



2019 ZJU International Summer School on Visual Analytics



Basics of Data Visualization II

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Outline

① Transformation

- Normalization
- Smoothness
- Sampling
- Binning/Discretization
- Dimensionality Reduction
- Clustering

② Statistical Charts

- Line Chart
- Sparkline
- Bar Chart
- Stacked Bar Chart
- Pie Chart
- Scatter Plot
- Box Plot
- Scale
- Tools

Transformation



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Normalization

- Why normalize?
 - Mapping data according to its distributions
 - Color/size/coordinate encoding
- $[0, 1]$ normalization
- $[-1, 1]$ normalization

Normalization

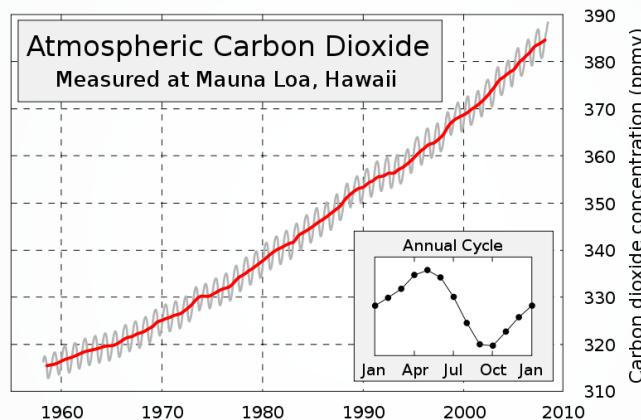
- Linear transformation
 - $y = (x - \text{MinValue}) / (\text{MaxValue} - \text{MinValue})$
- Arc tangent transformation
 - $y = \text{atan}(x) * 2/\text{PI}$
- User-defined transformation

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Curve Fitting/Smoothness

- Why curve fitting?
 - Finding the trends of data



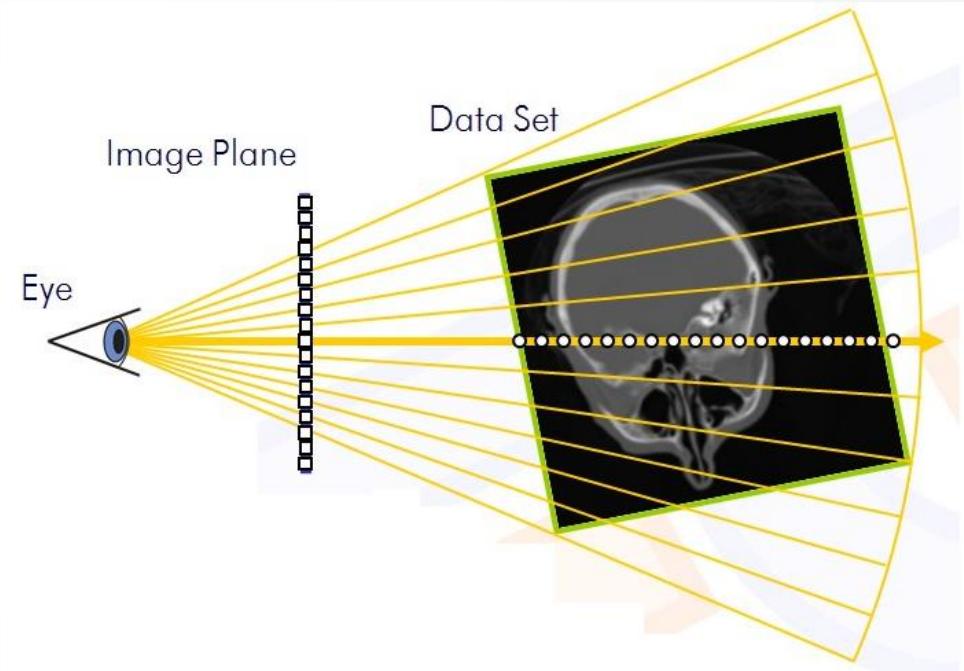
- Fitting data points to a polynomial curve
 - PLSR: partial least squares regression $\min \sum_{i=1}^n (y_m - y_i)^2$
 - Locally weighted scatterplot smoothing(LOESS)

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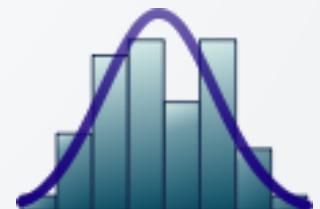
Sampling (Signal)

- What is sampling (signal)?
 - In signal field, sampling is the **reduction** of a **continuous** signal to a **discrete** signal.
- Sampling in Volume Rendering



Sampling (Statistics)

- What is sampling (statistics)?
 - The **selection** of a subset of individuals from within a statistical population to **estimate** characteristics of the whole population.
- Influencing factors of various sampling methods
 - Nature and quality of the frame
 - Availability of auxiliary information about units on the frame
 - Accuracy requirements, and the need to measure accuracy
 - Whether detailed analysis of the sample is expected
 - Cost/operational concerns

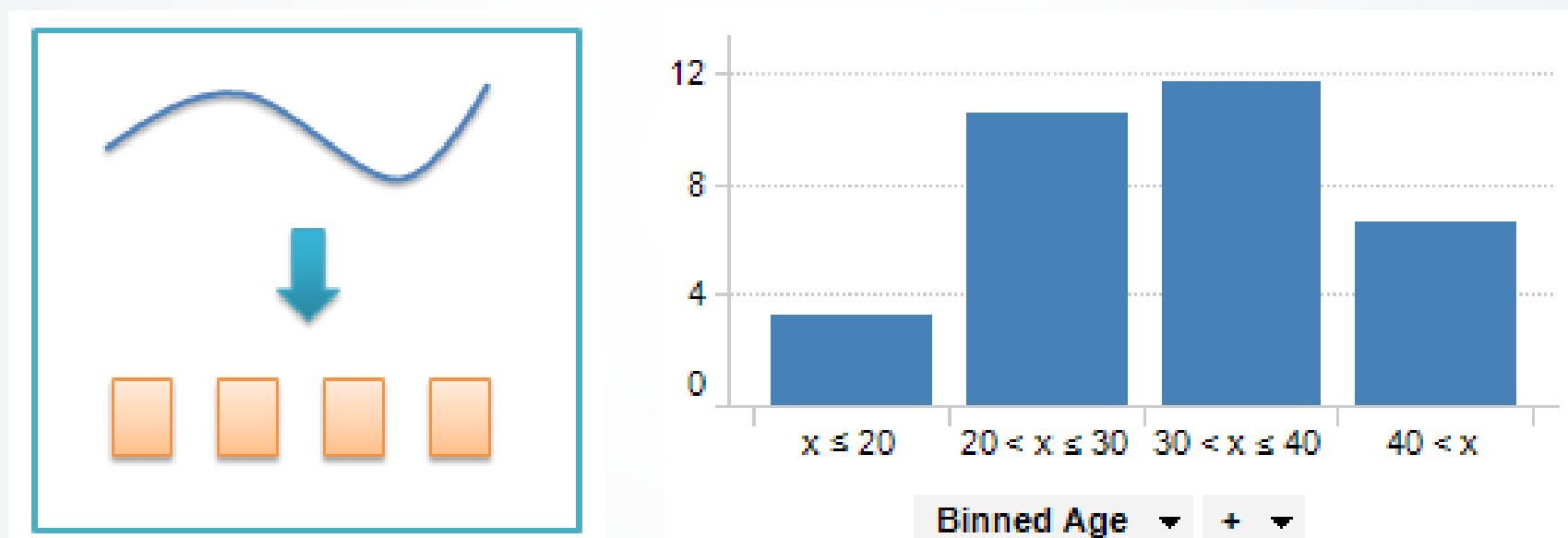


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Binning/Discretization

- Binning is a way to group a number of more or less continuous values into a smaller number of "bins".



<https://www.saedsayad.com/binning.htm>

https://docs.tibco.com/pub/spotfire/7.0.1/doc/html/bin/bin_what_is_binning.htm

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Dimensionality Reduction*

- Principal Components Analysis (PCA)
- Multidimensional Scaling (MDS)
- Self-Organizing Map (SOM)

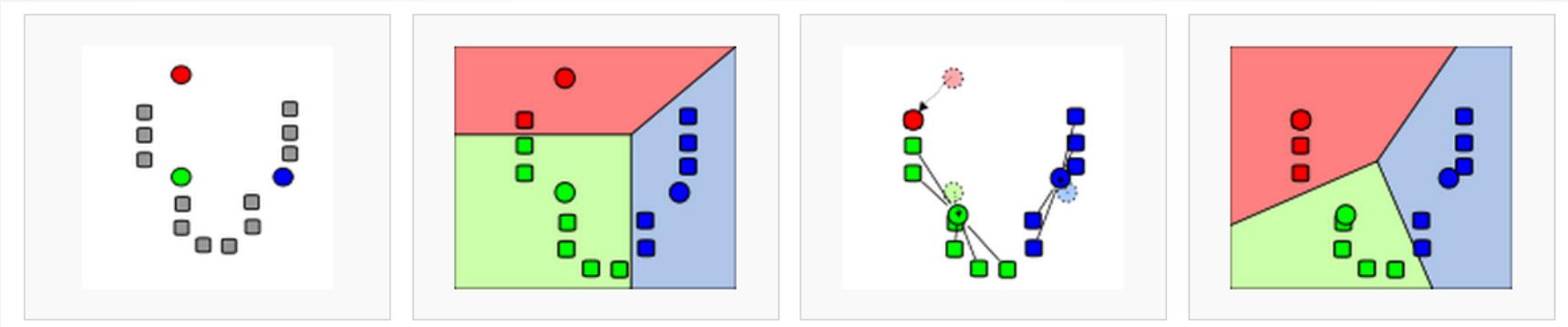
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Clustering

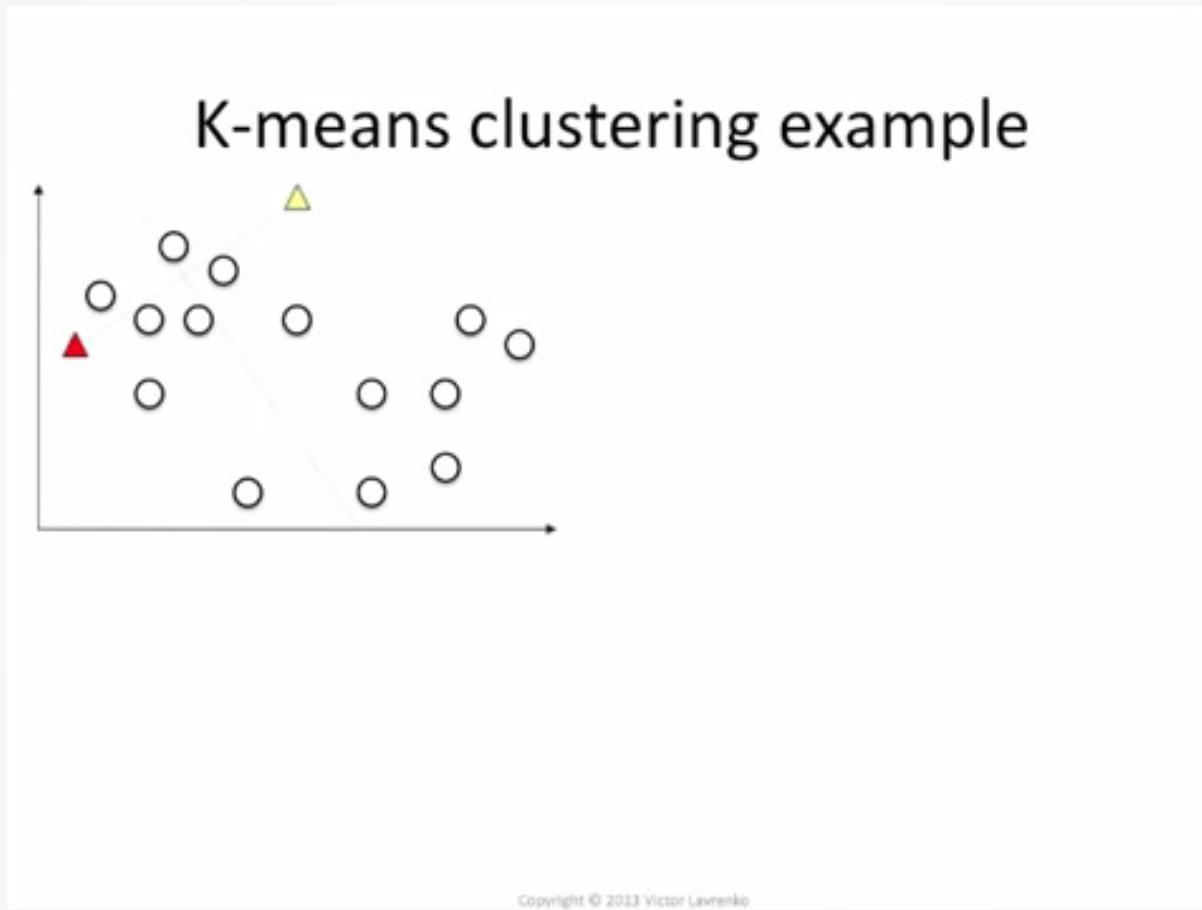
- K-means Clustering
- Expectation-Maximization Clustering (EM)*
- Gaussian Mixture Model (GMM)*
- Spectral Clustering*
- Hierarchical Clustering*

K-Means Clustering



- K-Means
 - k initial "means" (in this case $k=3$) are randomly generated within the data domain (shown in color).
 - k clusters are created by associating every observation with the nearest mean (*virtual points*). The partitions here represent the Voronoi diagram generated by the means.
 - The centroid of each of the k clusters becomes the new mean.
- K-Medoids —centroids are points in the dataset
 - Can be used in non-Euclidean space.

K-Means Clustering - Demo



<http://tech.nitoyon.com/en/blog/2013/11/07/k-means/>

Visualizing K-Means algorithm with D3.js



<http://tech.nitoyon.com/en/blog/2013/11/07/k-means/>

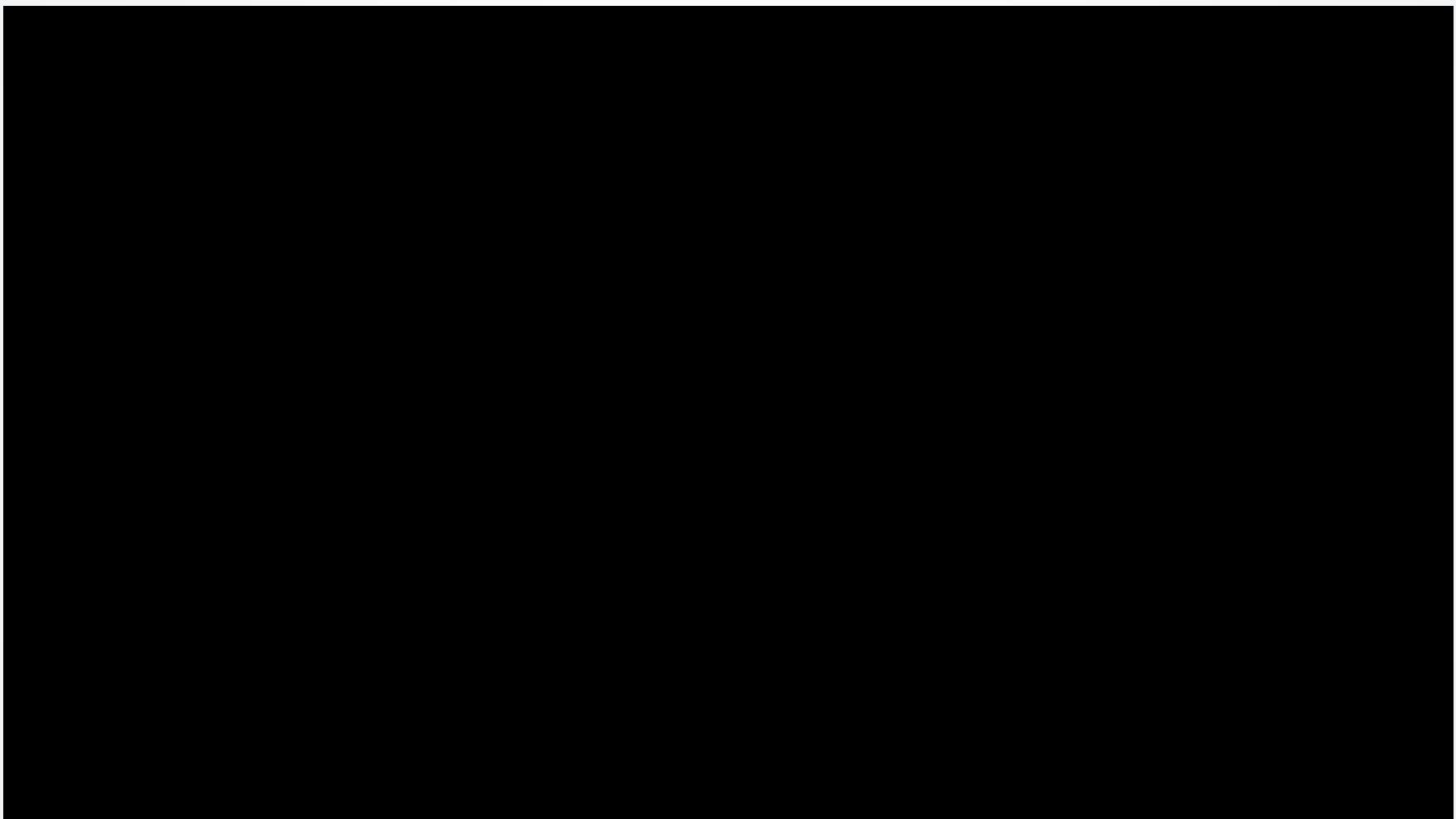
Transformation-Google Refine (1/2)

The logo for Google Refine, featuring the word "Google" in its signature multi-colored font (blue, red, yellow, blue) followed by the word "refine" in a smaller, standard blue sans-serif font.

Transformation-Google Refine (2/2)



Transformation - TRIFACTA



Statistical Charts



2

Statistical Charts

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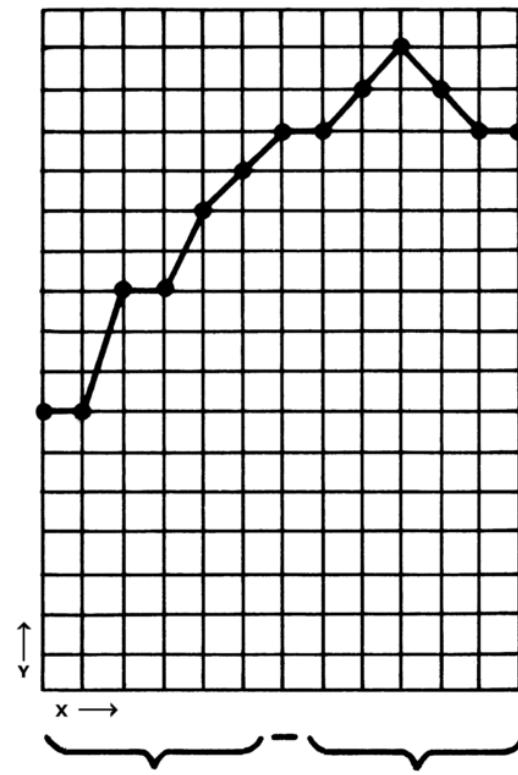
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Line Chart

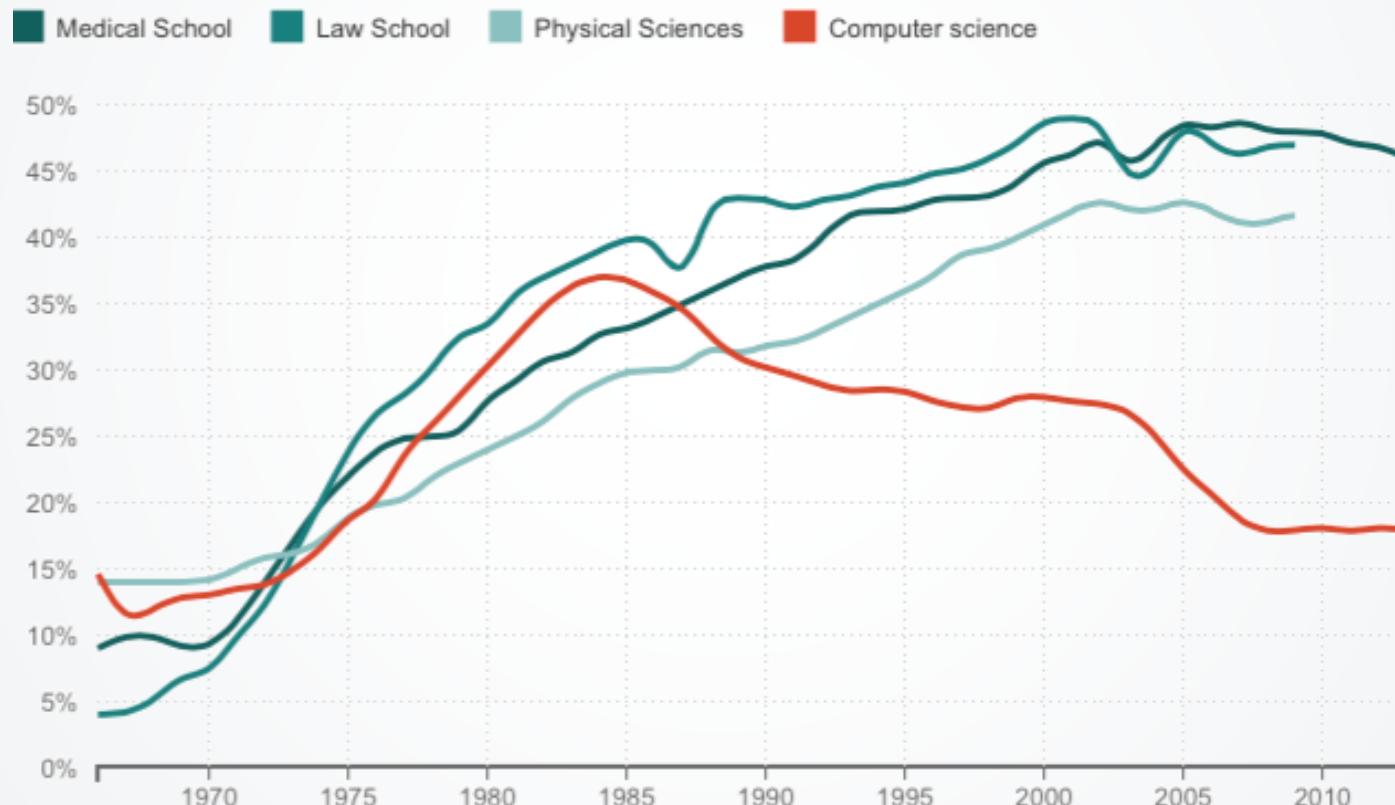
A line chart is a type of chart which displays information as a series of data points called 'markers' connected by straight line segments.



Line Chart

What Happened To Women In Computer Science?

