |
| 50 | 40 | 95 | 80 |
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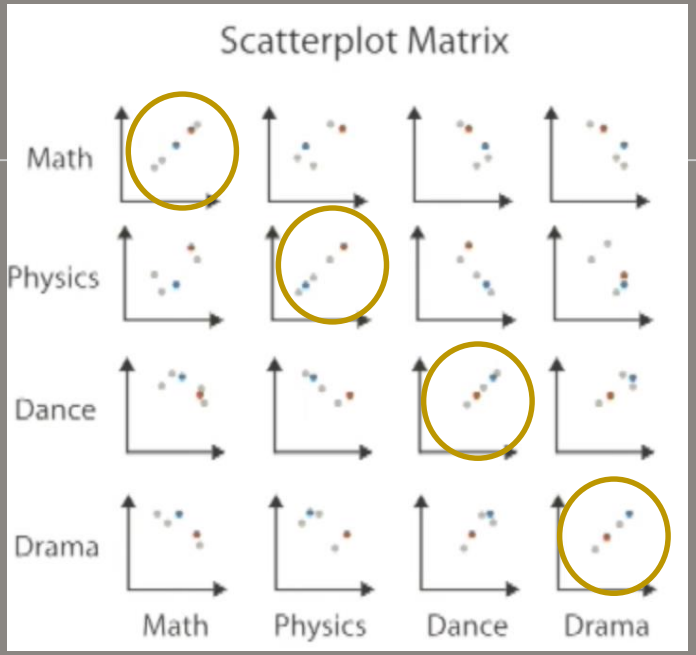
# Idioms: scatterplot matrix

- Scatterplot matrix (SPLOM)
  - Rectilinear axes, point mark
  - All possible pairs of axes
  - Scalability
    - **One dozen attributes**
    - Dozens to hundreds of items




Diagonal plots must be perfect correlation. We can consider use the diagonal space to show other information

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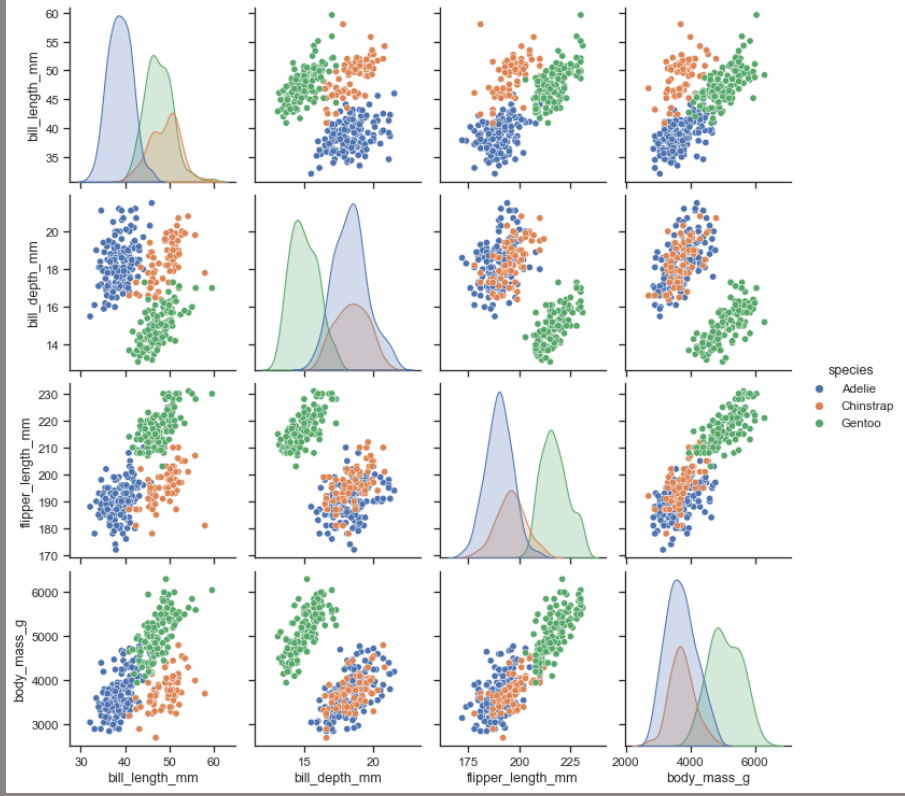
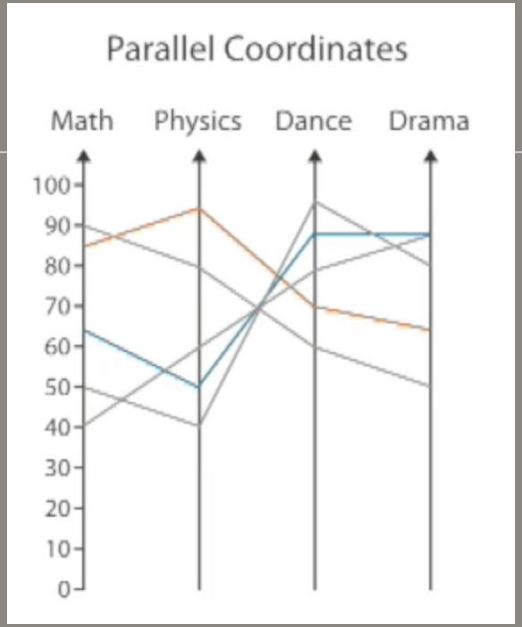