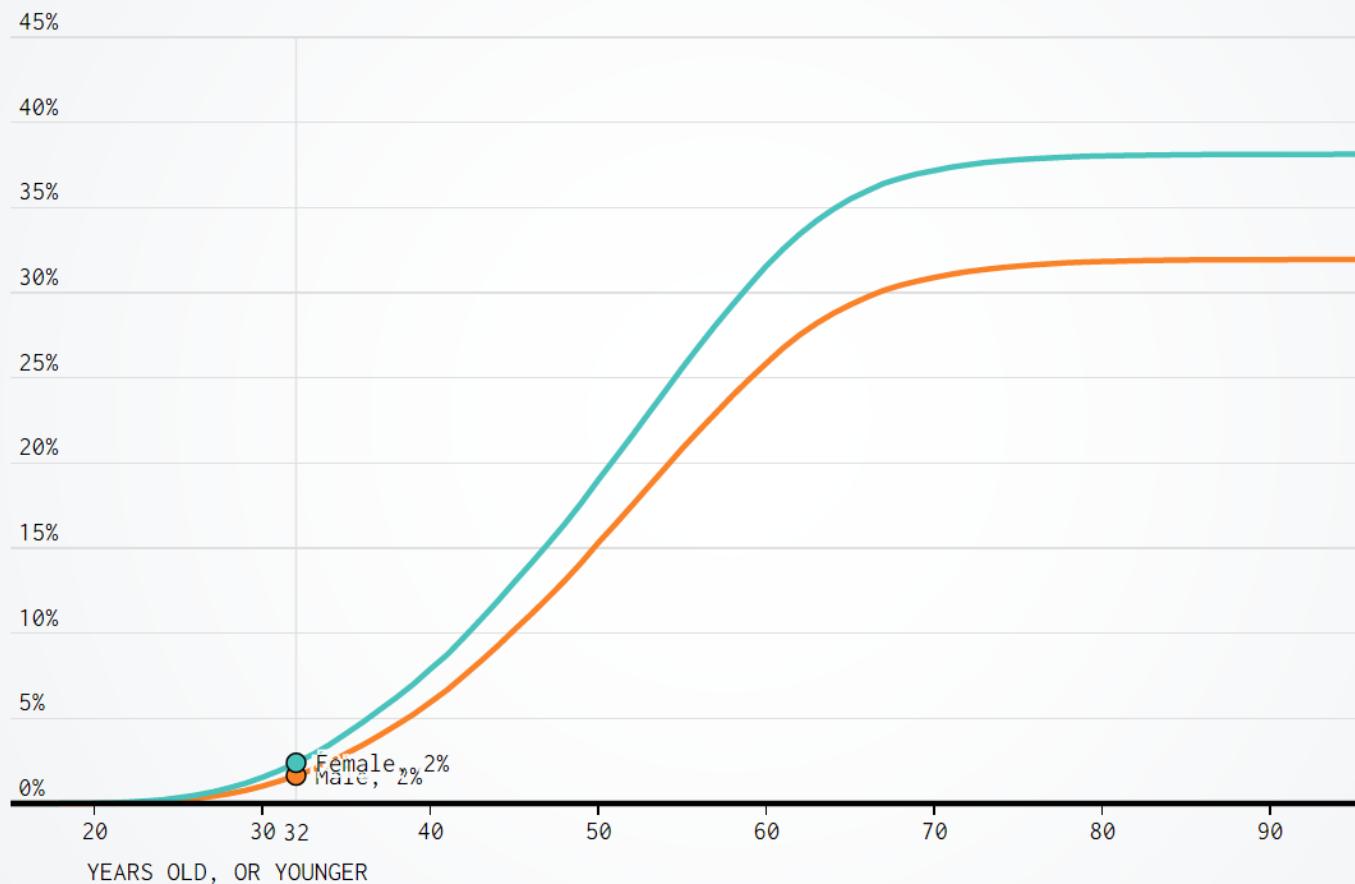
% Of Women Majors, By Field



Source: National Science Foundation, American Bar Association, American Association of Medical Colleges
Credit: Quoctrung Bui/NPR

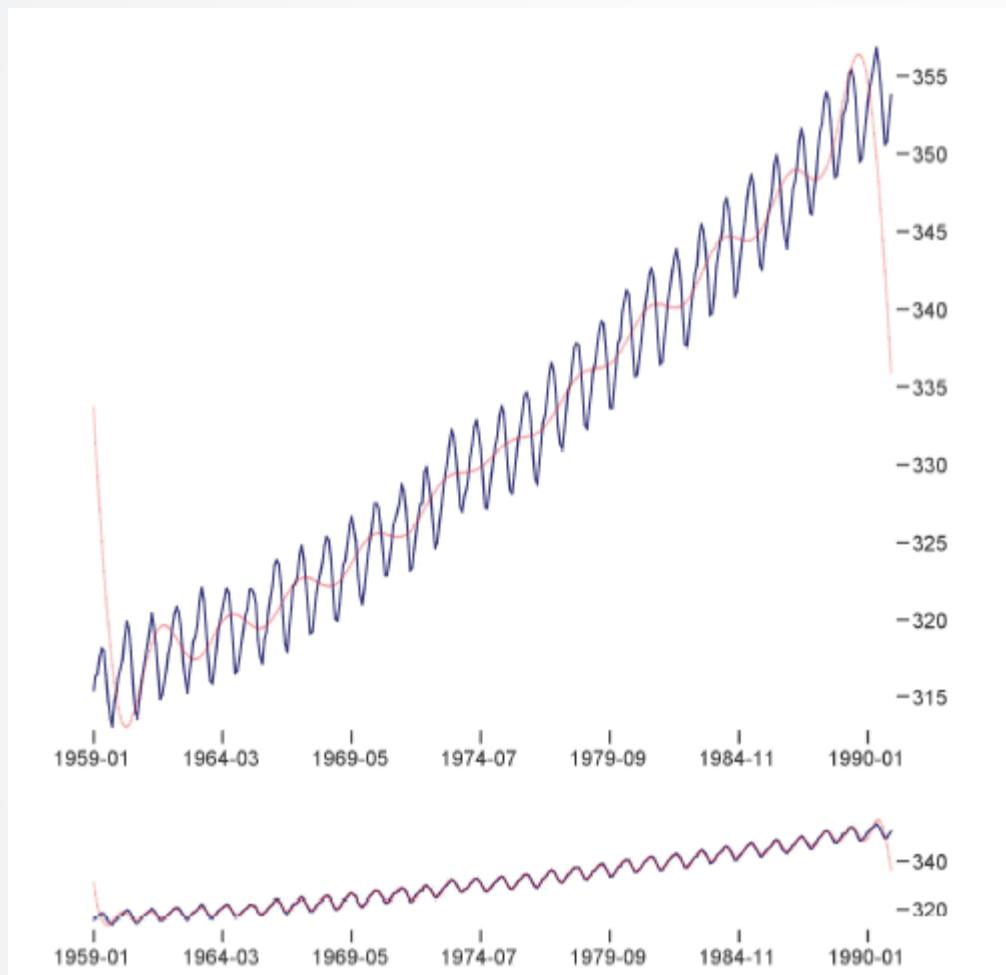
Line Chart

DIVORCED OR MARRIED MORE THAN ONCE, MALE AND FEMALE



<https://flowingdata.com/2016/03/30/divorce-rates-for-different-groups/>

Aspect Ratio



- Two plots of monthly atmospheric carbon dioxide measurements, taken from 1959 to 1990.
- The first plot, with an aspect ratio of 1.17, reveals an accelerating increase in CO₂ levels.
- The second plot, with an aspect ratio of 7.87, facilitates closer inspection of seasonal fluctuations, revealing a gradual attack followed by a steeper decay.
- These aspect ratios were automatically determined using multi-scale banking.

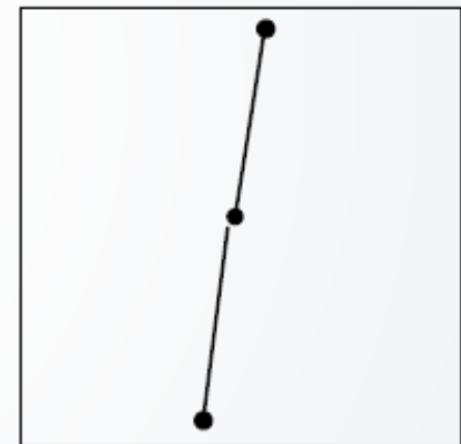
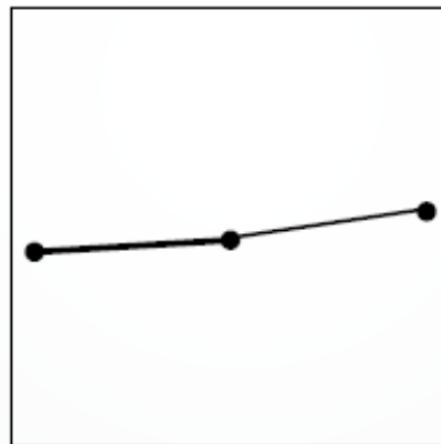
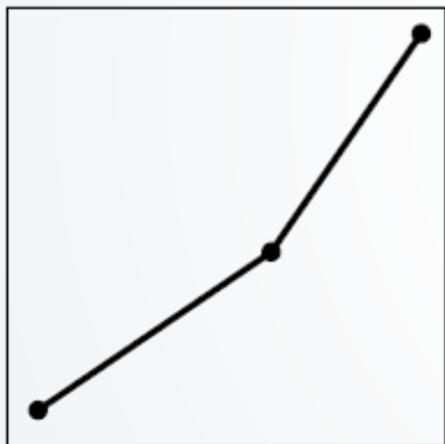
Aspect Ratio



<https://eagereyes.org/basics/banking-45-degrees>

Banking to 45°

The optimized aspect ratio is such that the average absolute orientation of line segments in the chart is equal to 45 degrees.

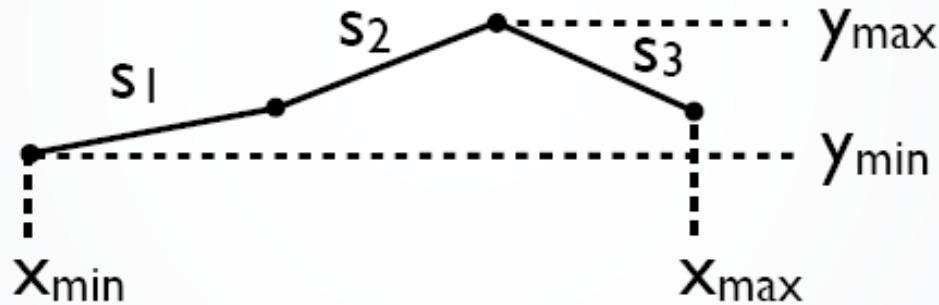


Median-Absolute-Slopes Banking

$$s_i = \frac{\Delta y}{\Delta x}$$

$$R_x = x_{max} - x_{min}$$

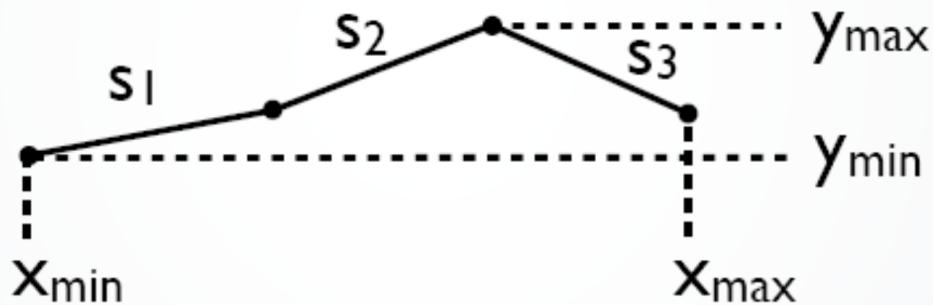
$$R_y = y_{max} - y_{min}$$



$$\alpha = \frac{w}{h} = median|s_i| \frac{R_x}{R_y}$$

Average-Absolute-Slopes Banking

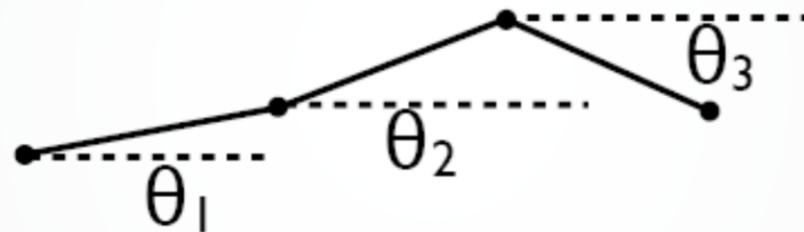
$$s_i = \frac{\Delta y}{\Delta x} \quad R_x = x_{max} - x_{min}$$
$$R_y = y_{max} - y_{min}$$



$$\alpha = \frac{w}{h} = mean|s_i| \frac{R_x}{R_y}$$

Average-Absolute-Orientation Banking

$$\theta_i(\alpha) = \tan^{-1}(s_i/\alpha)$$



$$\sum_i \frac{|\theta_i(\alpha)|}{n} = 45^\circ$$

Aspect Ratio Banking

- Average-Absolute-Slopes Banking

$$\alpha = \text{mean} |s_i| \frac{R_x}{R_y}$$

- Median-Absolute-Slopes Banking

$$\alpha = \text{median} |s_i| \frac{R_x}{R_y}$$

- Average-Absolute-Orientation Banking

$$\sum_i \frac{|\theta_i(\alpha)|}{n} = 45^\circ$$

Multi-Scale Banking to 45°

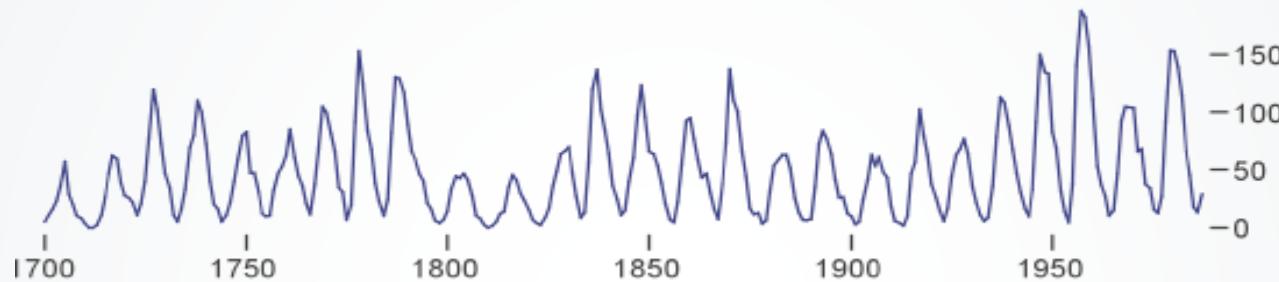
- Objective
 - maximize the discriminability of the orientations of the line segments in the chart
- Methods
 - Automatically identify frequency scales of interest
 - Generate trend curves for identified scales of interest
 - Bank the curves to 45°
 - cull similar aspect ratios

Multi-Scale Banking to 45°

- Search for trends of interest in the power spectrum
 - retain only the highest-frequency value
 - Low-pass filter the data to form the trend curves

Computing Power Spectrum

Original Data



applying a discrete Fourier transform (DFT) to the input data
computing the squared magnitude of each of the resulting Fourier
coefficients to form the power spectrum

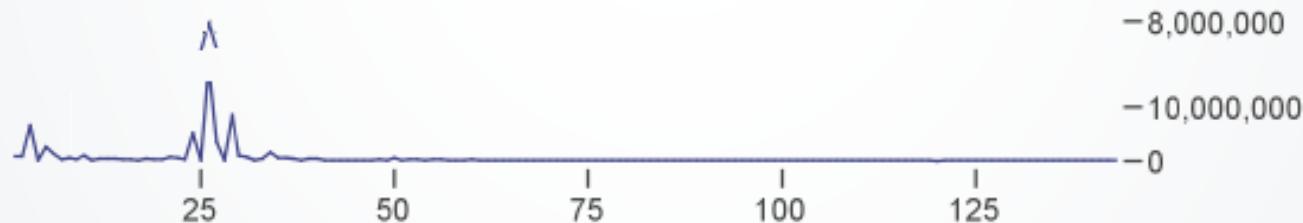
Power Spectrum



Smoothing Spectrum

convolving the power spectrum with a Gaussian filter
window size=3, $\sigma=1$

Power Spectrum
After Smoothness



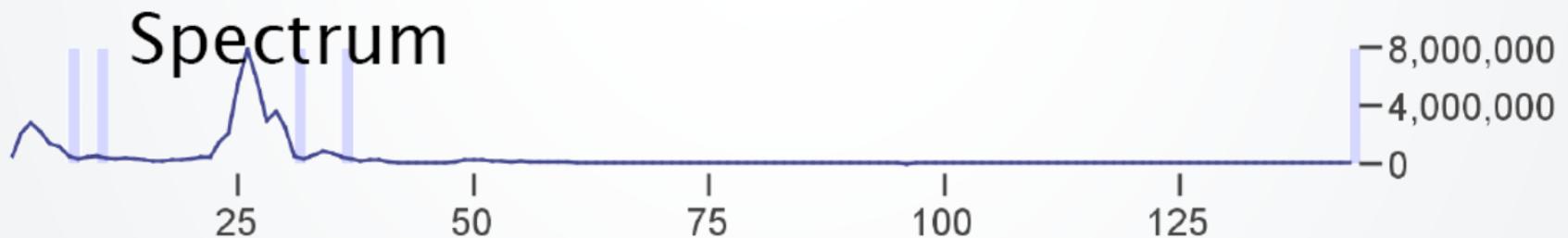
Power Spectrum

Spectrum Threshold

threshold the smoothed spectrum

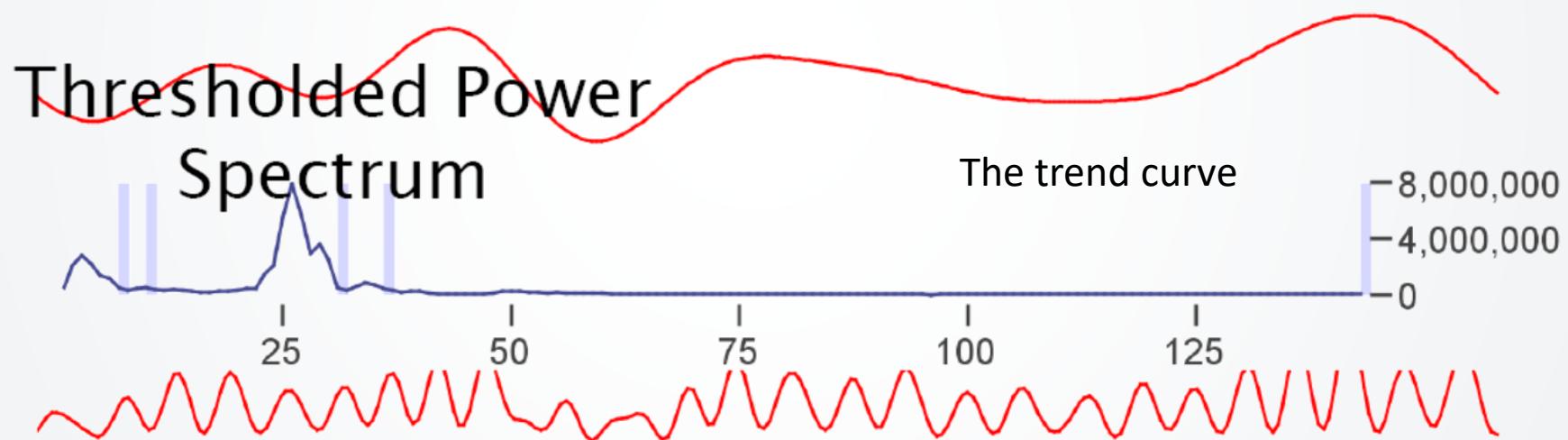
$$\text{Threshold} = \mu$$

Threshold Power

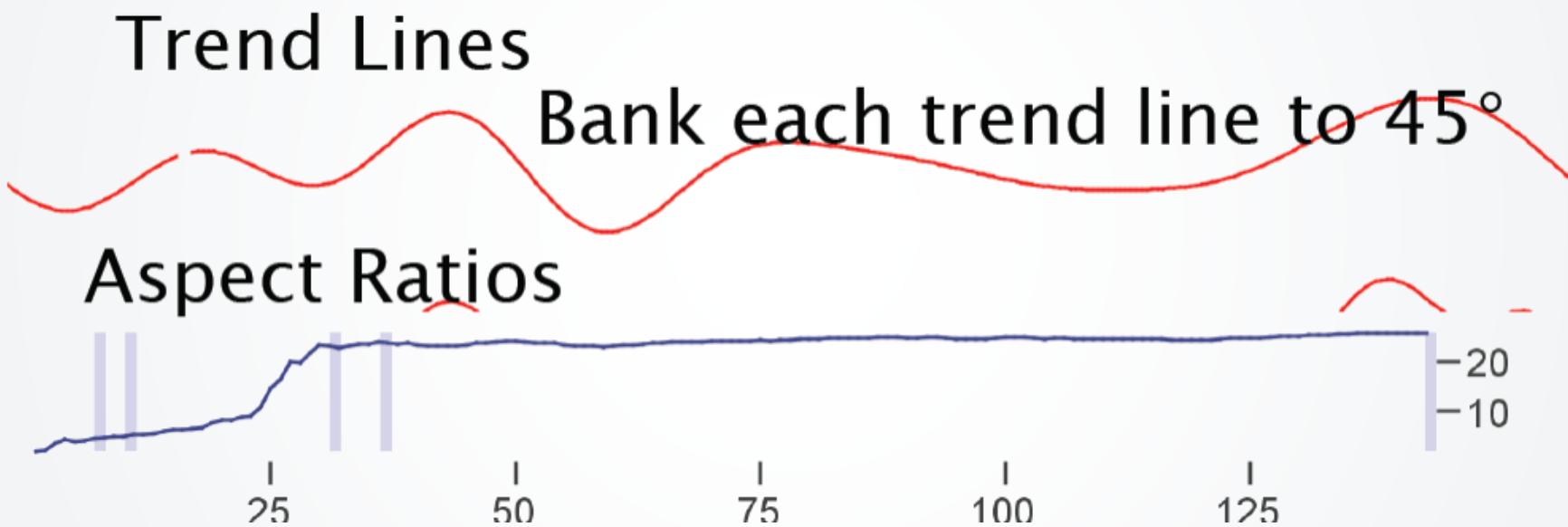


Creating Trend Curves

Low-pass filter the data to form the trend curves



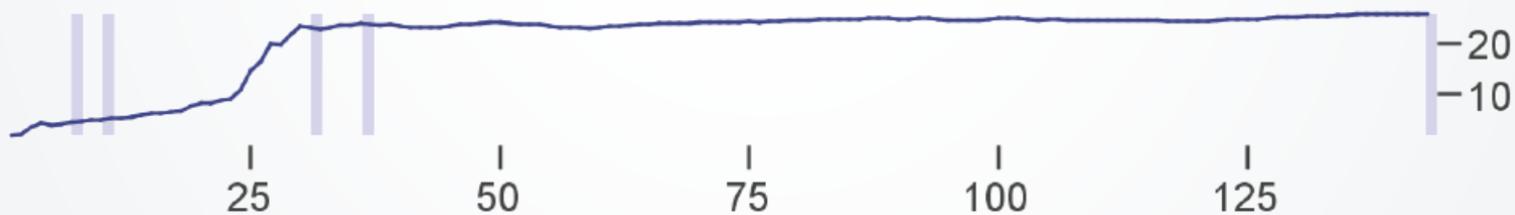
Banking Trend Lines to 45°



Filtering Aspect Ratios

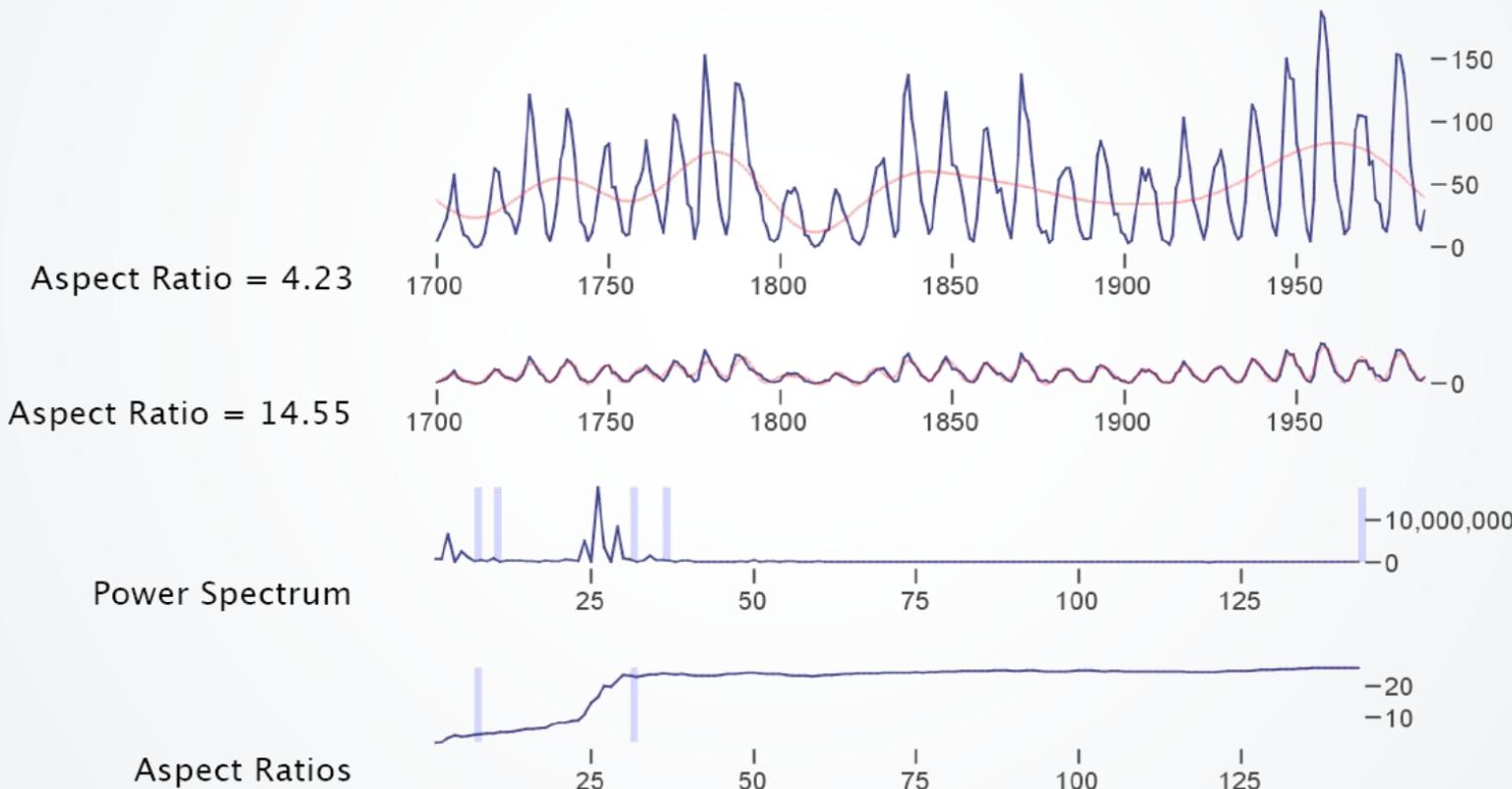
cull similar aspect ratios

Keep the aspect ratio if $\alpha_{i+1} > c\alpha_i$
 $C=1.25$ works well for most cases



Sunspot Cycles

Values from 1700-1987



CO₂

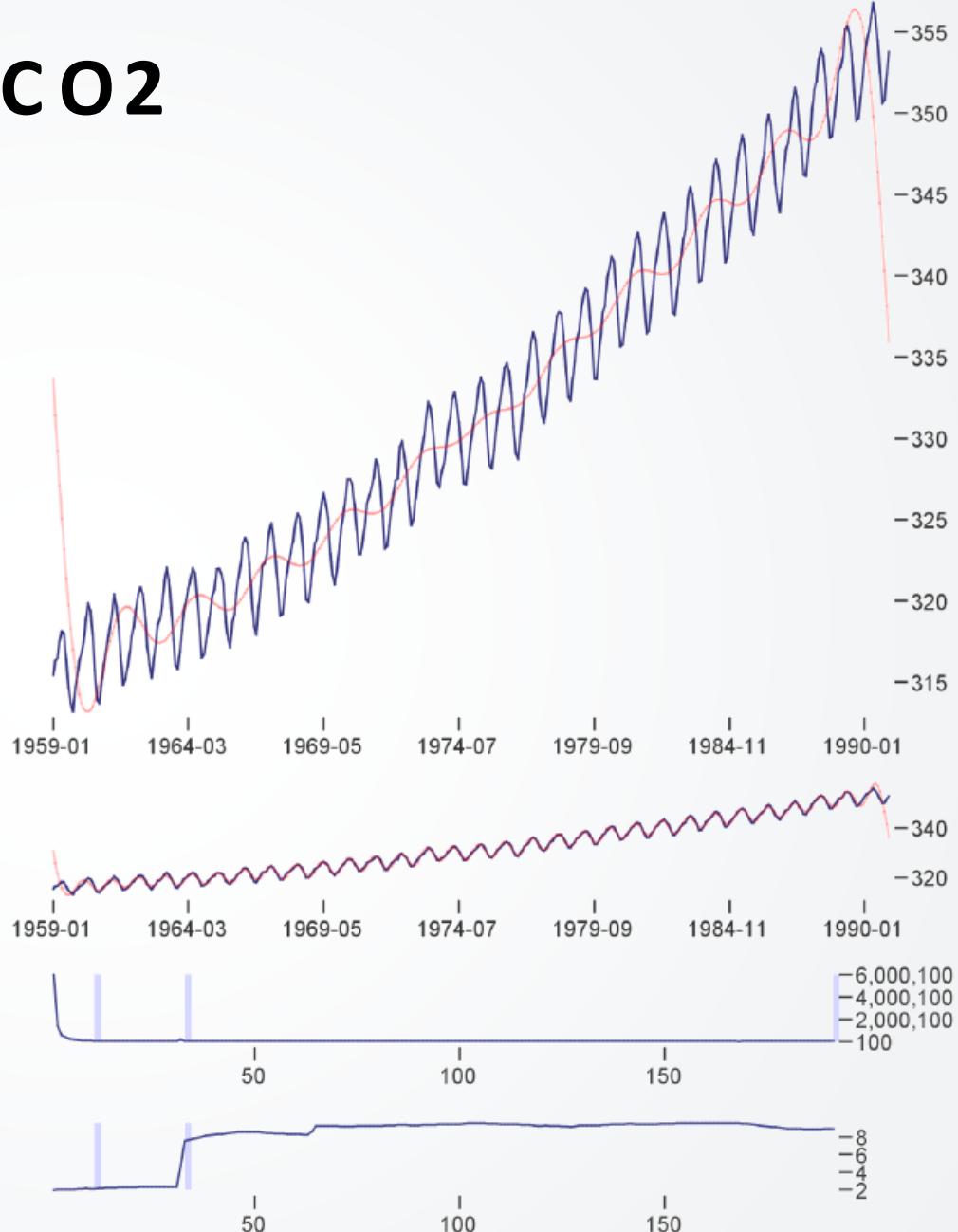
Carbon dioxide measurements taken at the Mauna Loa observatory (from 1950-1990)

Aspect Ratio = 1.17

Aspect Ratio = 7.87

Power Spectrum

Aspect Ratios

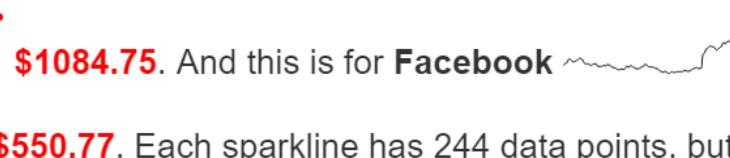


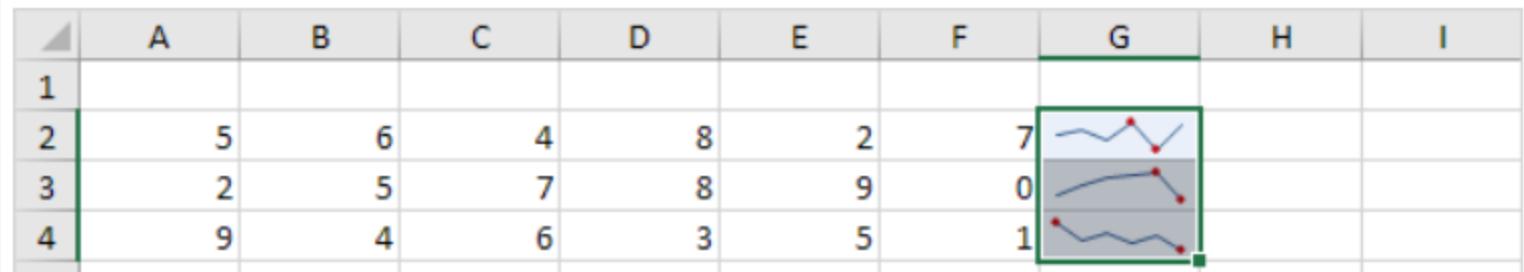
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Sparklines

- A sparkline is a very small line chart, typically drawn without axes.

Using d3.js, we can fairly easily draw SVG-based sparklines. This is 2013 historical stock prices for Google  \$1084.75. And this is for Facebook  \$55.57. And this is for Apple  \$550.77. Each sparkline has 244 data points, but it's condensed very nicely.



- Sparklines are small enough to be embedded in text, or several sparklines may be grouped together as elements of a small multiple.

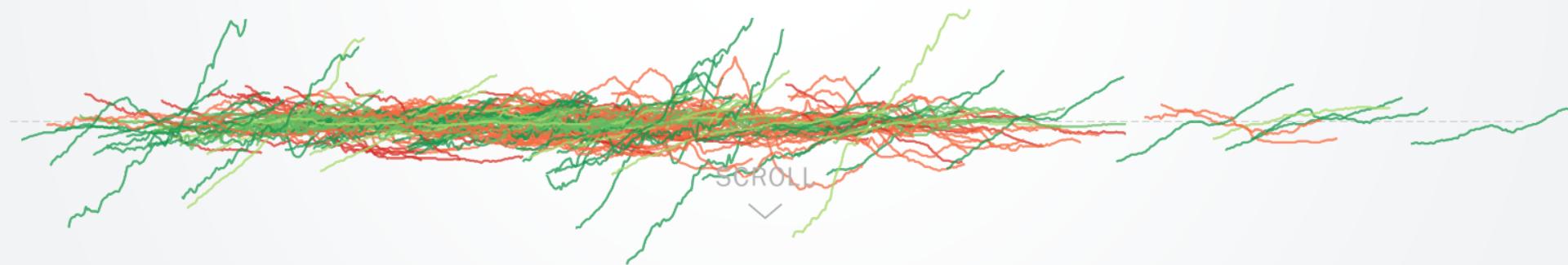
Sparklines in Small Multiple

TheUpshot

How the Recession Reshaped the Economy, in 255 Charts

By JEREMY ASHKENAS and ALICIA PARLAPIANO Updated: JUNE 6, 2014

Five years since the end of the Great Recession, the economy has finally regained the nine million jobs it lost. But not all industries recovered equally. Each line  below shows how the number of jobs has changed for a particular industry over the past 10 years. Scroll down to see how the recession reshaped the nation's job market, industry by industry.



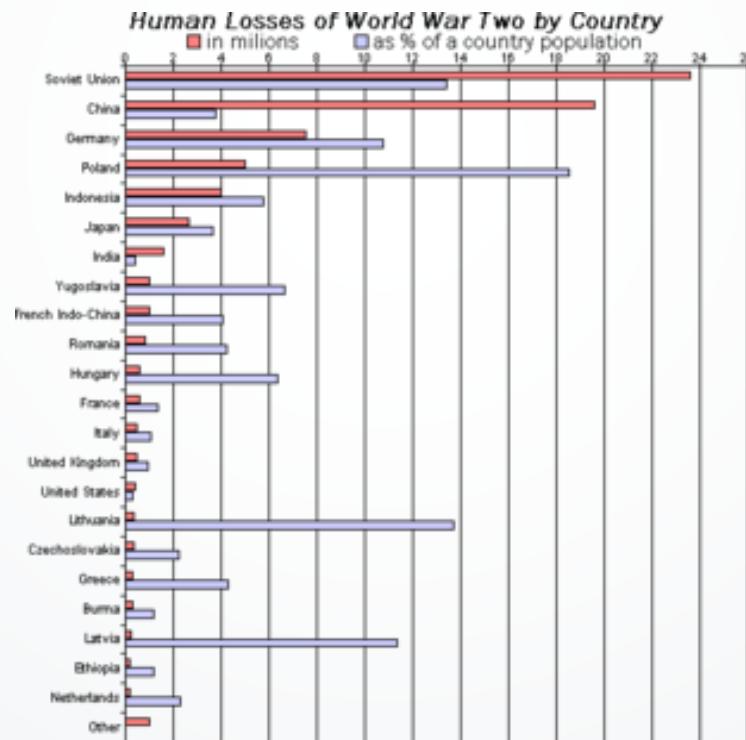
<http://www.nytimes.com/interactive/2014/06/05/upshot/how-the-recession-reshaped-the-economy-in-255-charts.html>

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Bar Chart

A bar chart or bar graph is a chart that presents categorical data with rectangular bars with heights or lengths proportional to the values that they represent.



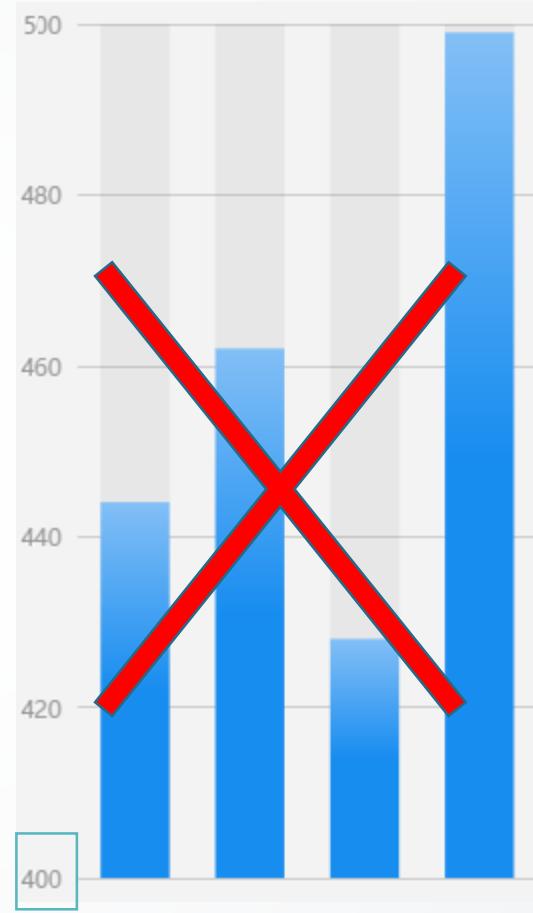
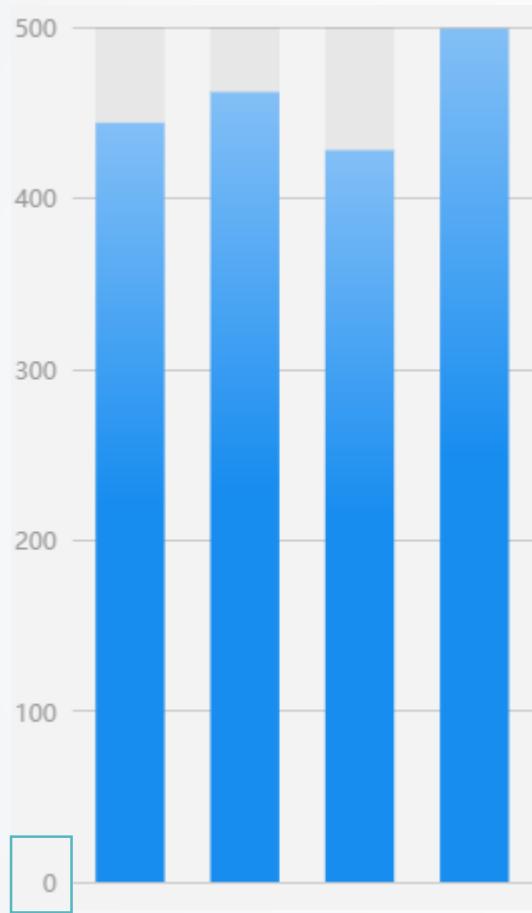
Bar Chart

How much beer does each country consume?

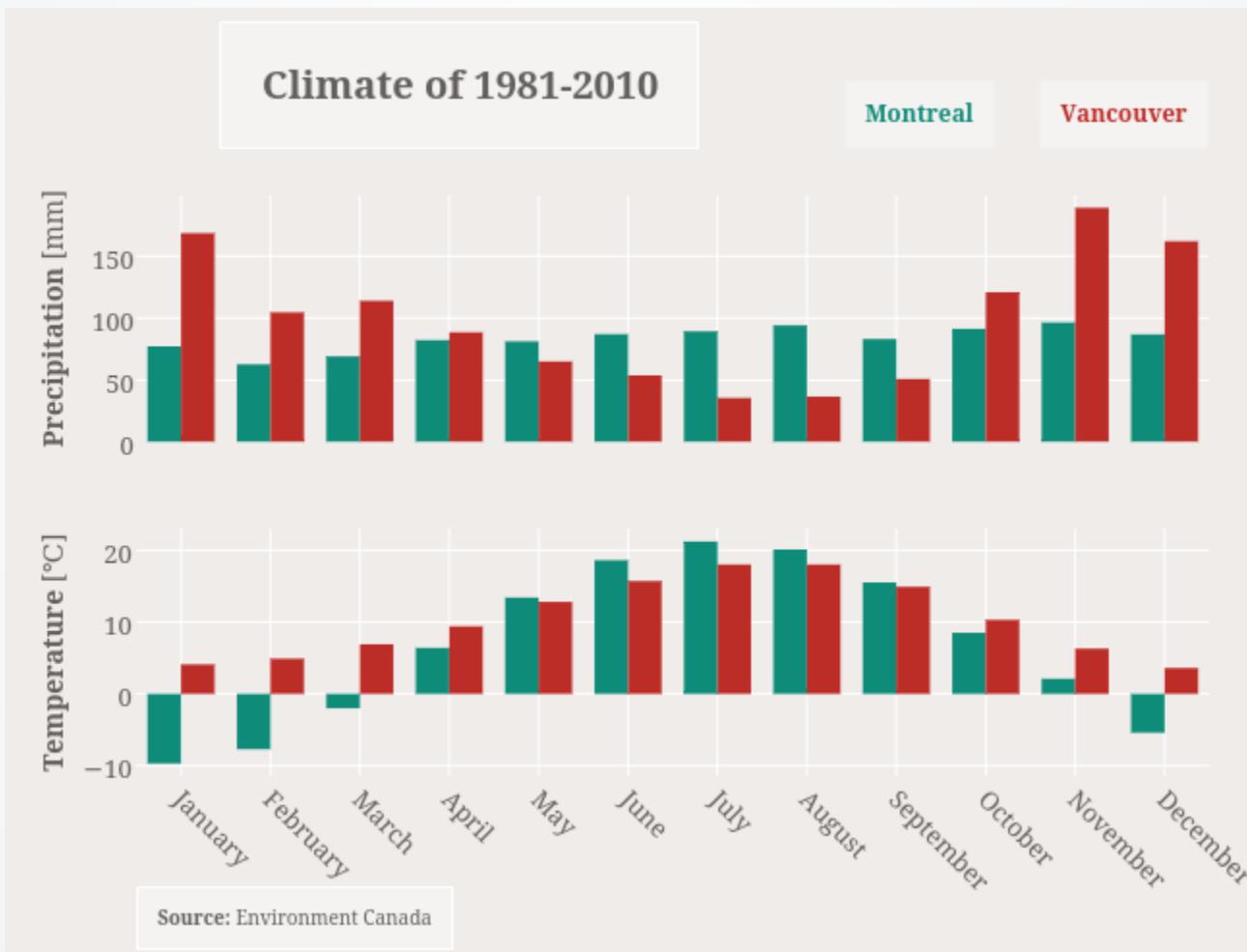
Average beer bottles per one per week



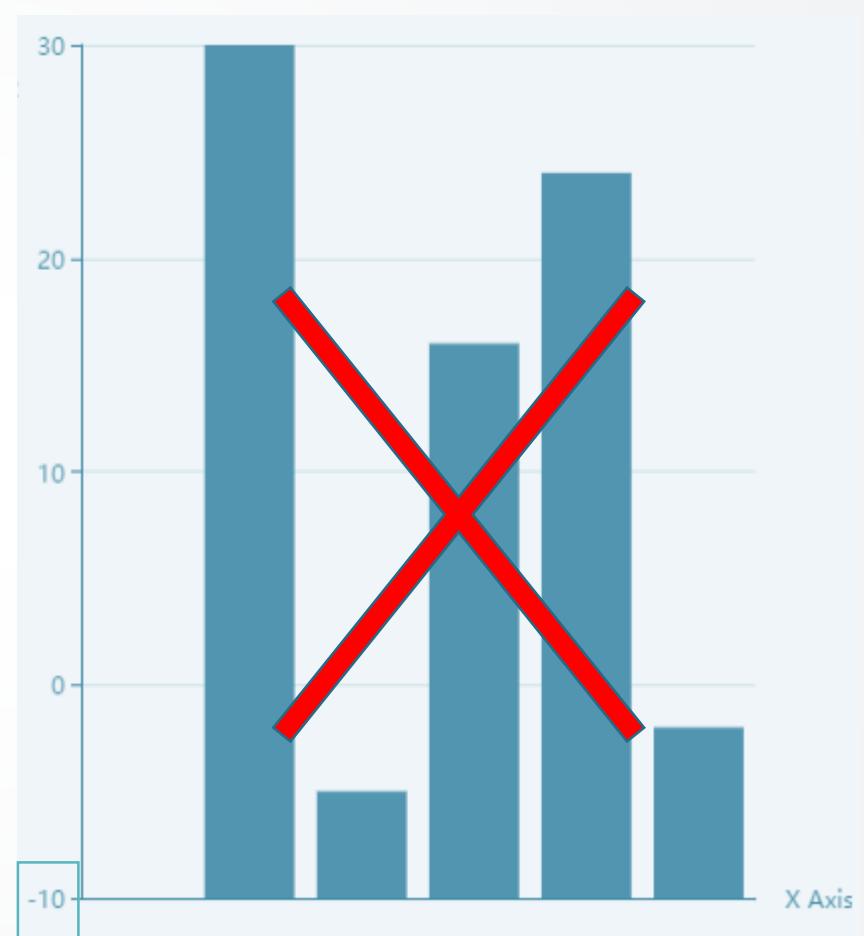
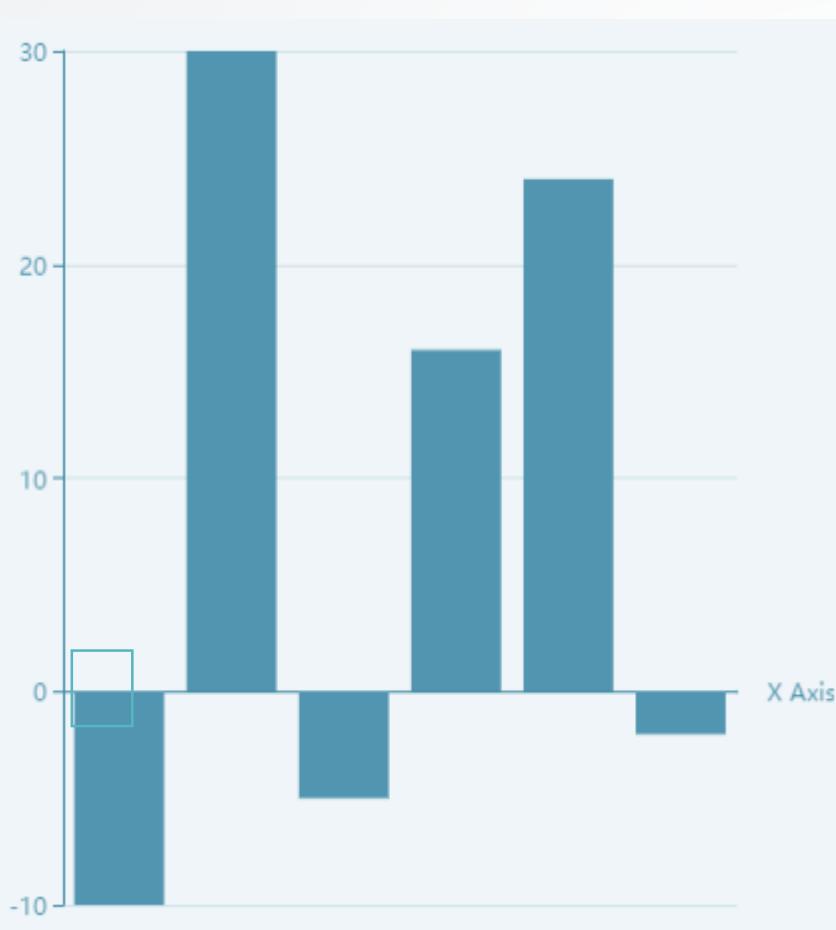
Scales