Diagonal plots must be perfect correlation. We can consider use the diagonal space to show other information

# Idioms: parallel coordinates

- Parallel coordinates
  - Parallel axes, jagged line representing item
  - Rectilinear axes, item as point
    - Axis ordering is major challenge
  - Scalability
    - **Dozens of attributes**
    - Hundreds of items

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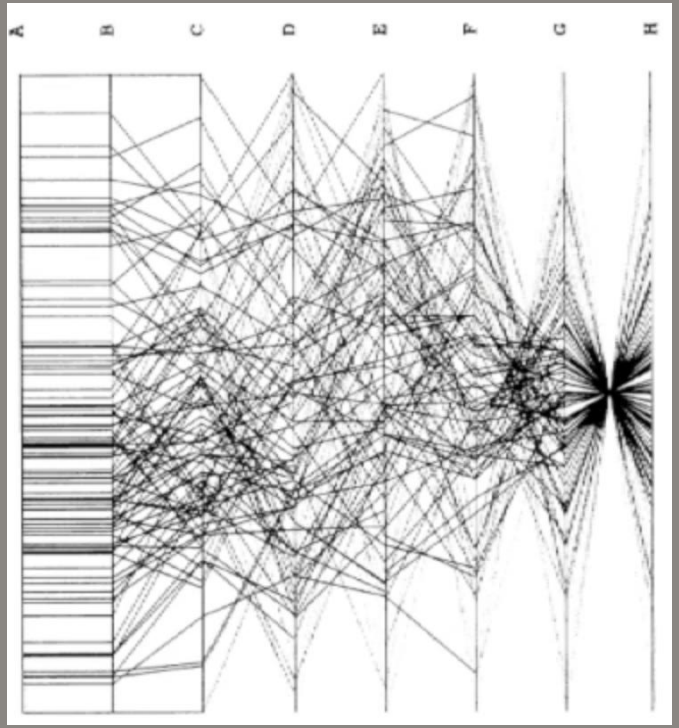
D3: https://bl.ocks.org/jasondavies/1341281