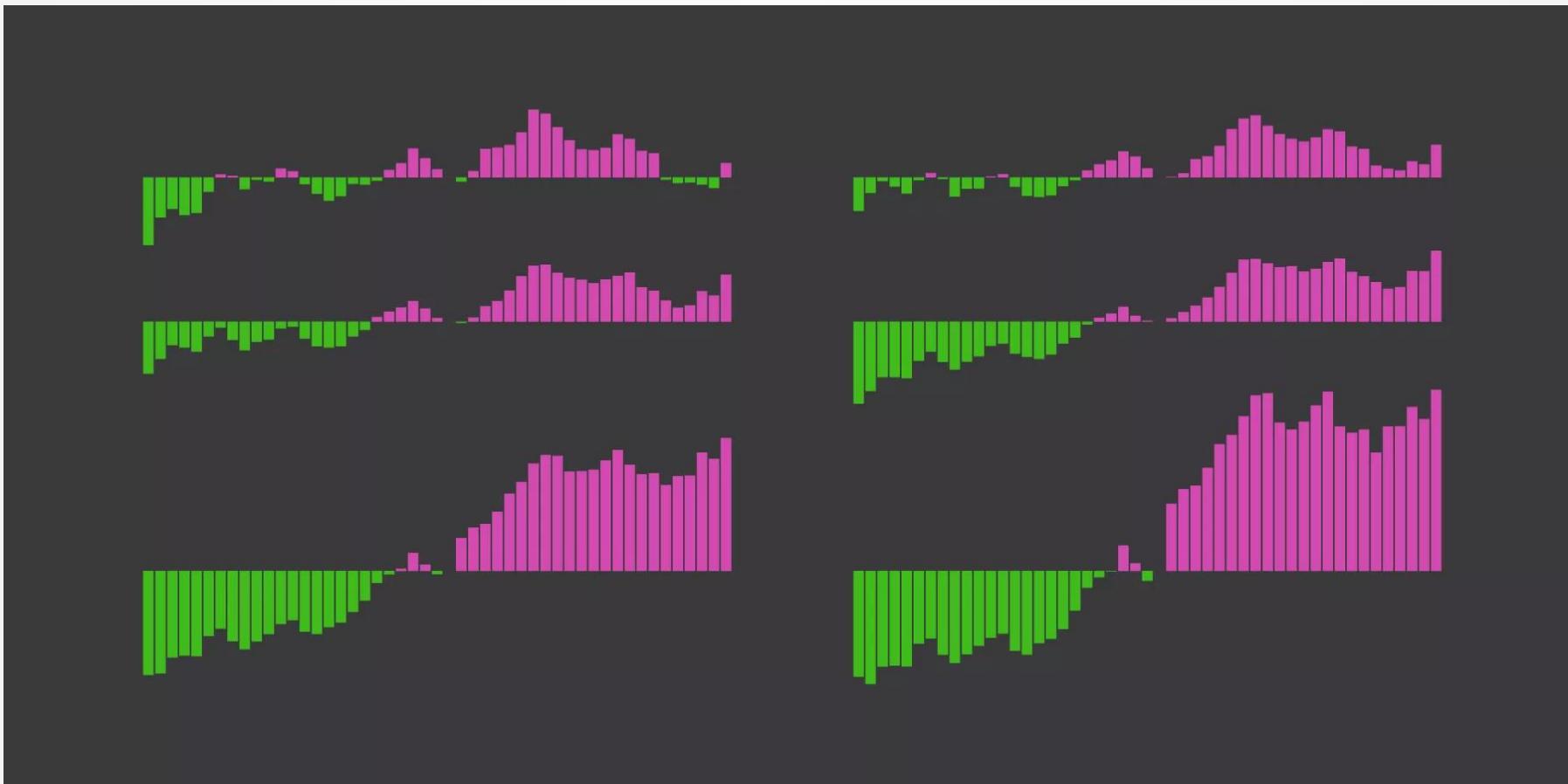
Deviation Design



Use Zero as Base



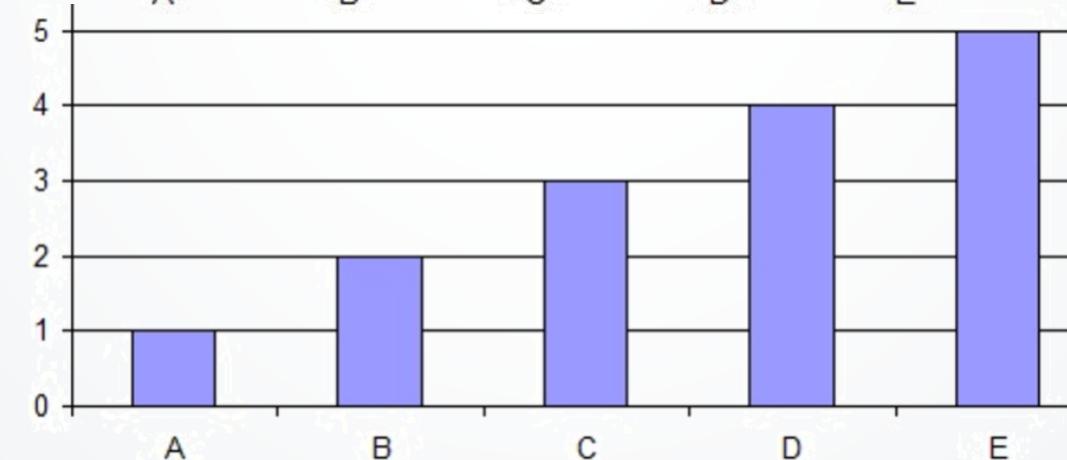
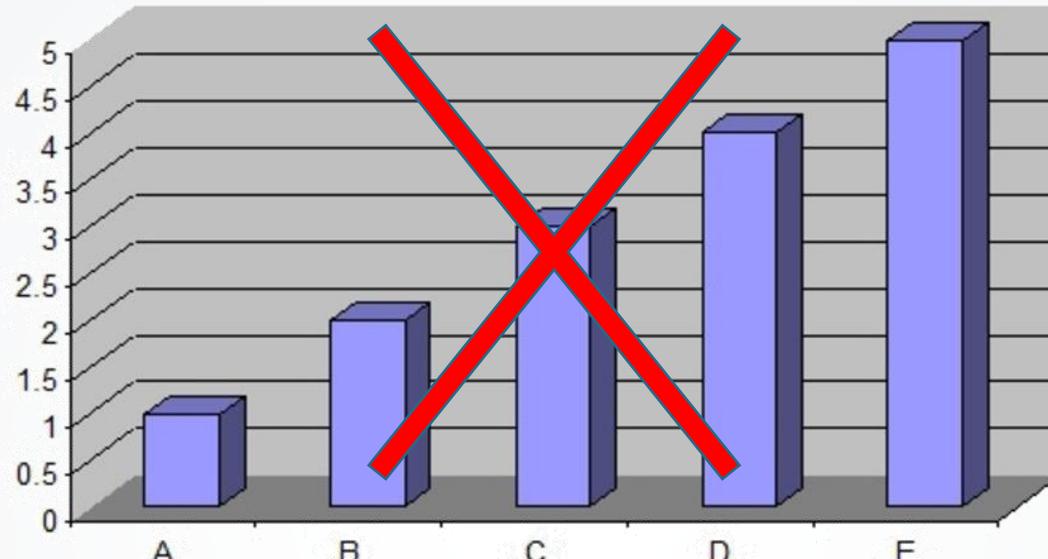
NATHAN YAU, 2016



Shift Your Point of View to When America Was “Better”

<https://flowingdata.com/2016/11/23/shift-your-point-of-view/>

3D is Usually not Preferred

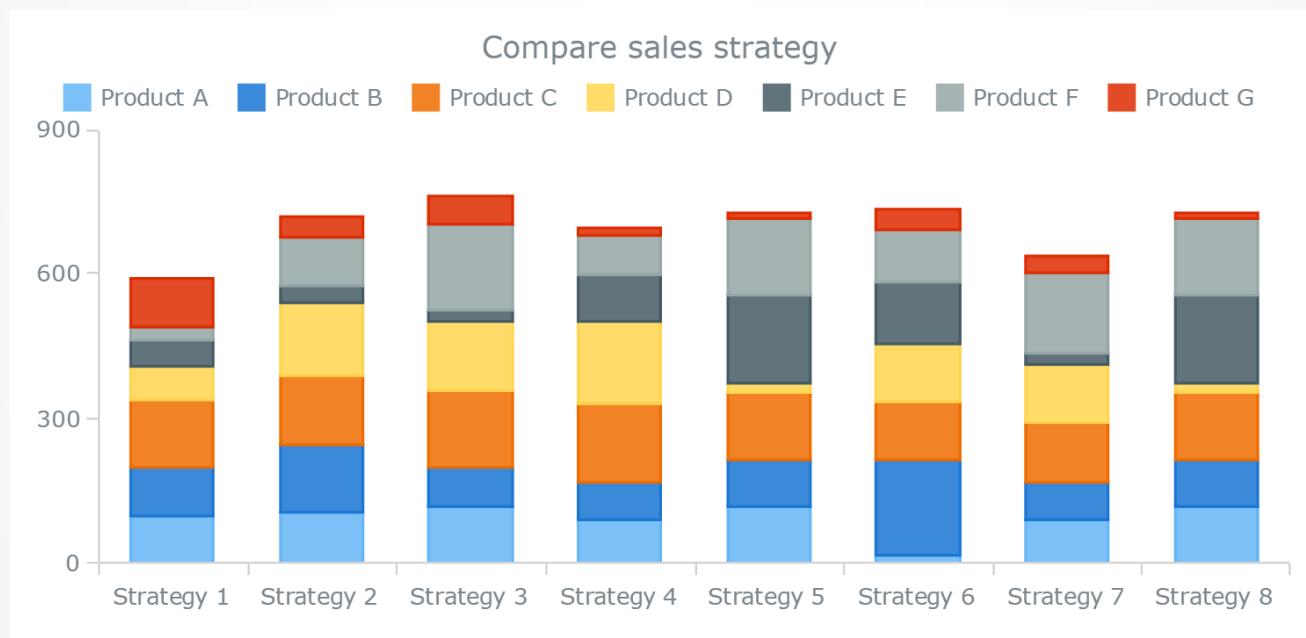


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Stacked Bar Chart

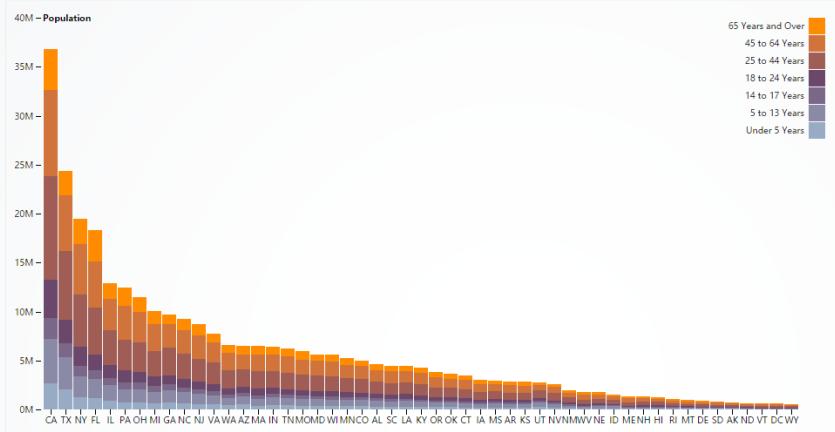
A stacked bar chart, also known as a stacked bar graph, is a graph that is used to break down and compare parts of a whole. Each bar in the chart represents a whole, and segments in the bar represent different parts or categories of that whole.



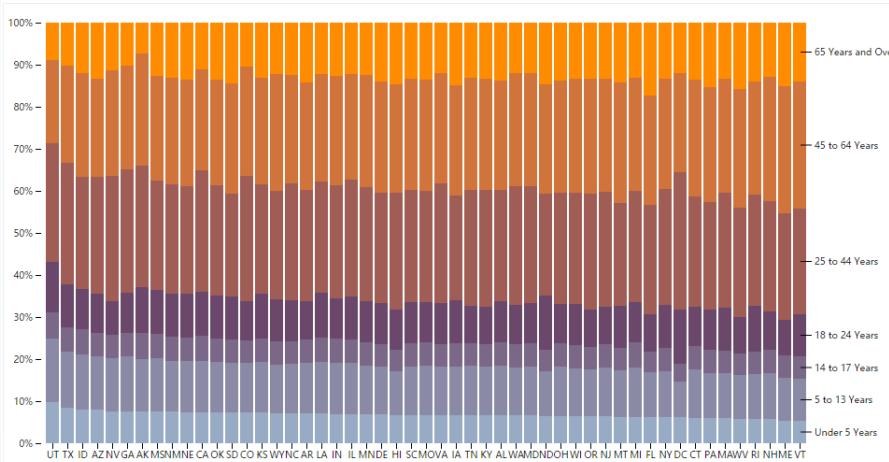
<https://www.smashingmagazine.com/2017/03/understanding-stacked-bar-charts/>

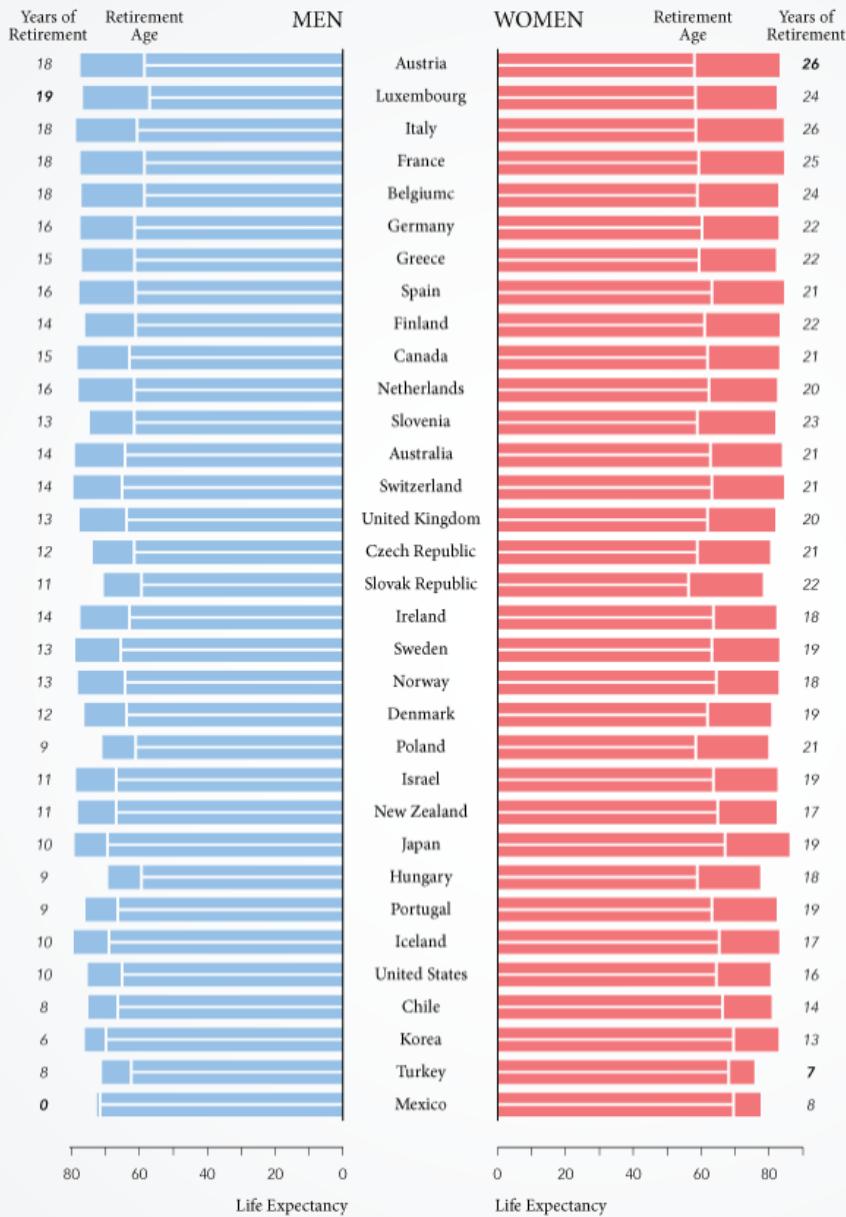
Stacked Bar Chart

Stacked Bar Chart



Normalized Stacked Bar Chart





Paired Bar Chart

Life Expectancy & Retirement Years

<http://Flowingdata.com>



Espresso
[ess-press-oh]



Espresso Macchiato
[ess-press-oh mock-e-ah-toe]



Espresso con Panna
[ess-press-oh kon pawn-nah]



Caffé Latte
[caf-ay lah-tey]



Flat White



Cafe Breve
[caf-ay brev-ay]



Cappuccino
[kapp-oo-chee-noh]



Caffé Mocha
[caf-ay moh-kuh]



Americano
[uh-mer-i-kan-oh]

You call it
stacked bar chart?

Black & White Chocolate
Black chocolate(72%)
White chocolate(36%)



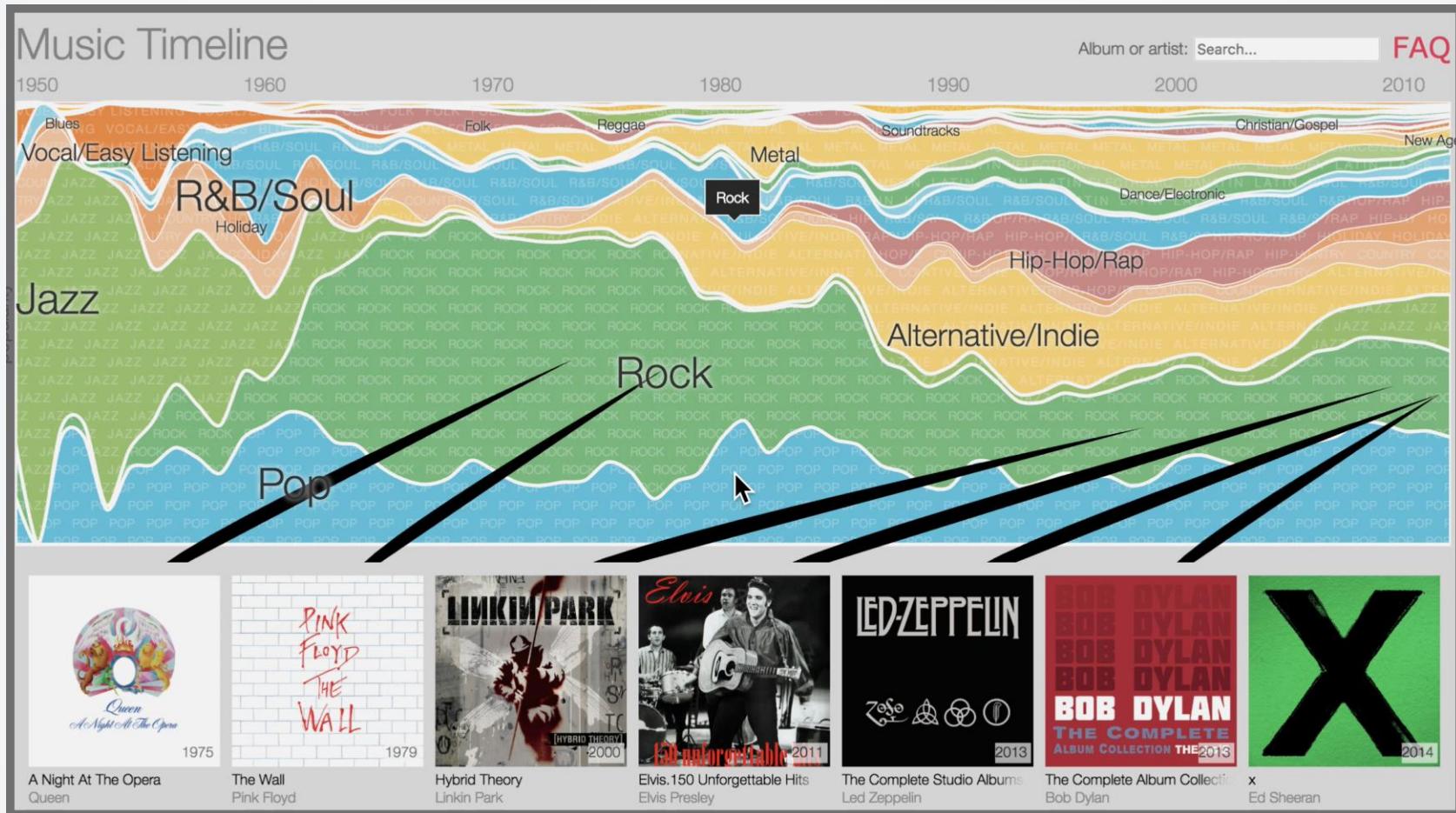
Brown & White Chocolate
Brown chocolate(66%)
White chocolate(36%)



Strawberry Stripe
Chocolate
Strawberry chocolate(72%)
White chocolate(38%)



Stacked Chart



Music timeline of plays and history

<http://research.google.com/bigpicture/music/#>

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Pie Chart

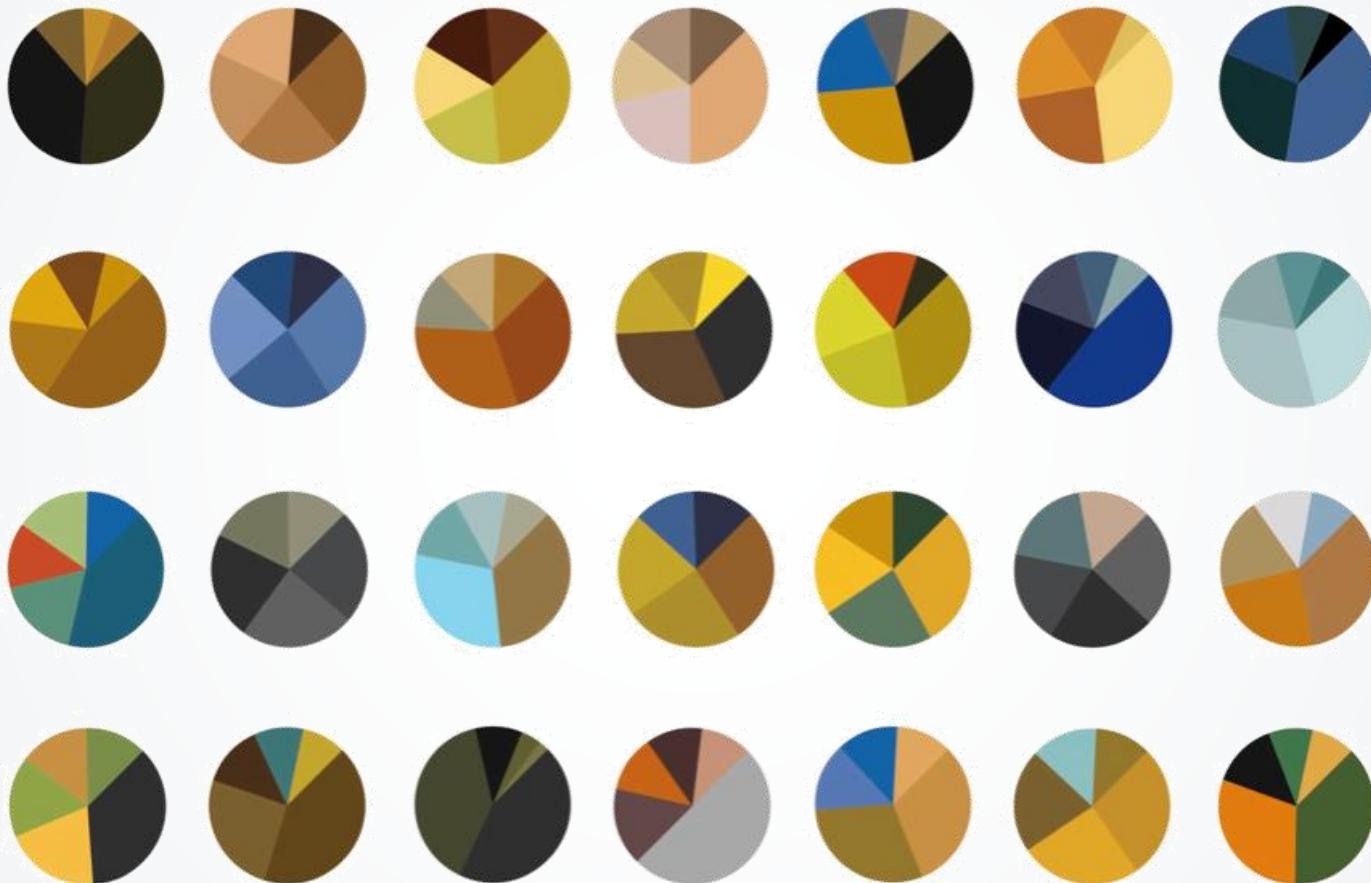


Percentage data

Van Gogh's Paintings



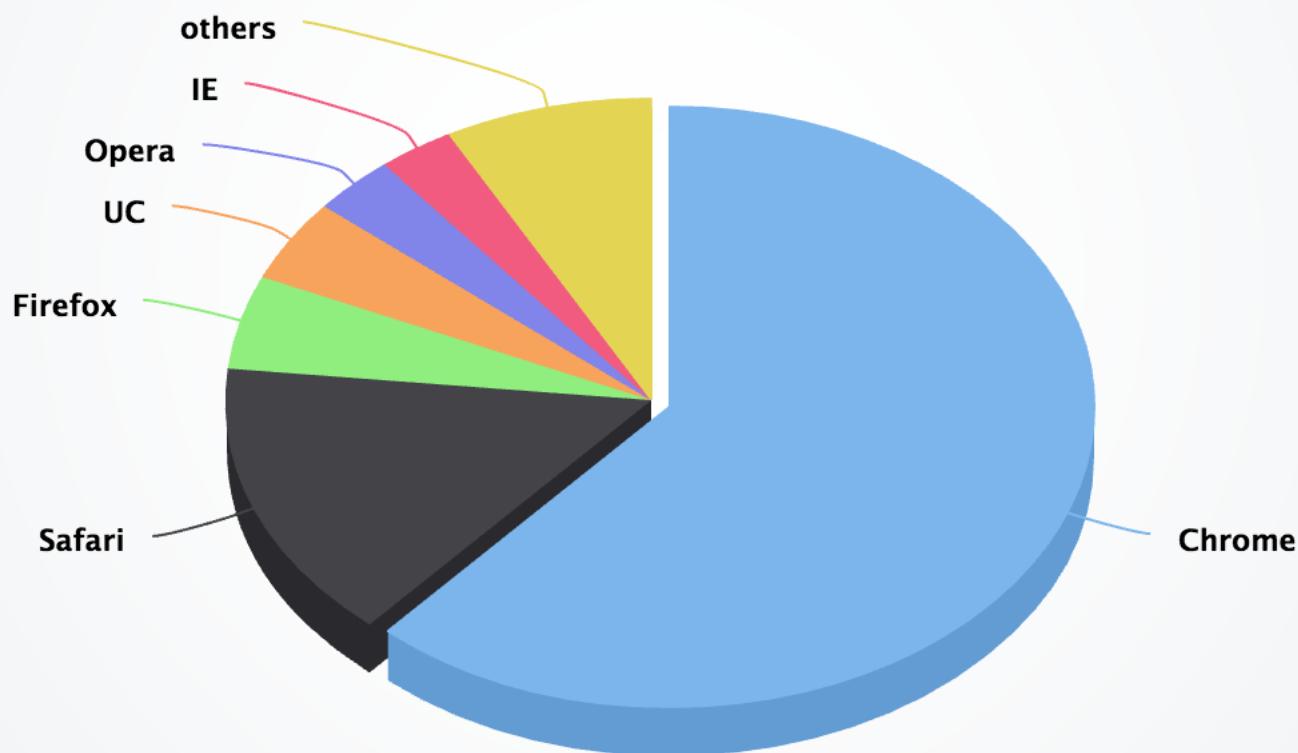
Van Gogh Visualization



<http://www.arthurbuxton.com/2010/11/van-gogh-visualisation.html>

Browser Pie Chart

Browser market shares at a specific website, October 2018



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Scatter Plot

Pay Gap Between Women and Men

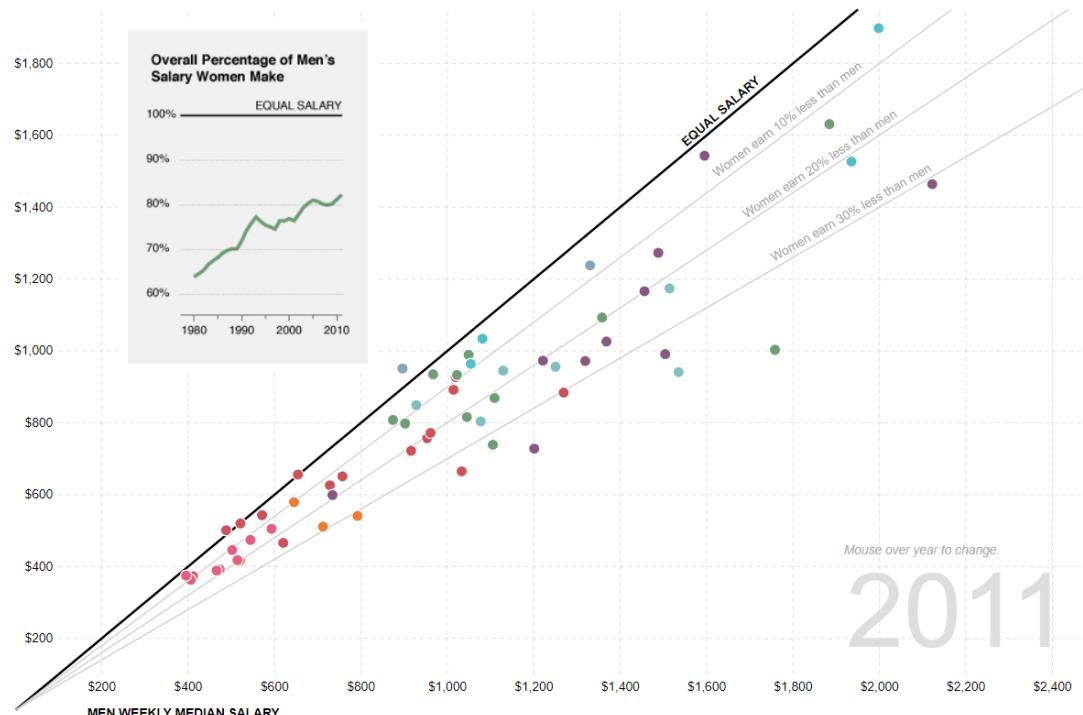
An update to [an interactive](#) by Hannah Fairfield and Graham Roberts of The New York Times in 2010, making use of Mike Bostock's [Wealth & Health of Nations D3 port](#).

On average, women are still paid less than men for working comparable jobs. Is it getting better? Below shows how salaries between the genders have changed over the past nine years.

Management	Computers & Mathematics	Service
Business Operations	Professional & Related	Production & Transportation
Sales & Office	Healthcare	

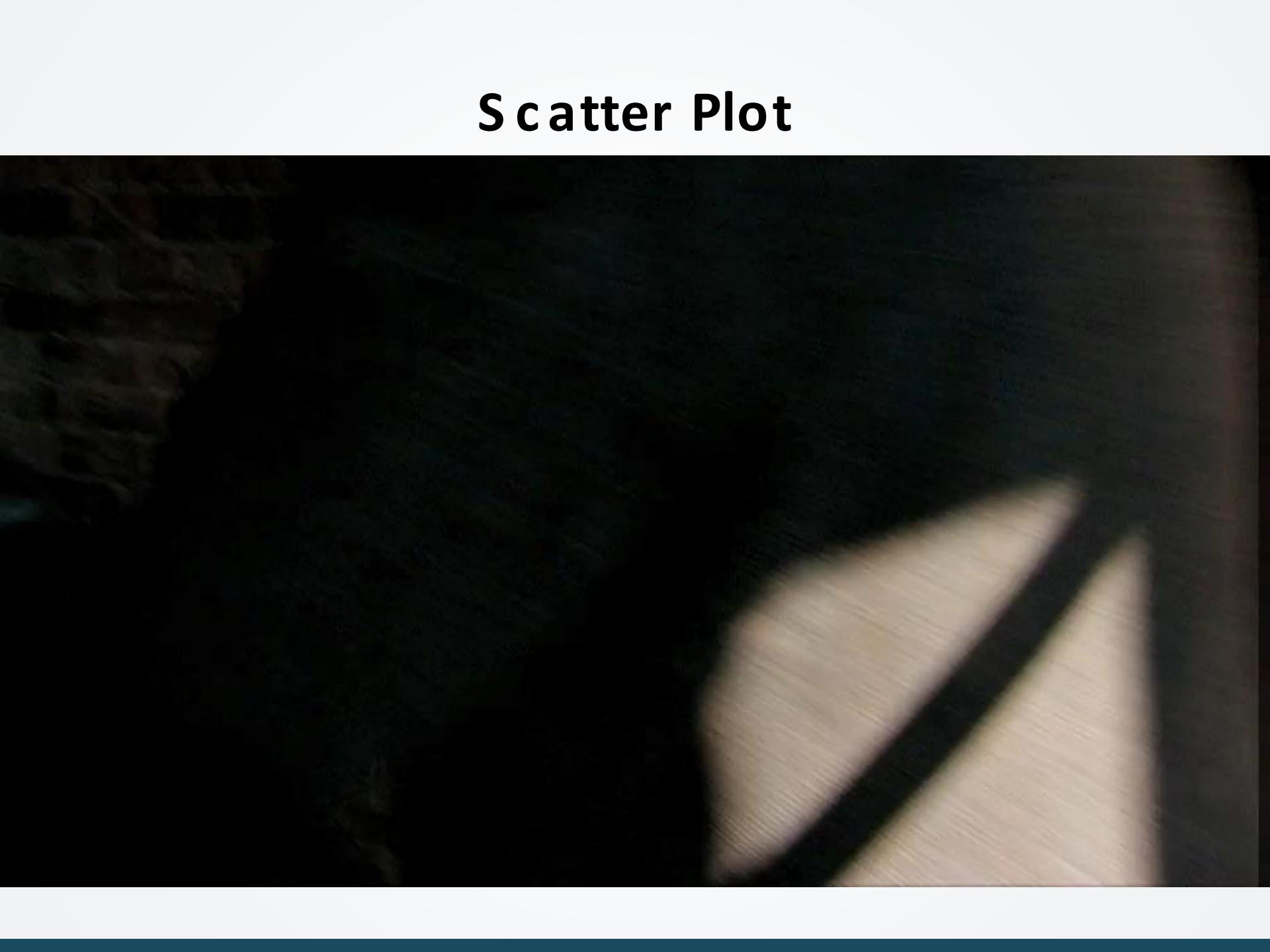
Show Paths

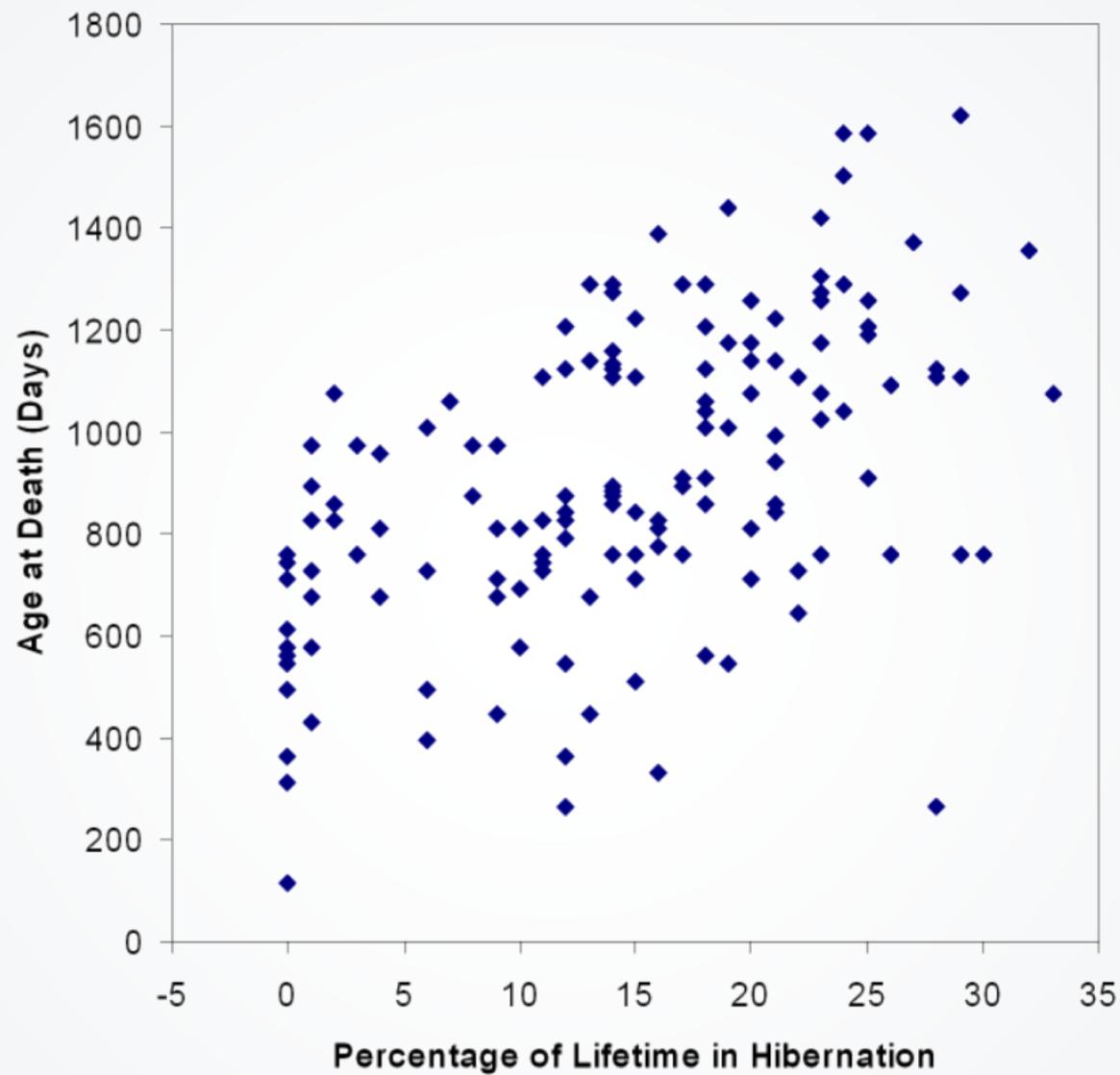
WOMEN WEEKLY MEDIAN SALARY



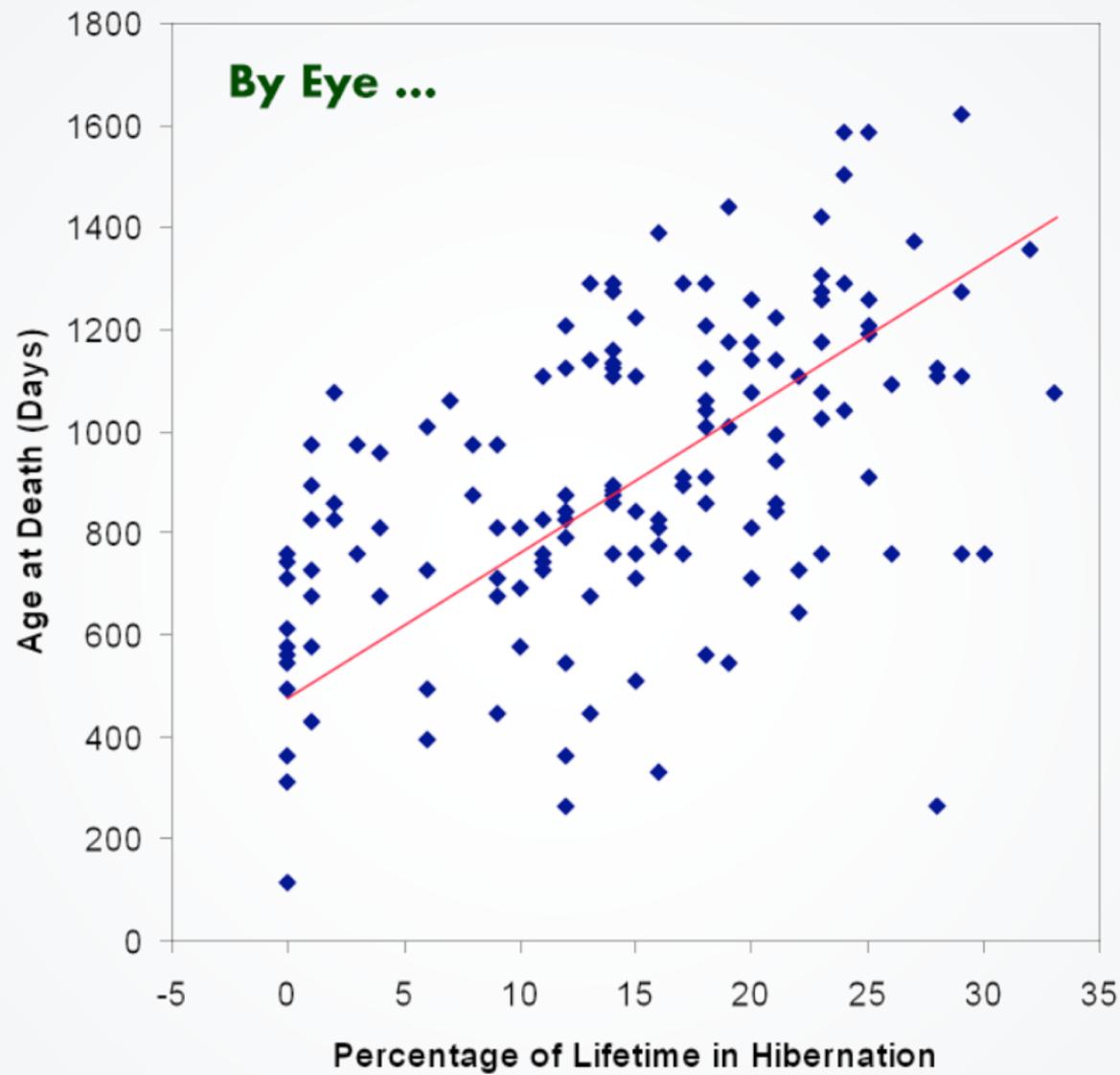
*Only occupations with data for all years and with at least 50,000 respondents for each sex are shown.
Source: Bureau of Labor Statistics — By [Nathan Yau](#)

Scatter Plot



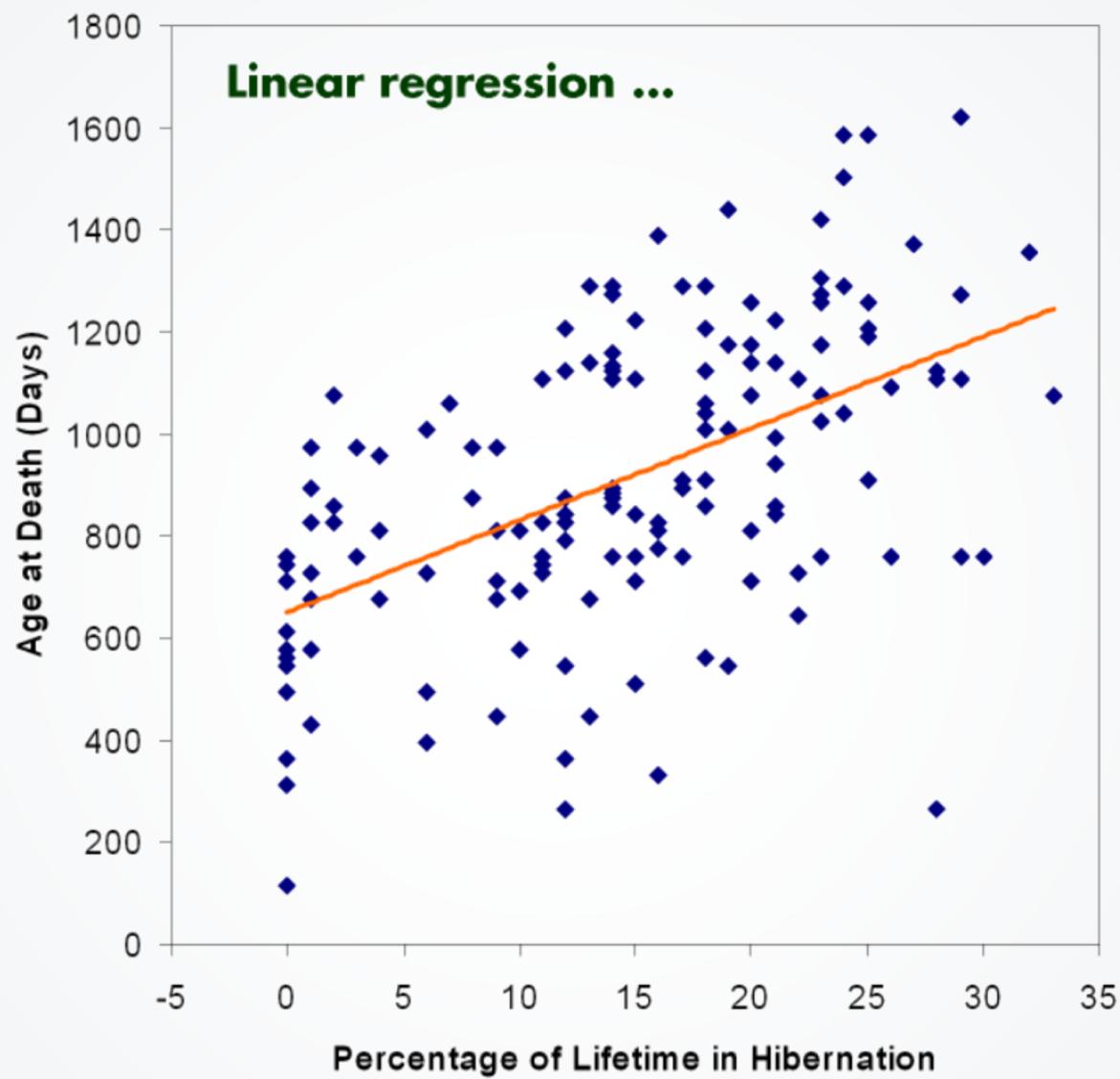


[The Elements of Graphing Data. Cleveland 94]