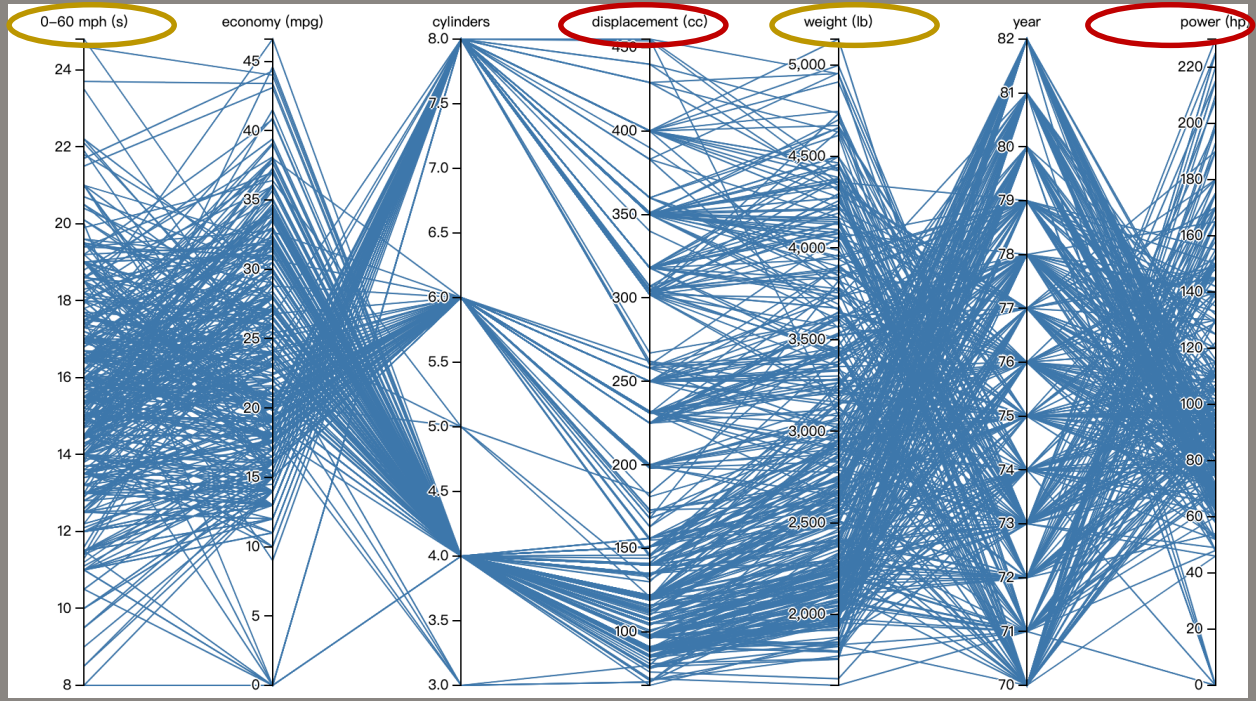
# Idioms: parallel coordinates

- Parallel coordinates
  - Positive correlation
    - Parallel line segments
    - E.g. A vs. B
  - Negative correlation
    - All segments cross at halfway point
    - E.g. G vs. H
  - Uncorrelated
    - Scattered crossings
    - E.g. D vs E



# Idioms: parallel coordinates

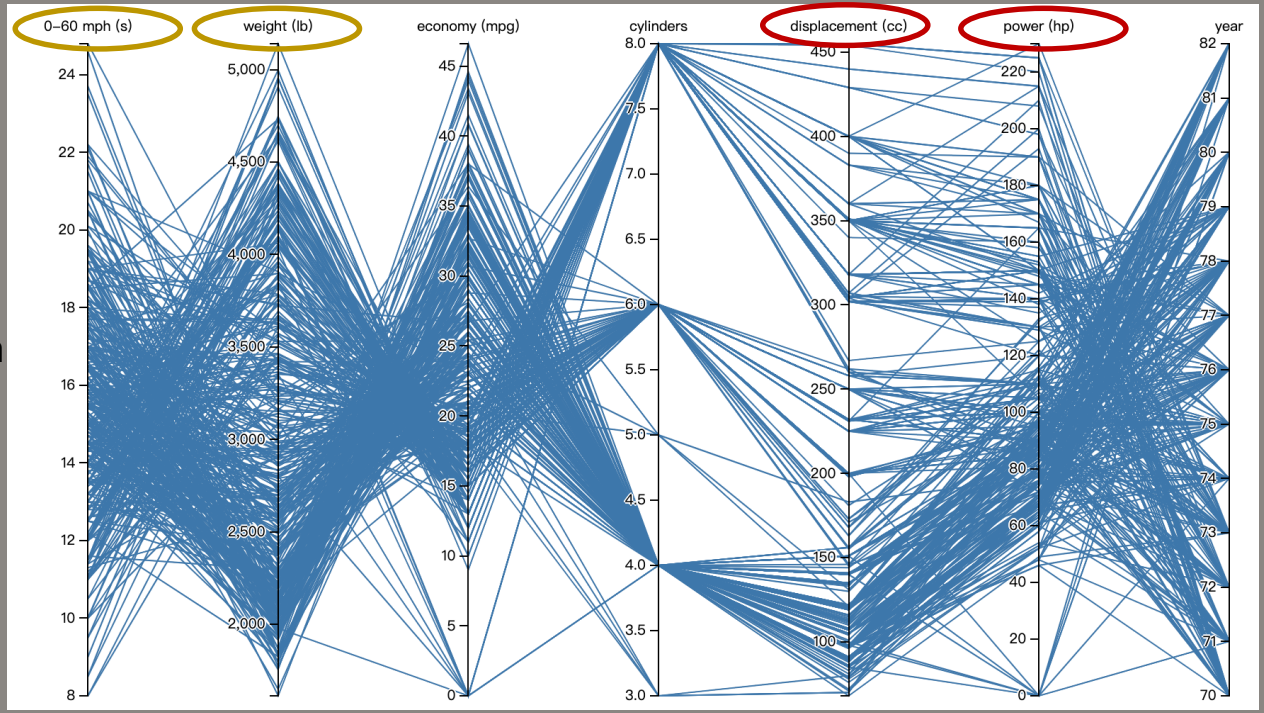
- Parallel coordinates
  - Order of axes matter
  - Correlation between
    - Mph vs. weight
    - Power vs. disp.




D3: https://bl.ocks.org/jasondavies/1341281

# Idioms: parallel coordinates

- Parallel coordinates
  - Order of axes matter
  - Correlation between
    - Mph vs. weight
    - Power vs. disp.
  - Reorder them
  - Usually, the interaction is required in PCP