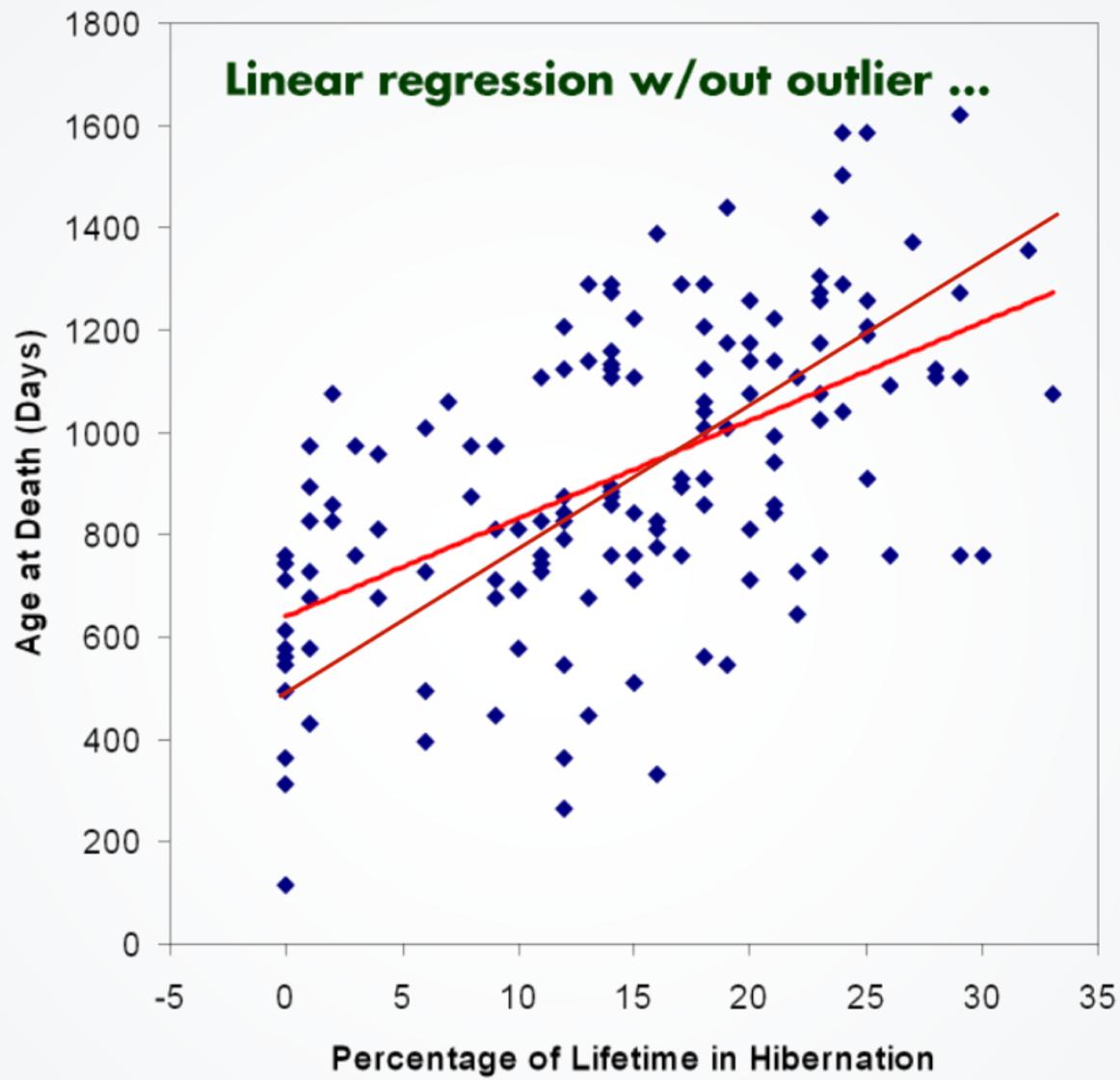


[The Elements of Graphing Data. Cleveland 94]

Linear regression ...



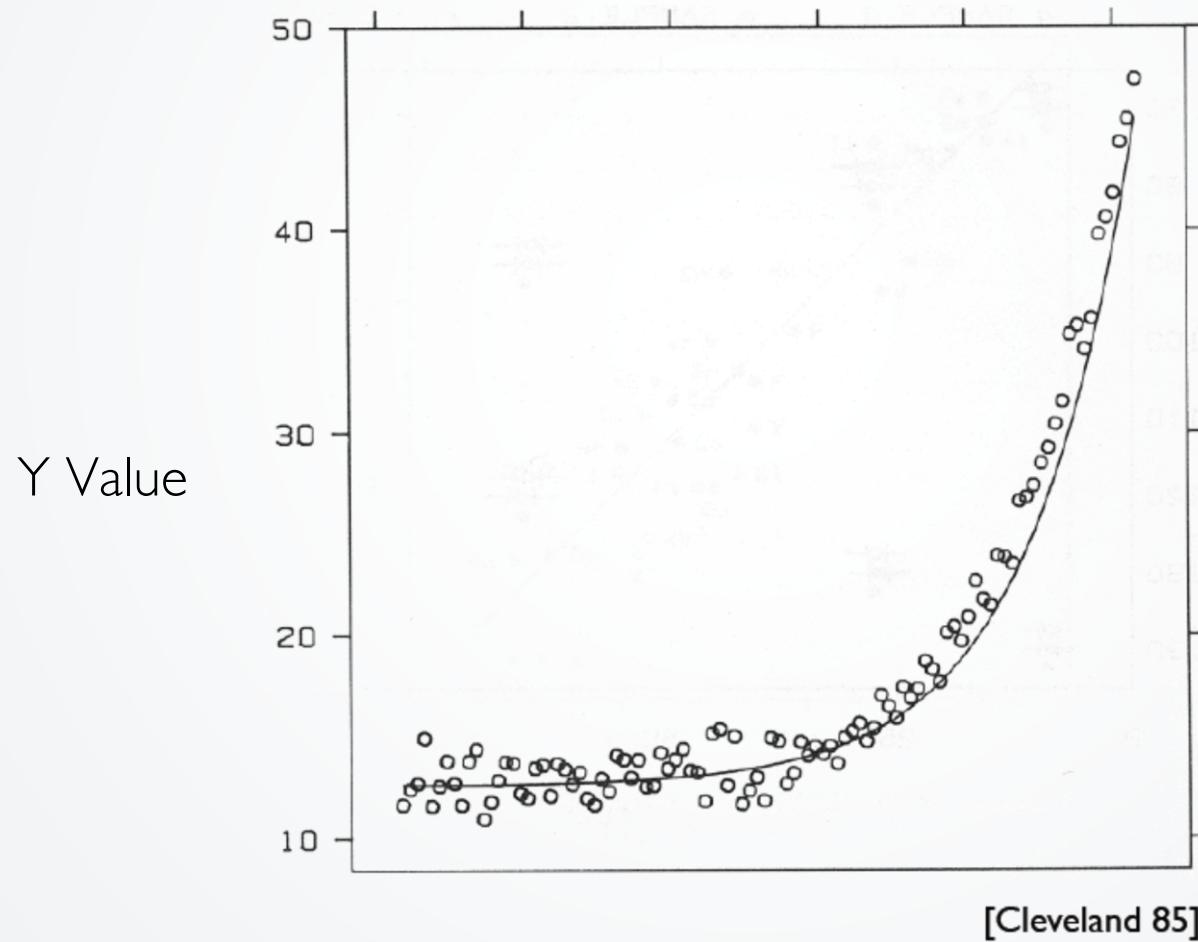
[The Elements of Graphing Data. Cleveland 94]



[The Elements of Graphing Data. Cleveland 94]

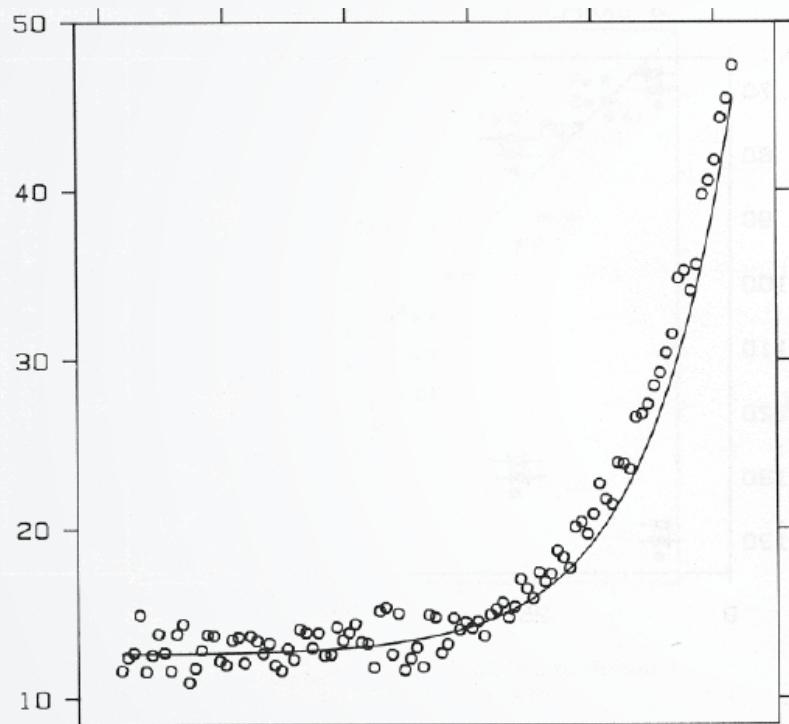
Fit Curve

How much it fits to the curve?

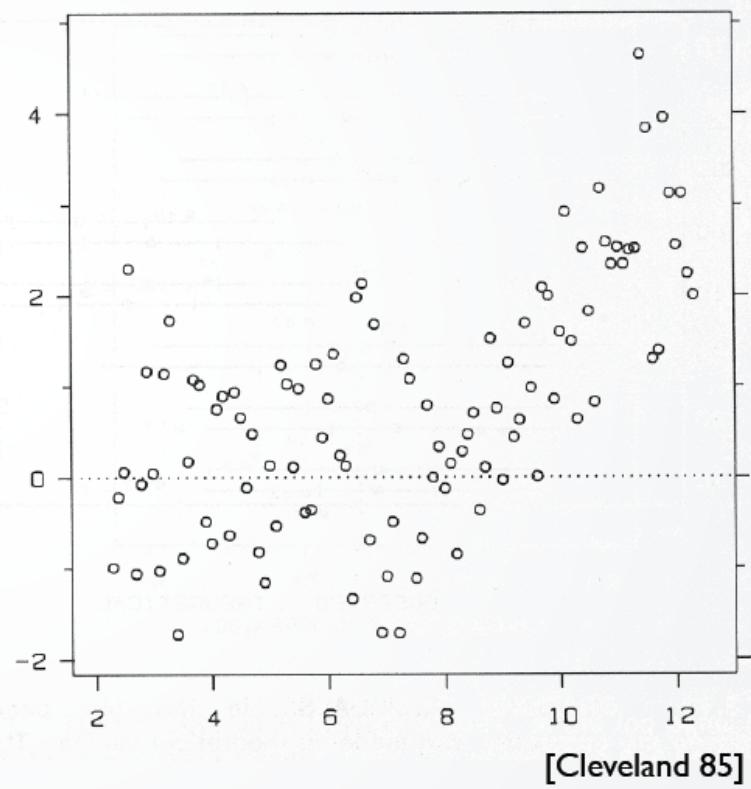


Remainder

Fit curve

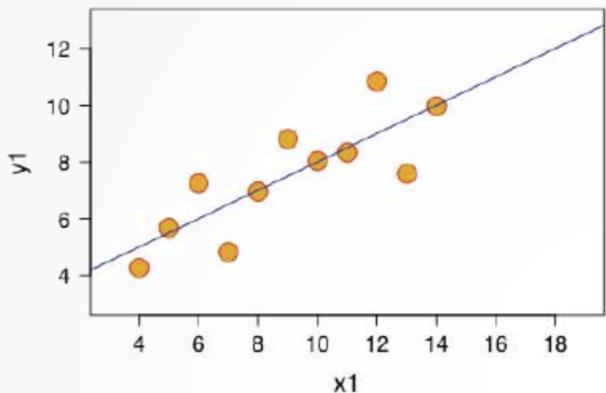


Remainder variation

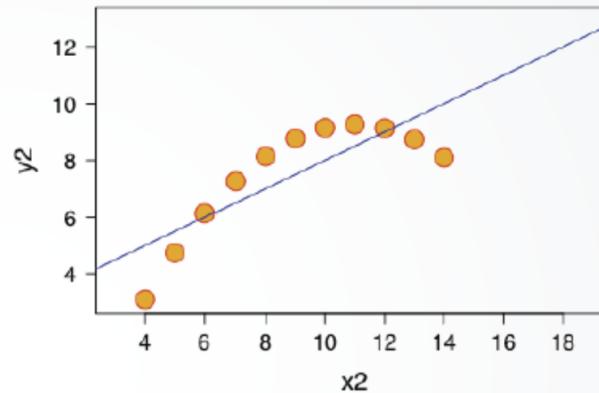


Show the Data

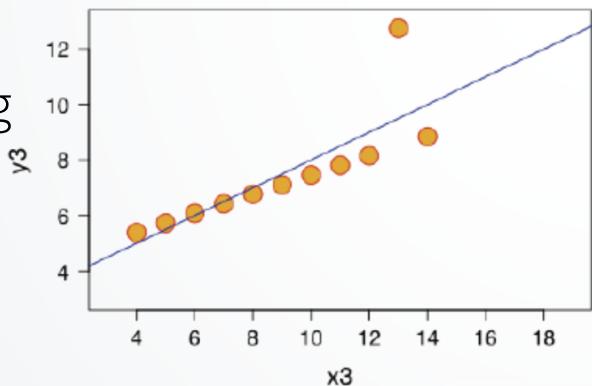
Mean



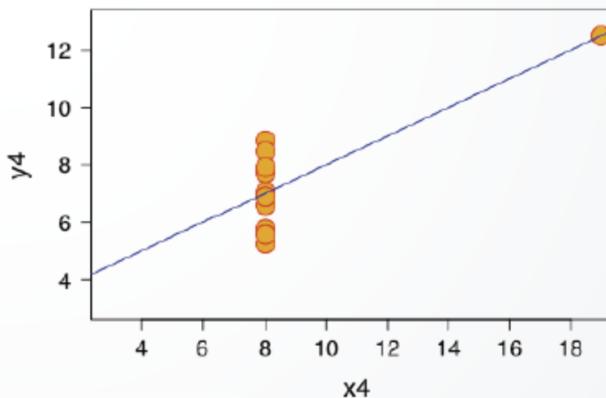
Deviation



Corresponding coefficient



Linear regression



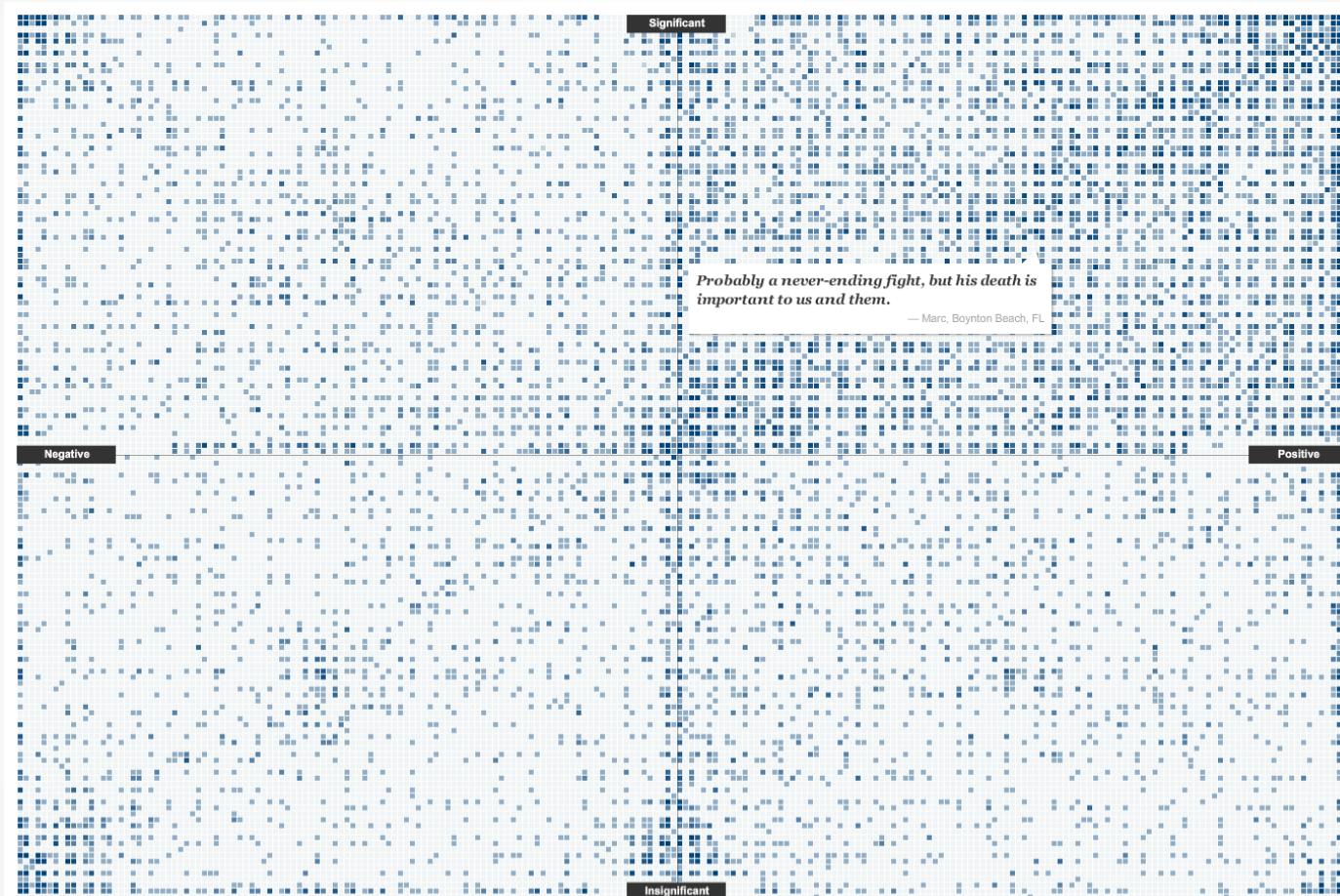
THE DEATH OF OSAMA BIN LADEN

Significant

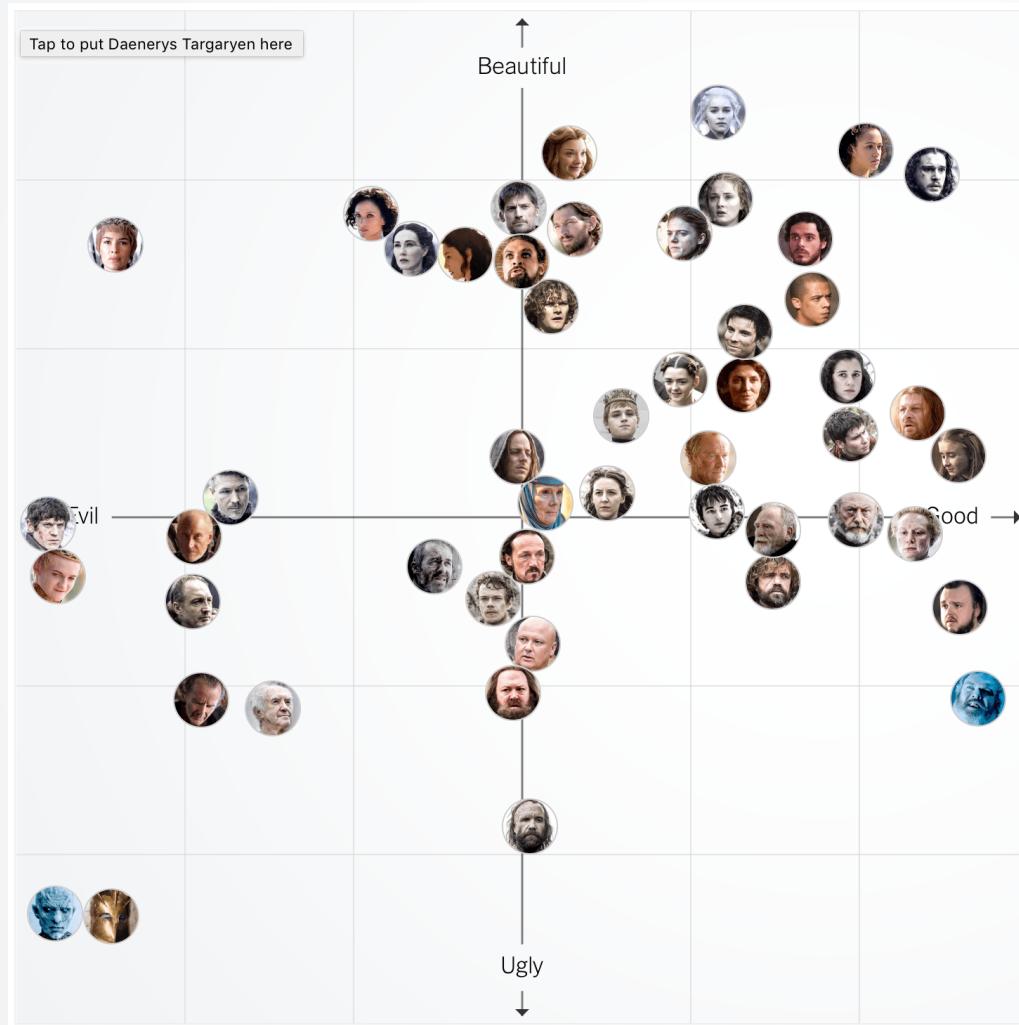
Negative

Positive

Insignificant

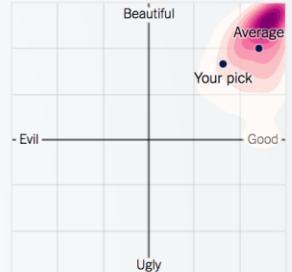


Game of Thrones character chart, you decide



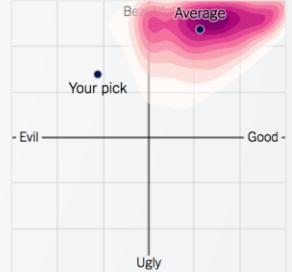
Jon Snow

The hero of the tale — so far. He's been the picture of fair and just and strong, though perhaps a little brooding at times.