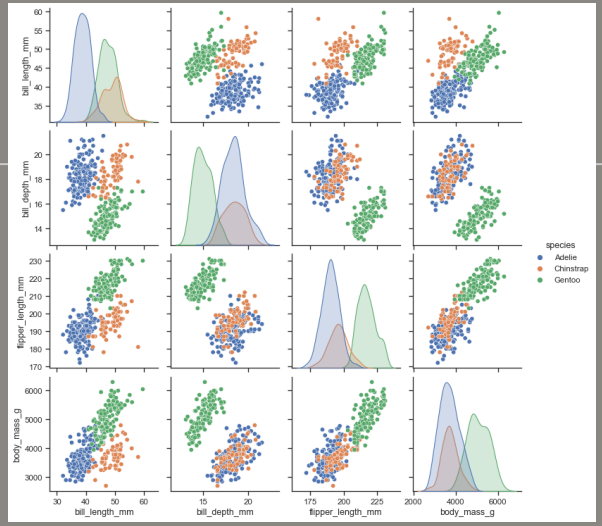



D3: https://bl.ocks.org/jasondavies/1341281

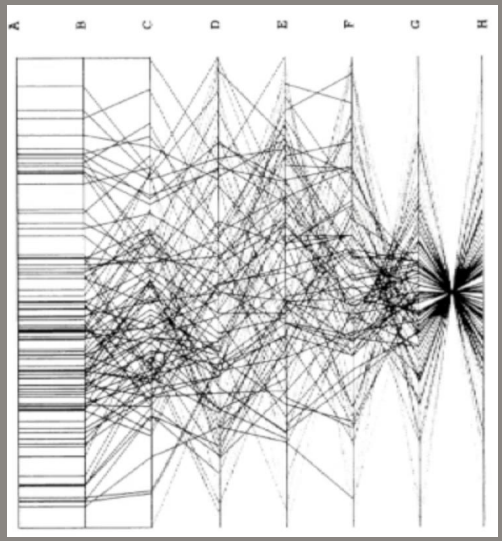
# S05-04

# Pros and Cons

- Scatterplot matrix
  - Pros: easy to understand
  - Cons: scalability
    - The number of the sub-scatter plots grows exponentially

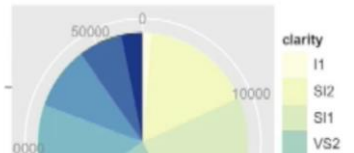



- Parallel coordinates
  - Pros: scalability
    - It can show much more variables
  - Cons:
    - Most people know how to interpret parallel coordinate plot.
    - People need to be trained to interpret it.
    - Not good to use it on news paper (interaction)

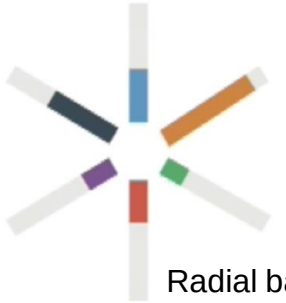


# Idiom: Radial Layout

- Pie chart (classic/controversial)
  - Area mark with angle channel
  - Data: 1 categorical key attribute, 1 quantitative value attribute
  - Task: Part-to-whole judgements




Pie chart



Radial bar

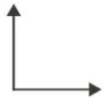

Radius pie chart

Star plot

D3: https://www.d3-graph-gallery.com/circular_barplot

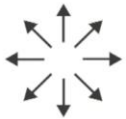
**Axis Orientation**

- Rectilinear



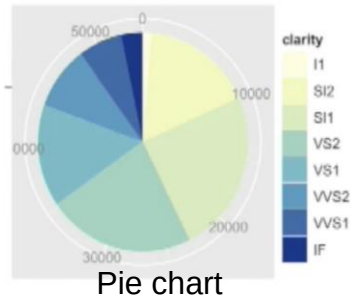
- Parallel

- Radial

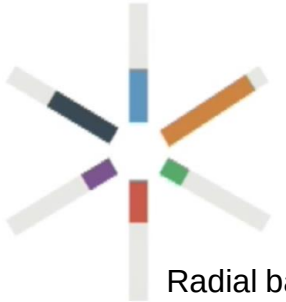


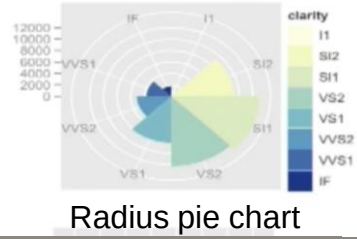
# Idiom: Radial Layout

- Pie chart (classic/controversial)
  - Area mark with angle channel
  - Data: 1 categorical key attribute, 1 quantitative value attribute
  - Task: Part-to-whole judgements
- Advantage: visually appealing and **ok for Part-to-whole judgements**

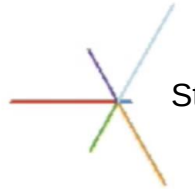


Pie chart

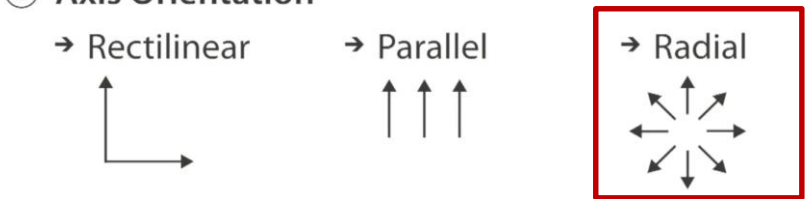

Radial bar



Radius pie chart


Star plot

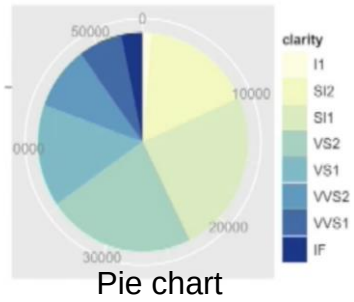
D3: https://www.d3-graph-gallery.com/circular_barplot