Daenerys Targaryen

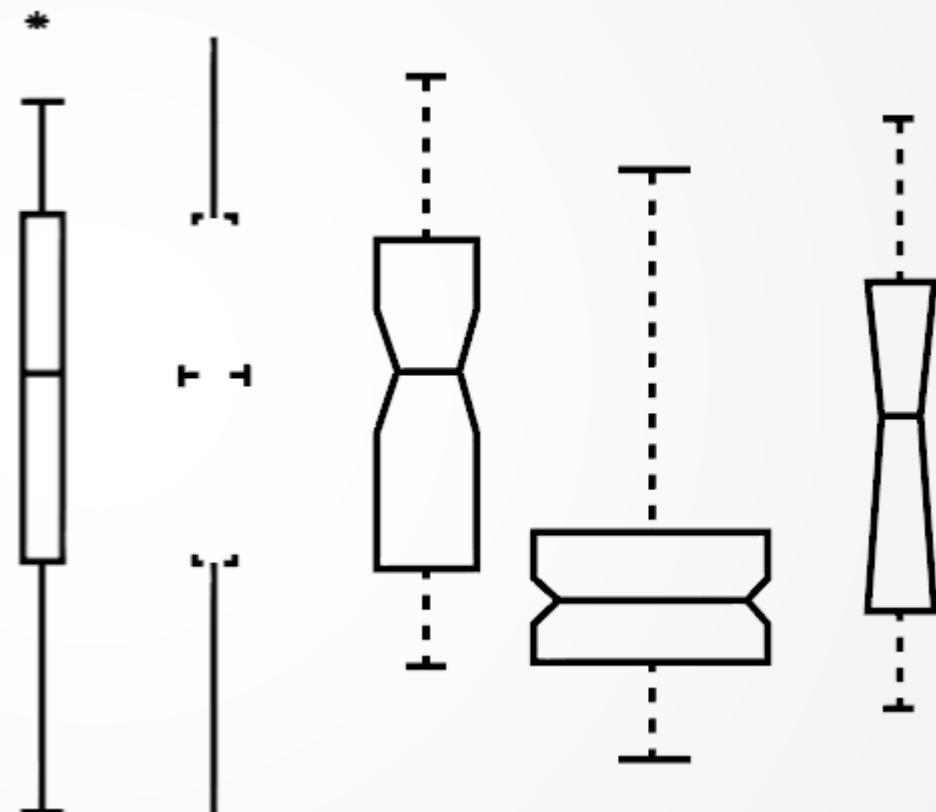
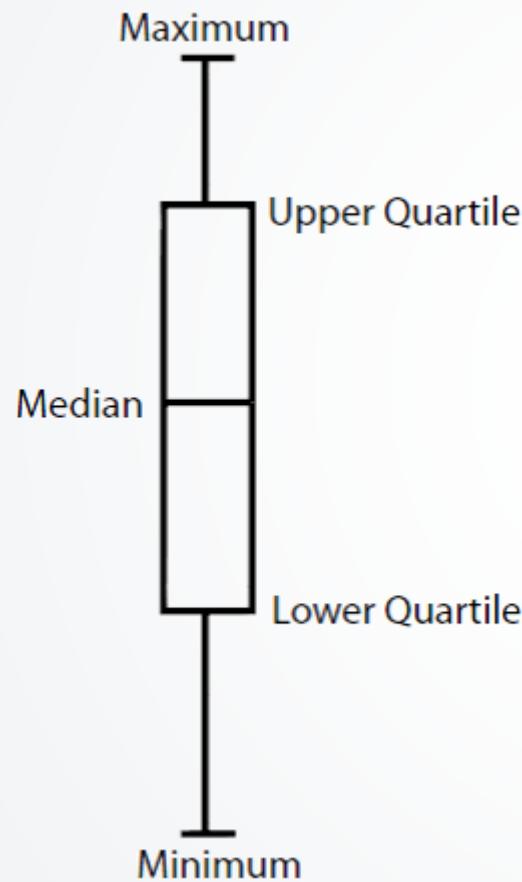
A stunning beauty who feels for the oppressed. But she has no problem sending people to their deaths as she conquers kingdoms.



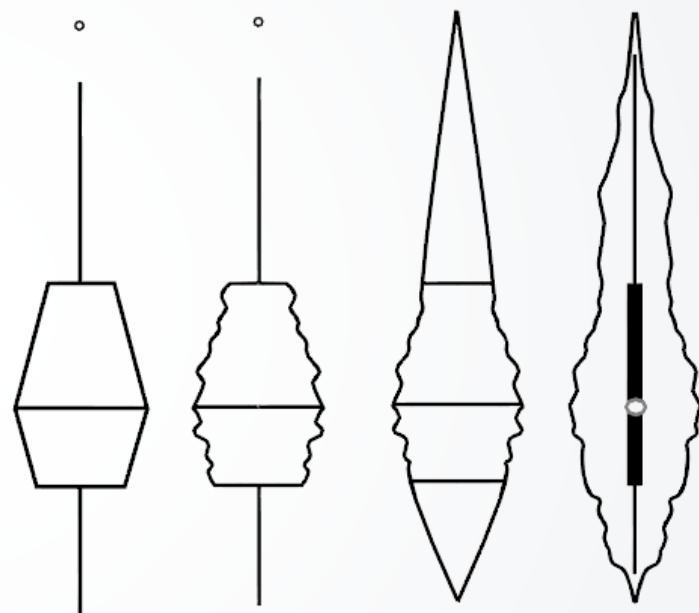
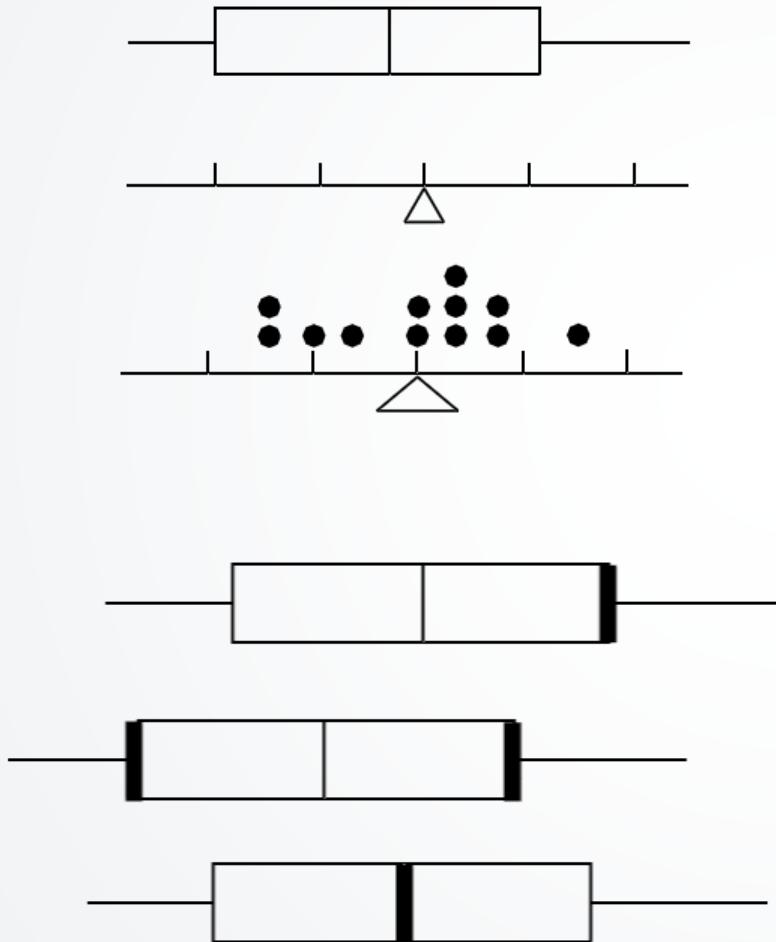
OUTLINE

- Transformation
 - Normalization
 - Smoothness
 - Sampling
 - Binning/Discretization
 - Dimensionality Reduction*
 - Clustering
- Statistical Charts
 - Line chart
 - Sparkline
 - Bar chart
 - Stacked bar chart
 - Pie chart
 - Scatter plot
 - Box plot
 - Scale
 - Tools

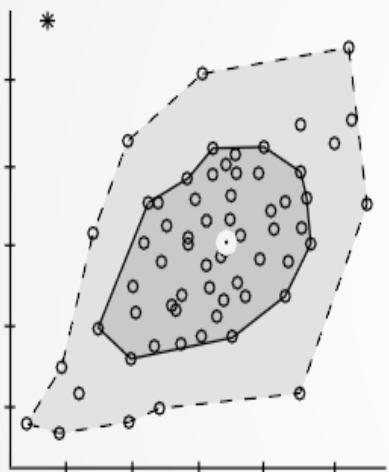
Box Plot



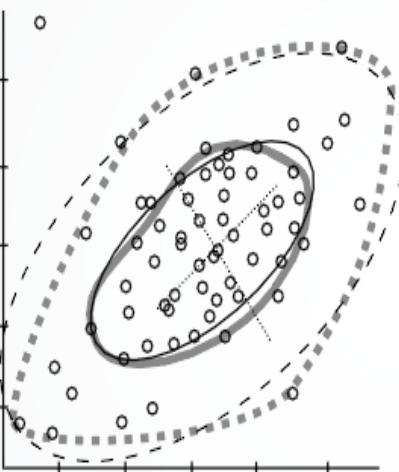
Box Plot Variations



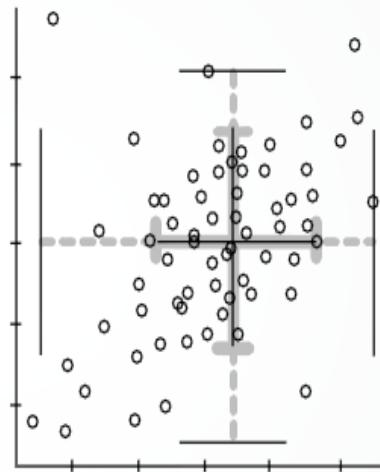
Box Plot Variations



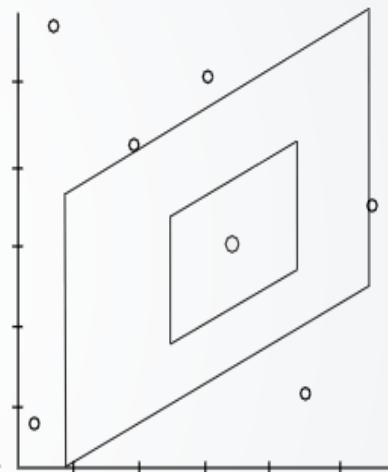
2D Box Plot



Relplot



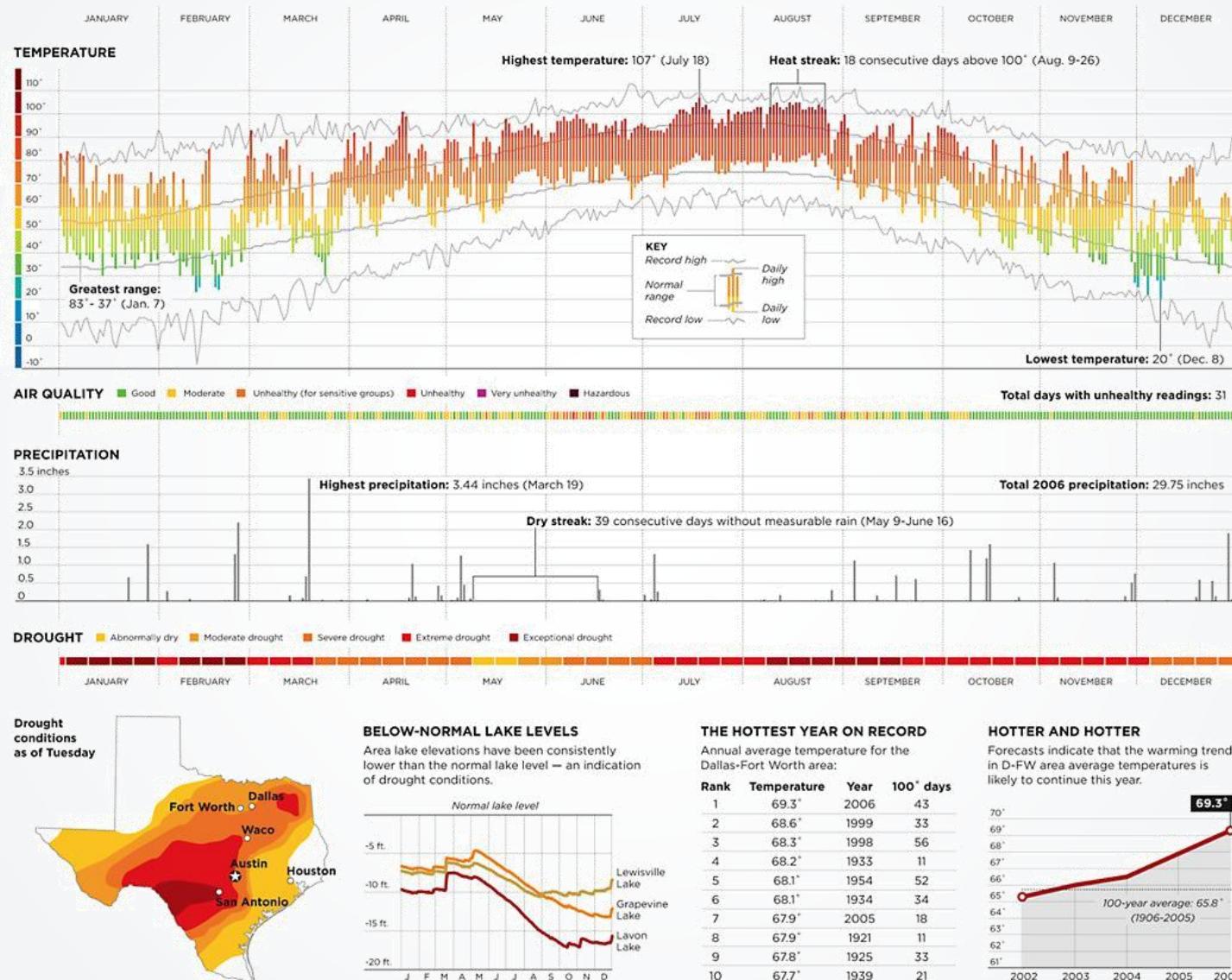
Rangefinder Box Plot



Bag Plot

2006: The warmest year on record in the D-FW area

Drought persists as the annual average temperature increased for the fifth consecutive year with 43 days at 100° or above



NOTES: Monthly temperatures for the D-FW area are recorded from different locations but are considered continuous. Air quality readings are daily summations for the D-FW area. Trace amounts of precipitation are marked as zero inches. Drought readings are weekly.

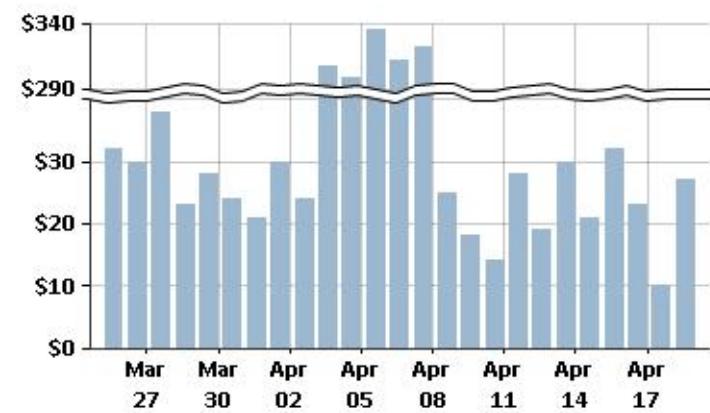
SOURCES: National Weather Service in Fort Worth; Texas Commission on Environmental Quality; U.S. Drought Monitor; U.S. Army Corps of Engineers-Fort Worth District; Dallas Morning News research

TROY OXFORD, TOM SETZER/Staff Artists. E-mail: Graphics@dallasnews.com

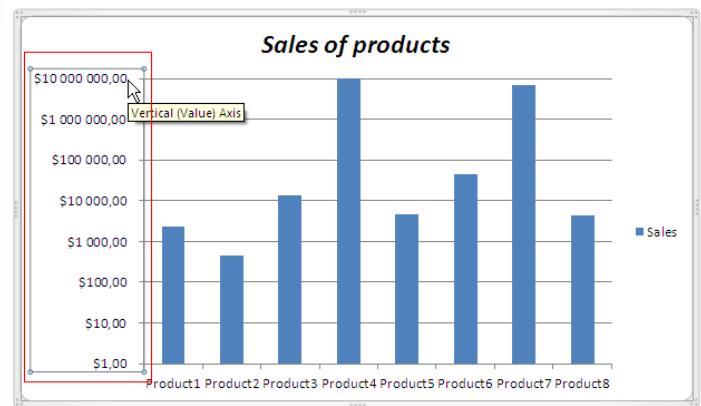
OUTLINE

- Transformation
 - Normalization
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 - Sparkline
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Scale Break and Log Scale



Scale Break

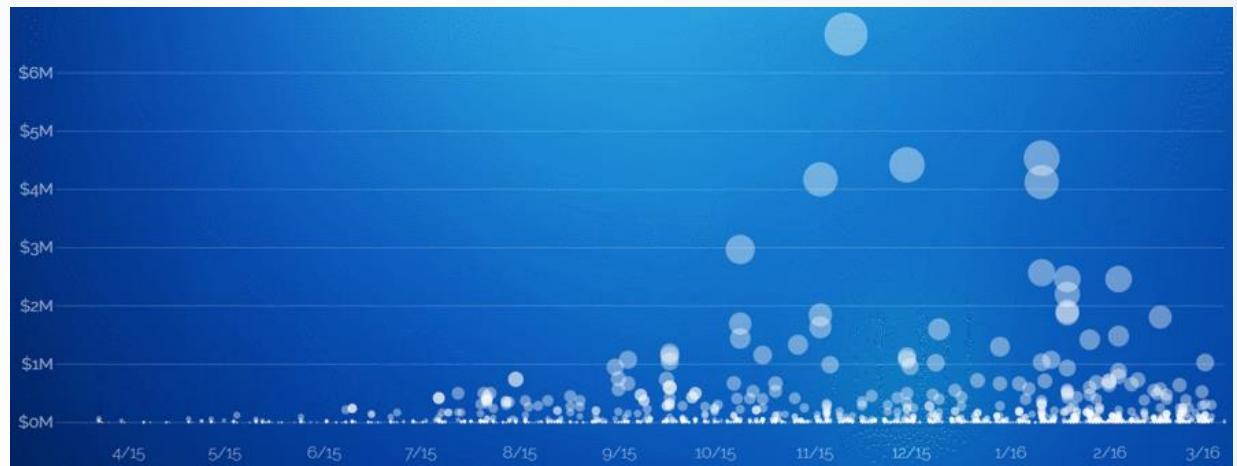


Logarithmic transformation
 $y=\log_{10}(x)$

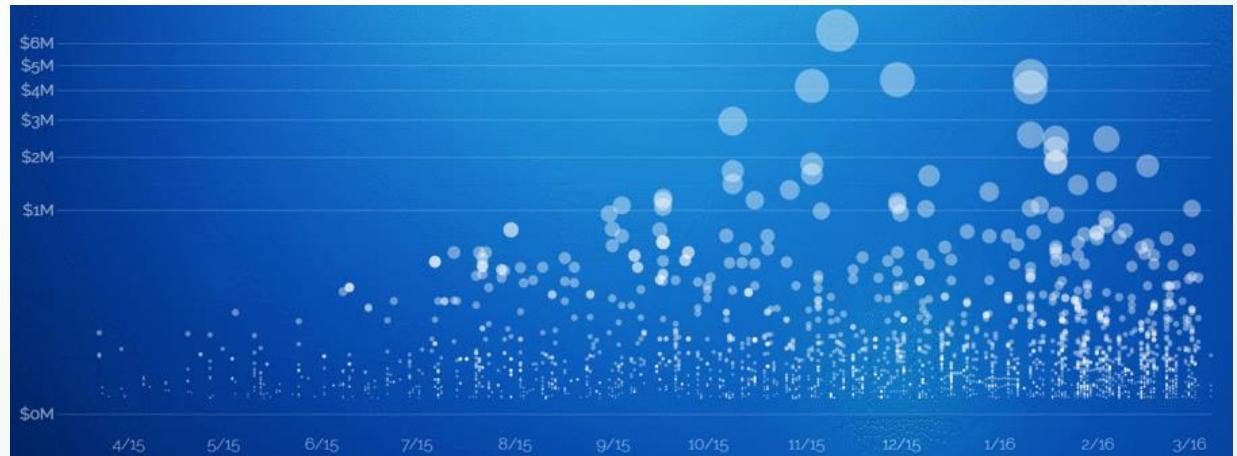
Both improve visual resolution
But it is hard to compare all the data in scale break

Linear Scale and Log Scale

Linear Scale



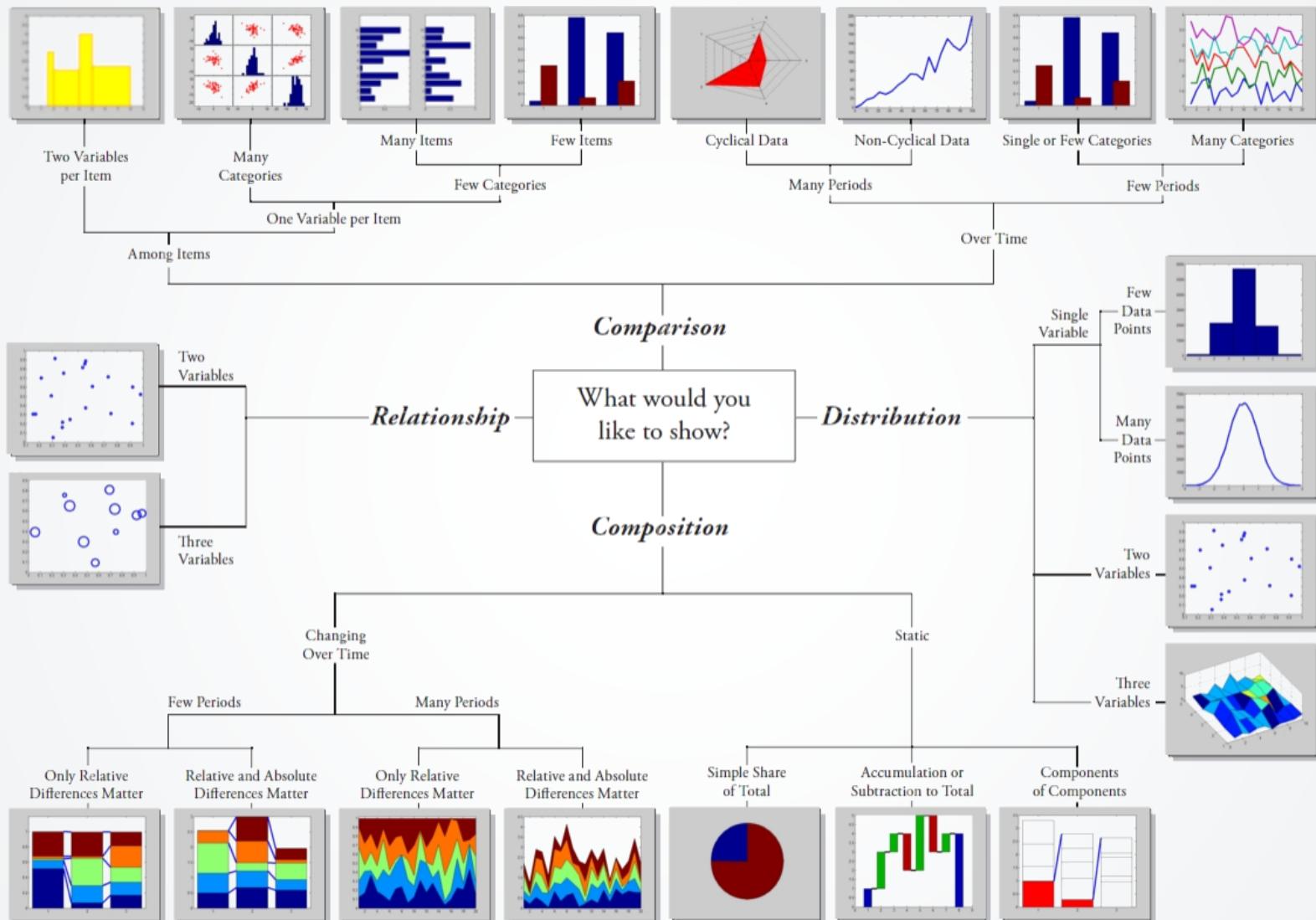
Log Scale



Variable Scale



Chart Suggestions—A Thought-Starter



Modified with permission - Doug Hull
blogs.mathworks.com/videos
hull@mathworks.com 2009