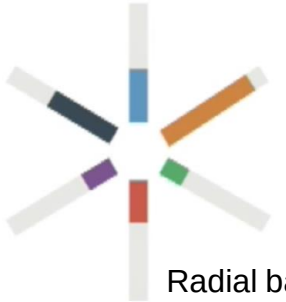

# S05-05

# Idiom: Radial Layout

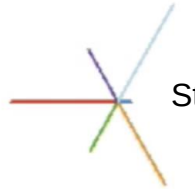
- Pie chart (classic/controversial)
  - Area mark with angle channel
  - Data: 1 categorical key attribute, 1 quantitative value attribute
  - Task: Part-to-whole judgements
- Advantage: visually appealing and ok for Part-to-whole judgements
- Many alternative visualization is better than radial layout in terms of data understanding purpose
  - **Accuracy: angle/area less accurate than line length**
    - **Arc length also less accurate than line length**



Pie chart


Radial bar

Radius pie chart


Star plot

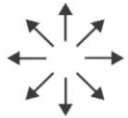
D3: https://www.d3-graph-gallery.com/circular_barplot

**Axis Orientation**

- Rectilinear

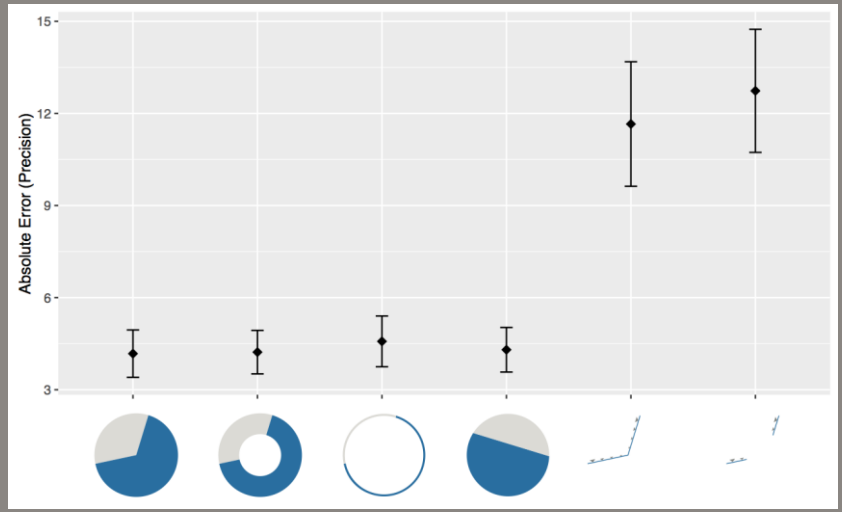
- Parallel

- Radial



# Pie Chart Perception

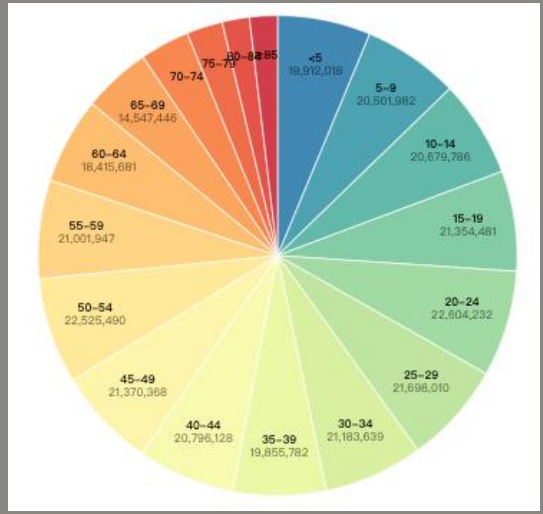
- Some empirical evidence that people respond to arc length
  - Not angle
  - Maybe also area
- Donut chart no worse than pie charts

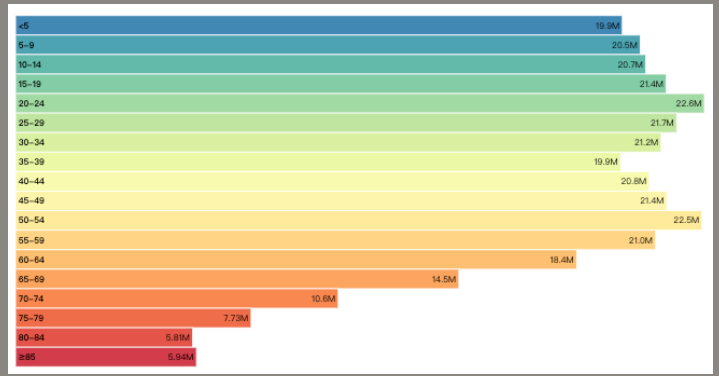


# Pie Chart vs Bar Chart

the U.S. population from 2015, divided into 5-year age buckets

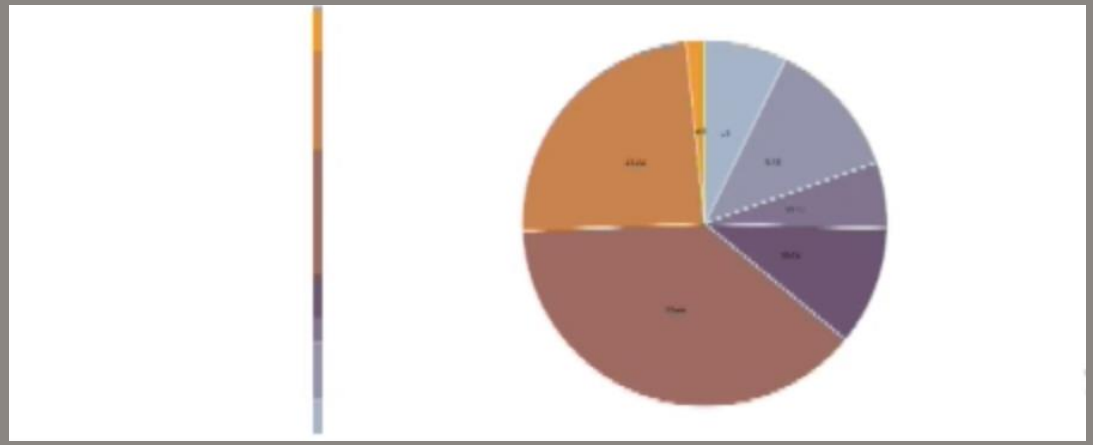
- Impression of this pie chart: “each age group is roughly the same size, decreasing for the older groups.”
- Check the same data shown by bar chart
  - humans are better at comparing lengths than angles



# Pie Chart vs One Stacked Bar Chart

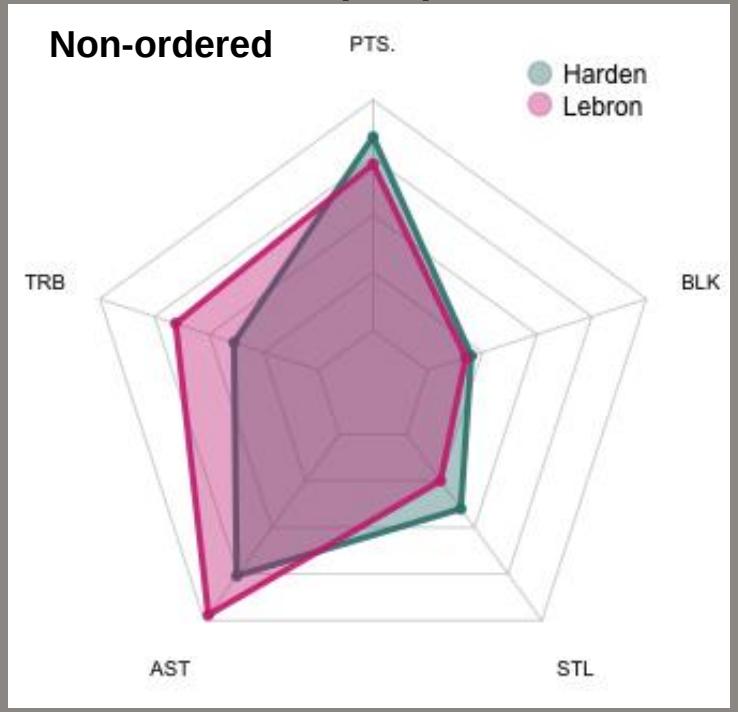
- Single stacked bar equivalent to full pie
  - High information density: requires narrow rectangle
- Pie chart
  - Information density: requires large circle