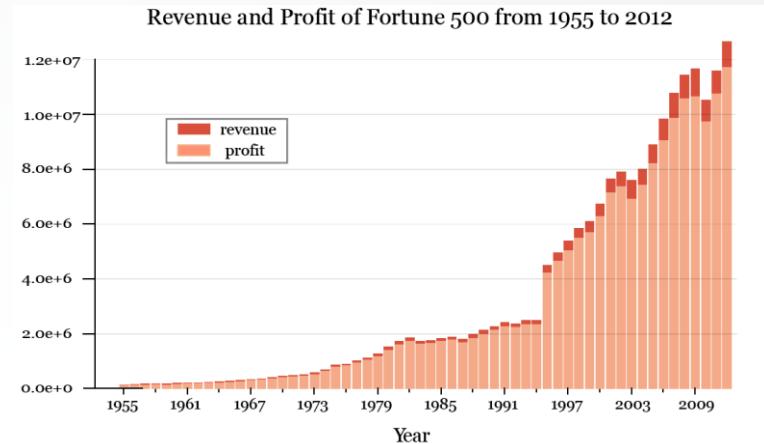
www.ExtremePresentation.com
 © 2009 A. Abela — a.v.abela@gmail.com

OUTLINE

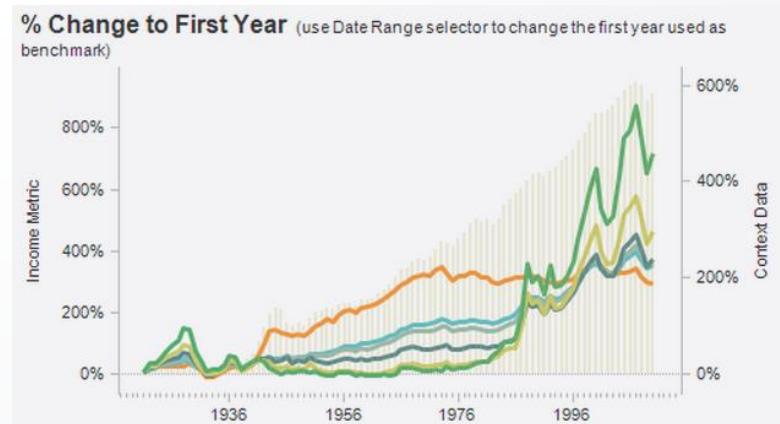
- Transformation
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- Statistical Charts
 - Line chart
 - Sparkline
 - Bar chart
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 - Scatter plot
 - Box plot
 - Scale
 - Tools

Tools

- Tableau
- D3js
- Echarts
- Google Refine
- Google Charts
- R

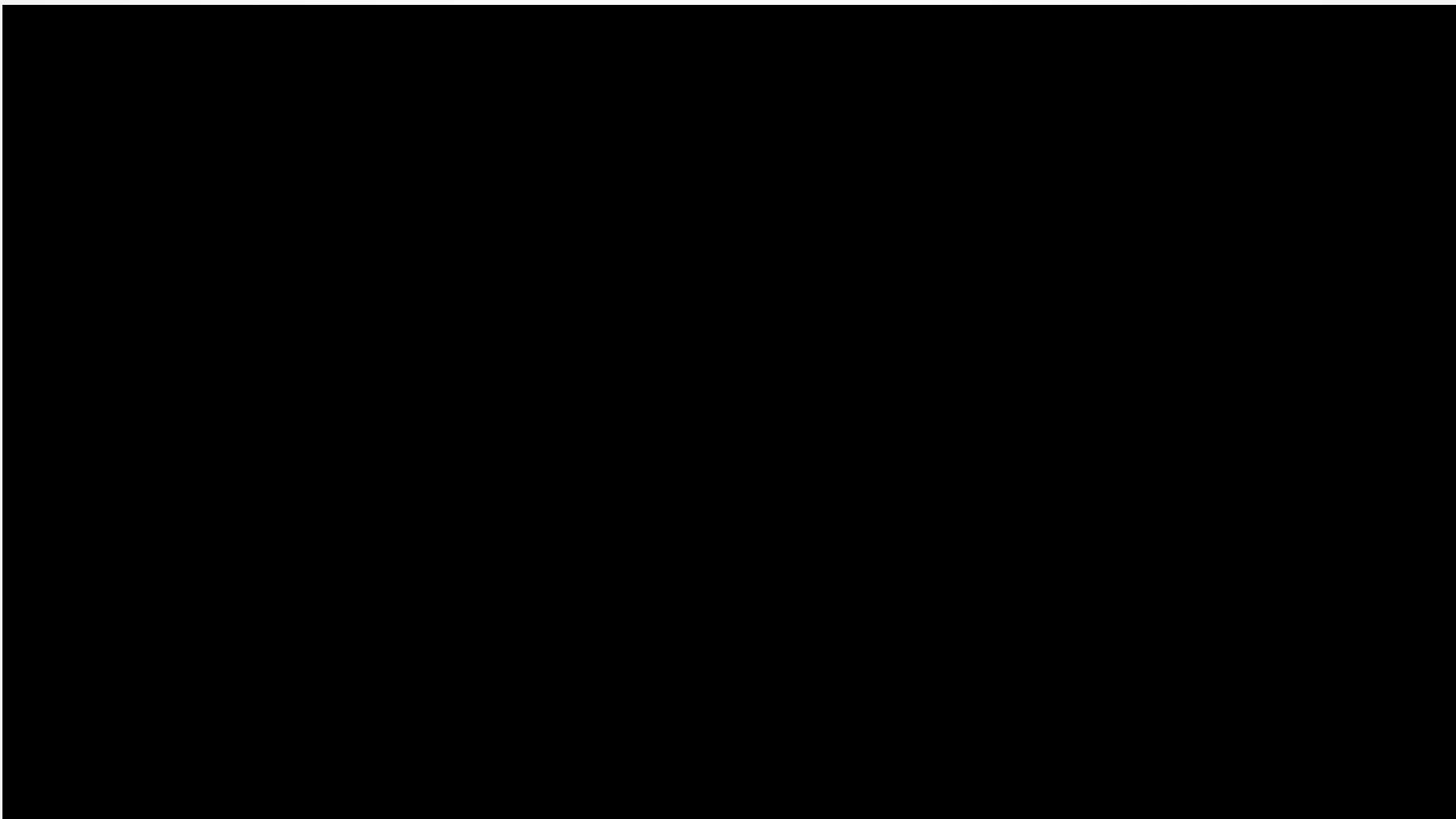


www.r-project.org/



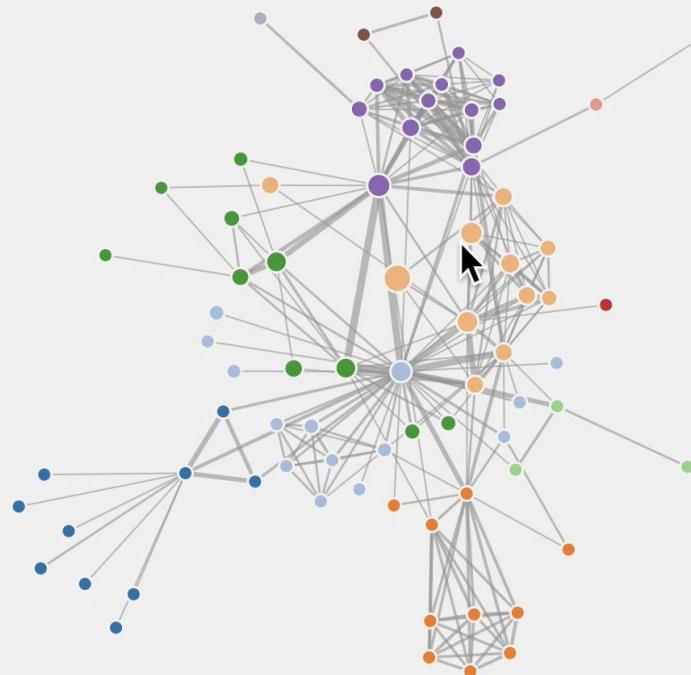
<http://www.tableausoftware.com>

Tableau Visualization



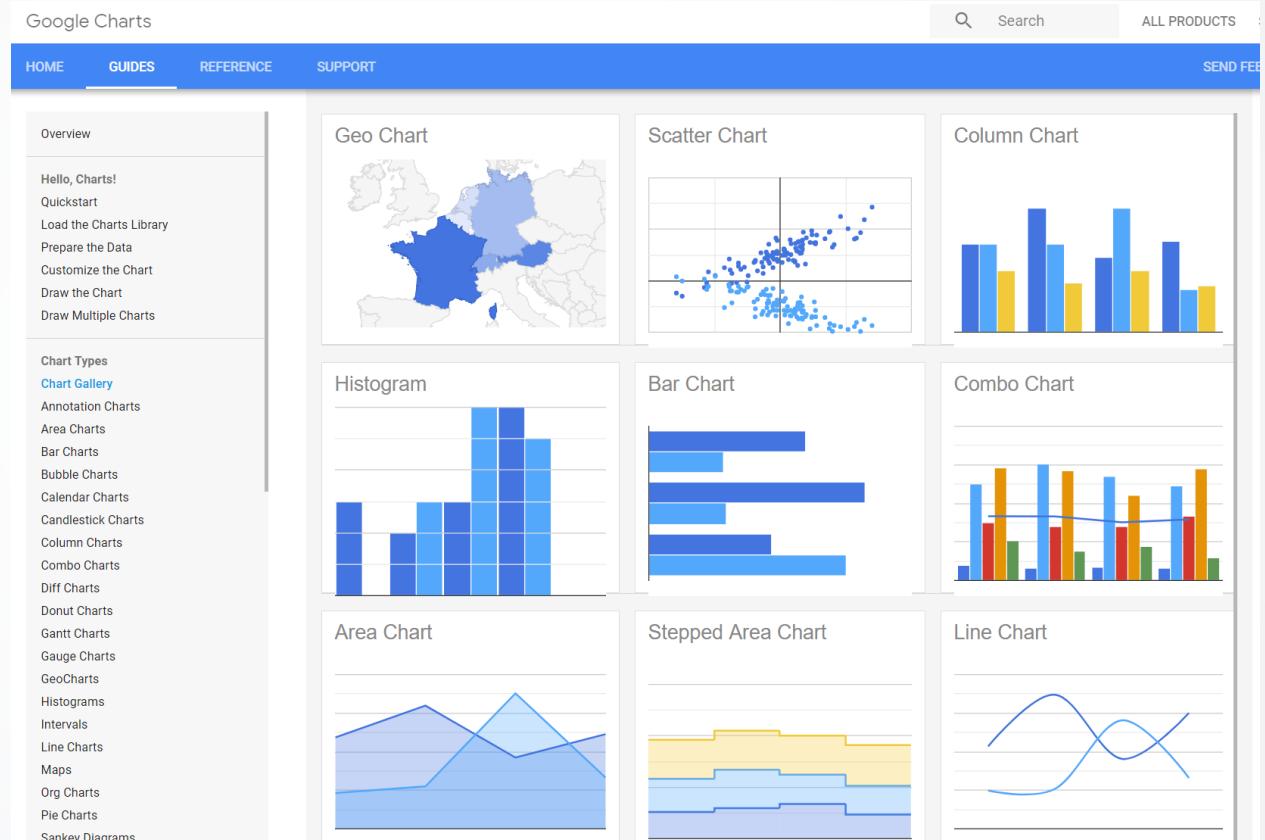
Example of D3 Visualization

Fisheye Distortion



The Google Chart Tools

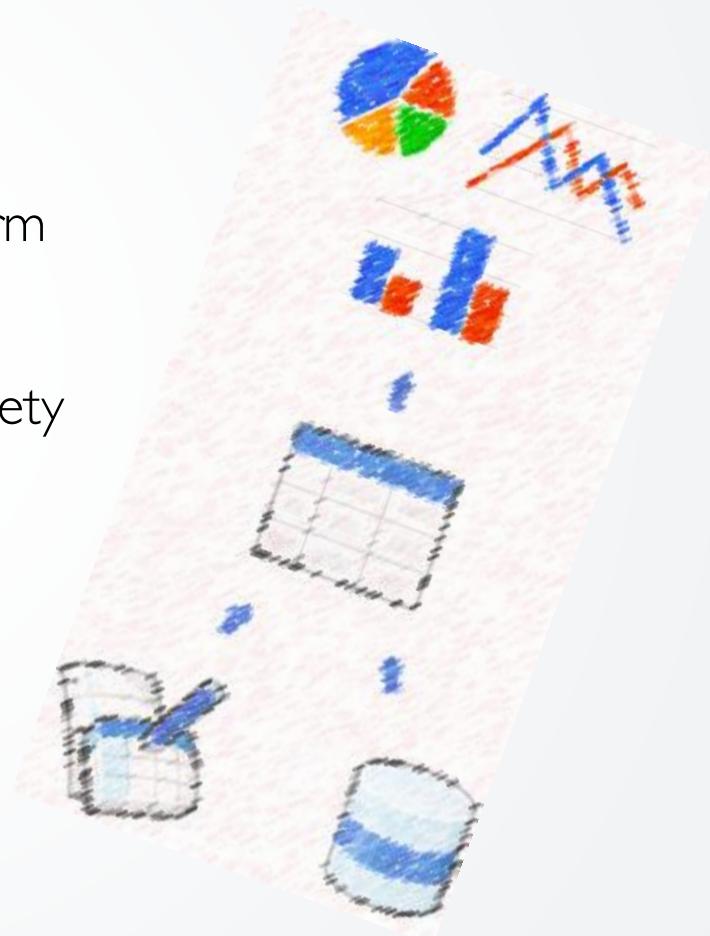
The gallery provides a variety of charts designed to address your data visualization needs. These charts are [based on pure HTML5/SVG technology](#) (adopting VML for old IE versions), so no plugins are required. All of them are interactive, and many are pannable and zoomable. Adding these charts to your page can be done in [a few simple steps.](#)



<https://google-developers.appspot.com/chart/>

Google Charts Features

- Rich and custom charts
- Free and compatibility guaranteed
- Cross-browser compatibility and cross-platform portability, even to IOS and Android
- Connect to your data in real time using a variety of data connection tools and protocols.



Tutorial—Hello Charts !

- Loading the Libraries
 - The Google JSAPI API, The Google Visualization library, The library for the chart itself.
- Preparing your data in DataTable
 - A DataTable is a two-dimensional table with rows and columns (datatype, ID, label)
- Customizing the Chart
 - title, colors, size, line thickness, background fill
- Drawing the Chart—draw()
- Adding Interactivity
 - ready ,select, error , onmouseover and onmouseout

Google Chart Examples

Google Charts

Display live data on your site

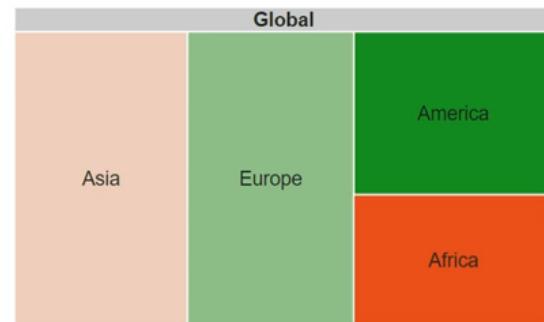
About Google chart tools

Google chart tools are powerful, simple to use, and free. Try out our rich gallery of interactive charts and data tools.

[GET STARTED](#)

[CHART GALLERY](#)

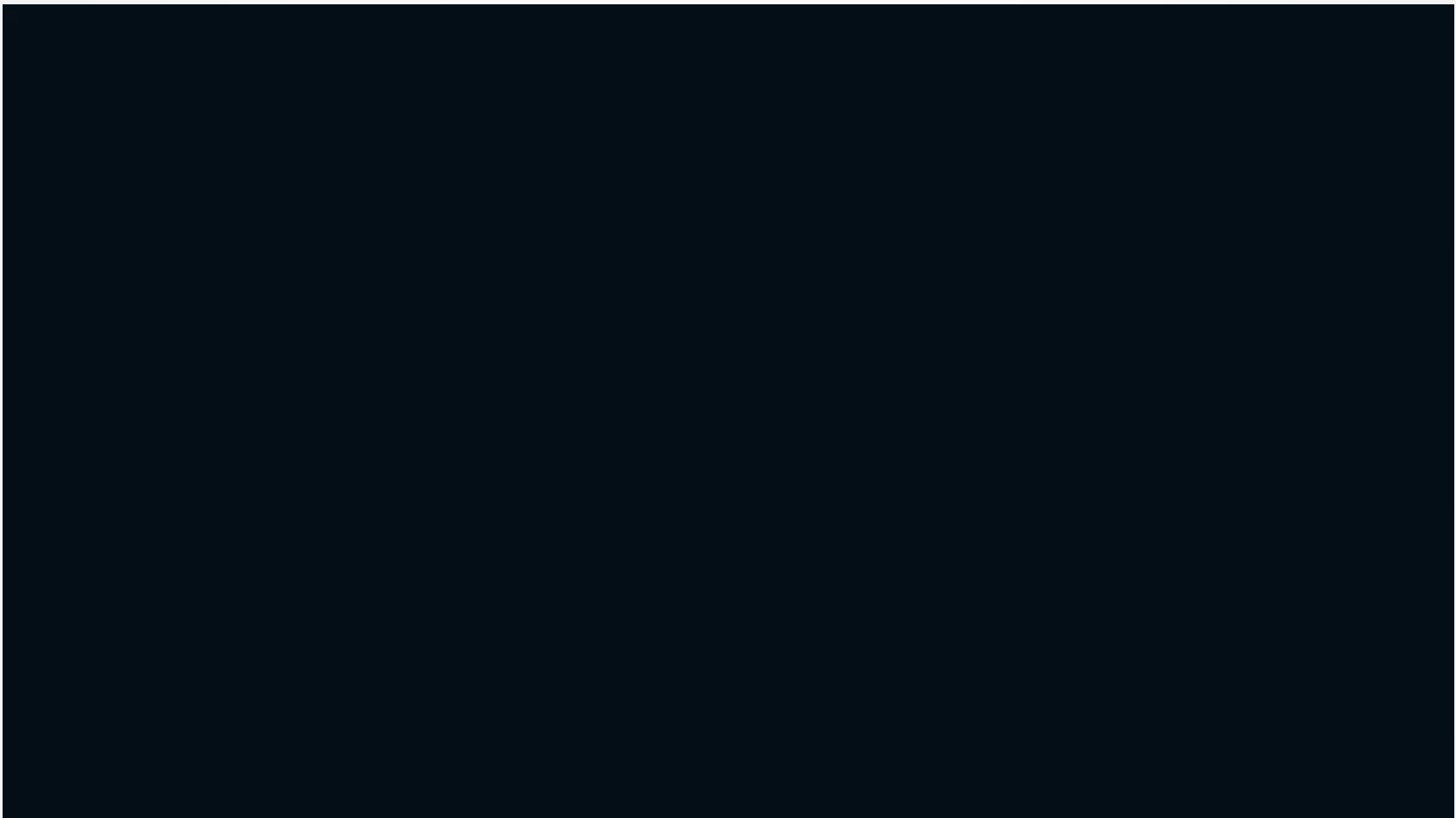
Tree Map - [view source](#)



GOOGLE CHART

Examples 2017

ECharts



ECharts

16:54:21 图表已生成, 62ms

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130        color: '#fff',
131        fontSize: 14
132      },
133      selectedMode: 'single'
134    },
135    // visualMap: {
136    //   show: true,
137    //   max: 20,
138    //   dimension: 6,
139    //   inRange: {
140    //     colorLightness: [0.5, 0.8]
141    //   }
142    // },
143    radar: {
144      indicator: [
145        {name: 'AQI', max: 300},
146        {name: 'PM2.5', max: 250},
147        {name: 'PM10', max: 300},
148        {name: 'CO', max: 5},
149        {name: 'NO2', max: 200},
150        {name: 'SO2', max: 100}
151      ],
152      shape: 'circle',
153      splitNumber: 5,
154      name: {
155        textStyle: {
156          color: 'rgb(238, 197, 102)'
157        }
158      },
159      splitLine: {
160        color: [
161          'rgba(238, 197, 102, 0.1)', 'rgba(238, 197, 102, 0.2)',
162          'rgba(238, 197, 102, 0.4)', 'rgba(238, 197, 102, 0.6)',
163          'rgba(238, 197, 102, 0.8)', 'rgba(238, 197, 102, 1)'
164        ].reverse()
165      },
166      splitArea: {
167        show: false
168      },
169      exline: {
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171          color: 'rgba(238, 197, 102, 0.5)'
172        }
173      }
174    },
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176      {
177        name: '北京',
178        type: 'radar',
179        lineStyle: lineStyle,
180        data: dataB,
181        symbol: 'none',
182        itemStyle: {
183          normal: {
184            color: '#F9713C'
185          }
186        },
187        areaStyle: {
188          normal: {
189            opacity: 0.1
190          }
191        }
192      },
193      {
194        name: '上海',
195        type: 'radar',
196        lineStyle: lineStyle,
197        data: dataS,
198        symbol: 'none',
199        itemStyle: {
200          normal: {
201            color: '#3CB371'
202          }
203        },
204        areaStyle: {
205          normal: {
206            opacity: 0.1
207          }
208        }
209      },
210      {
211        name: '广州',
212        type: 'radar',
213        lineStyle: lineStyle,
214        data: dataG,
215        symbol: 'none',
216        itemStyle: {
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219          }
220        },
221        areaStyle: {
222          normal: {
223            opacity: 0.1
224          }
225        }
226      }
227    ]
228  }
229}
```

AQI - 雷达图

The chart displays the Air Quality Index (AQI) for three Chinese cities: Beijing, Shanghai, and Guangzhou. The radar chart has six axes representing different pollutants: AQI, PM2.5, PM10, CO, NO2, and SO2. The data shows that Beijing has the highest overall AQI, followed by Shanghai and then Guangzhou.

City	AQI	PM2.5	PM10	CO	NO2	SO2
北京	300	250	300	5	200	100
上海	280	230	280	4	180	90
广州	250	220	250	3	160	80

<http://echarts.baidu.com/demo.html#radar-aqi>

Suggest Readings

- 漫谈Clustering by pluskid
 - http://blog.pluskid.org/?page_id=78
- Google Charts
 - <https://google-developers.appspot.com/chart/>
- Echarts
 - <http://echarts.baidu.com/index.html>



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International Summer School on Visual Analytics

Thank You!