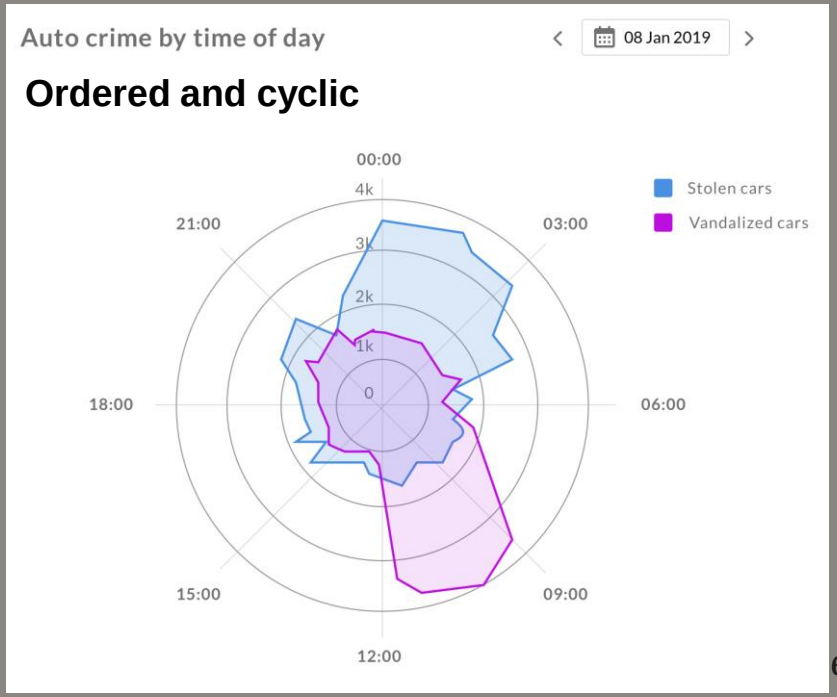


# S05-06

# Radar Plot

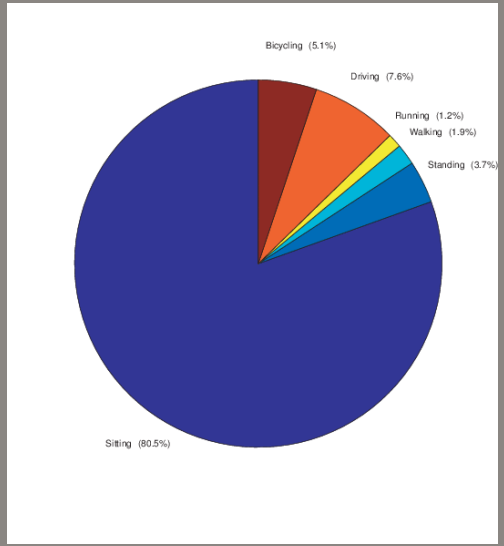
- Not so proper when categories are not ordered/cyclic

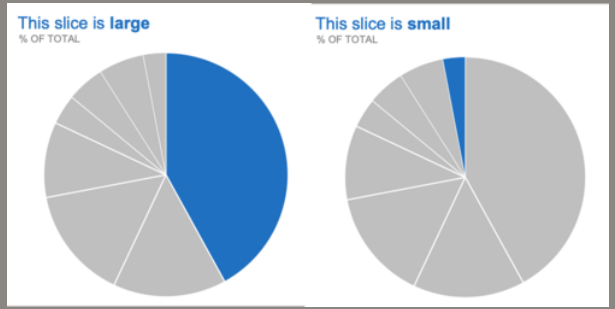


# When to Use Radial Layout

- Is pie chart or radial layout always bad choice?
  - Part-to-whole/one segment ratio/precision is less important
    - If you want your audience to have a **general sense of the part-to-whole relationship in your data** and comparing the precise sizes of the slices is less important.
    - To convey that one segment of the total is relatively **small** or **large.**

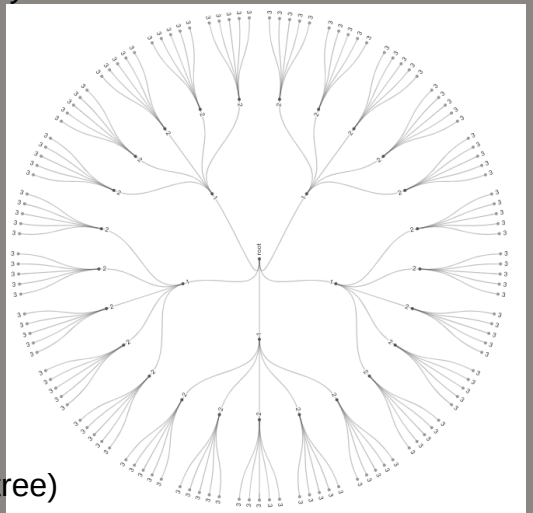


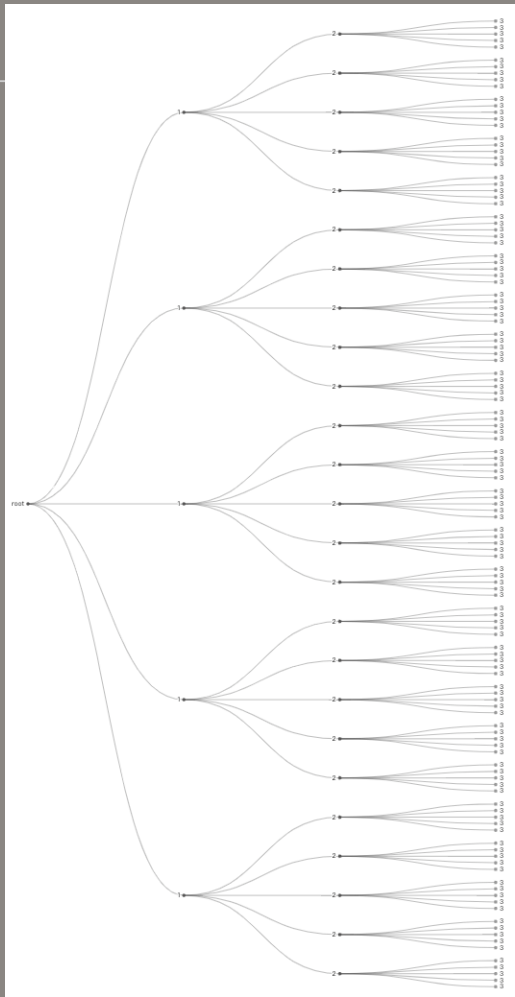




You can use it if no need to compare an arc with another arc

# When to Use Radial Layout

- Is pie chart or radial layout always bad choice?
  - Part-to-whole/one segment ratio/precision is less important
  - Compact
    - Tree: give leaf nodes the same size for interaction
    - We have display limit





D3: https://bl.ocks.org/d3noob/8375092 (tree)

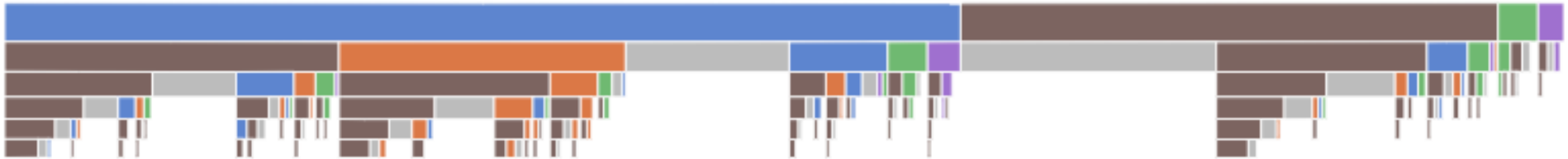
D3: https://observablehq.com/@d3/radial-tidy-tree (radial tree)

# When to Use Radial Layout

- Is pie chart or radial layout always bad choice?
  - Part-to-whole/one segment ratio/precision is less important
  - Compact
    - Tree: give leaf nodes the same size for interaction
    - We have display limit

sunburst

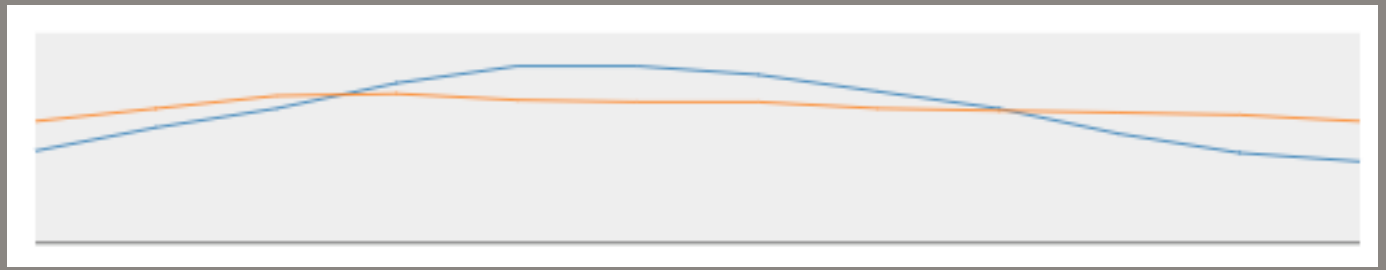
D3: https://bl.ocks.org/kerryrodden/7090426



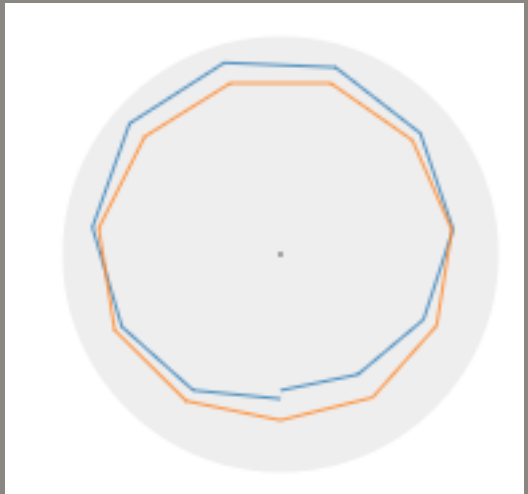
# When to Use Radial Layout

- Is pie chart or radial layout always bad choice?
  - Part-to-whole/one segment ratio/precision is less important
  - Compact
  - Cyclic data
    - e.g. continuity between the winter months

Line chart is still easy to interpret




New York (blue) vs LA (orange) average temperature each month



## Limitations of Orientation

- Rectilinear: scalability (axes)
  - 2 axes is best
  - 3 problematic
  - 4+ impossible
- Parallel
  - unfamiliarity, training time
- Radial: perceptual limits
  - Angles lower precision than lengths
  - Asymmetry between angle and length

## Axis Orientation

→ Rectilinear

→ Parallel

→ Radial