Using Space Effectively

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CS 448B: Visualization
Winter 2020

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Last Time: EDA

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Data “Wrangling”

One often needs to manipulate data prior to analysis. Tasks include reformatting, cleaning, quality assessment, and integration

Some approaches:

- Writing custom scripts
- Manual manipulation in spreadsheets
- Trifacta Wrangler: http://trifacta.com/products/wrangler/
- Open Refine: http://openrefine.org

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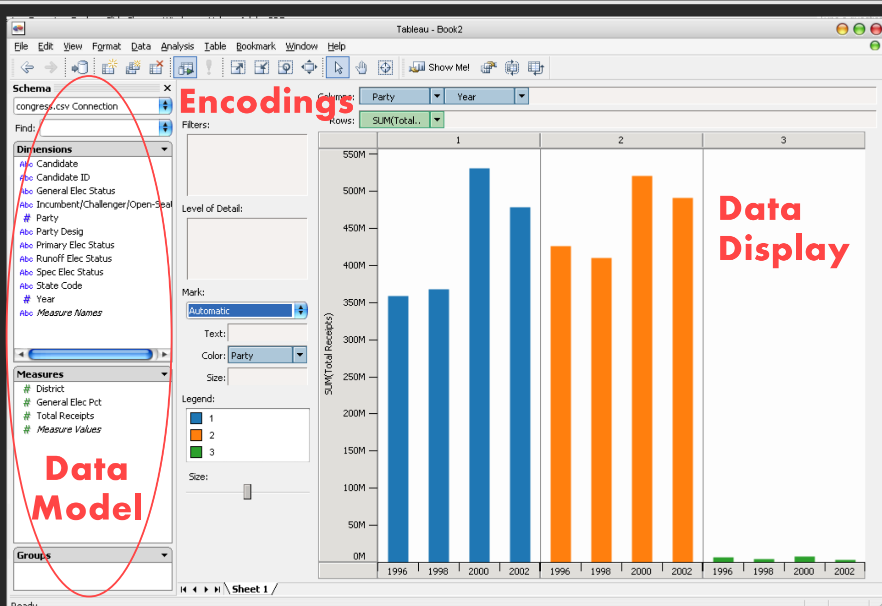
Tableau



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Specifying Table Configurations

Operands are names of database fields

Each operand interpreted as a set {…}

Data is either O or Q and treated differently

Three operators:

- concatenation (+)
- cross product (x)
- nest (/)

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Table Algebra

The operators (+,x,/) and operands (O,Q) provide an algebra for tabular visualization

Algebraic statements are mapped to

- **Visualizations** – trellis partitions, visual encodings
- **Queries** – selection, projection, group-by

In Tableau, users make statements via drag-and-drop

- Users specify operands NOT operators!
- Operators are inferred by data type (O,Q)

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Table Algebra: Operands

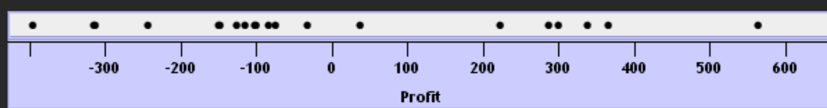
Ordinal fields: interpret domain as a set that partitions table into rows and columns

Quarter = {(Qtr1),(Qtr2),(Qtr3),(Qtr4)} →

Qtr1	Qtr2	Qtr3	Qtr4
95892	101760	105282	98225

Quantitative fields: treat domain as single element set and encode spatially as axes

Profit = {(Profit[-410,650])} →



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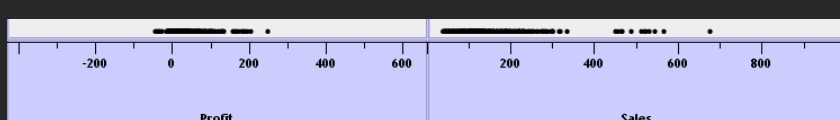
Concatenation (+) Operator

Ordered union of set interpretations

Quarter + Product Type
= {(Qtr1),(Qtr2),(Qtr3),(Qtr4)} + {(Coffee), (Espresso)}
= {(Qtr1),(Qtr2),(Qtr3),(Qtr4),(Coffee),(Espresso)}

Qtr1	Qtr2	Qtr3	Qtr4	Coffee	Espresso
48	59	57	53	151	21

Profit + Sales = {(Profit[-310,620]),(Sales[0,1000])}



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Cross (x) Operator

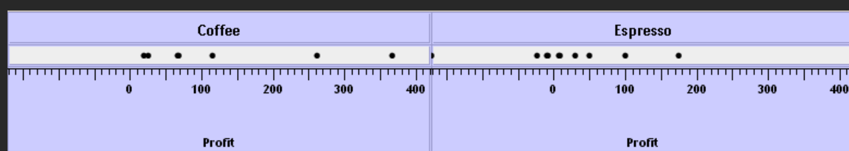
Cross-product of set interpretations

Quarter x Product Type

= {(Qtr1,Coffee), (Qtr1, Tea), (Qtr2, Coffee), (Qtr2, Tea), (Qtr3, Coffee), (Qtr3, Tea), (Qtr4, Coffee), (Qtr4,Tea)}

Qtr1		Qtr2		Qtr3		Qtr4	
Coffee	Espresso	Coffee	Espresso	Coffee	Espresso	Coffee	Espresso
131	19	160	20	178	12	134	33

Product Type x Profit =



Nest (/) Operator

Cross-product filtered by existing records

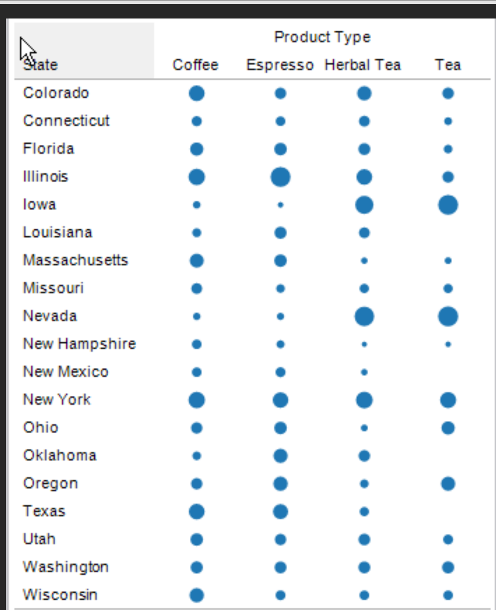
Quarter x Month

creates 12 entries for each qtr. i.e., (Qtr1, Dec)

Quarter / Month

creates three entries per quarter based on tuples in database (not semantics)

Ordinal - Ordinal



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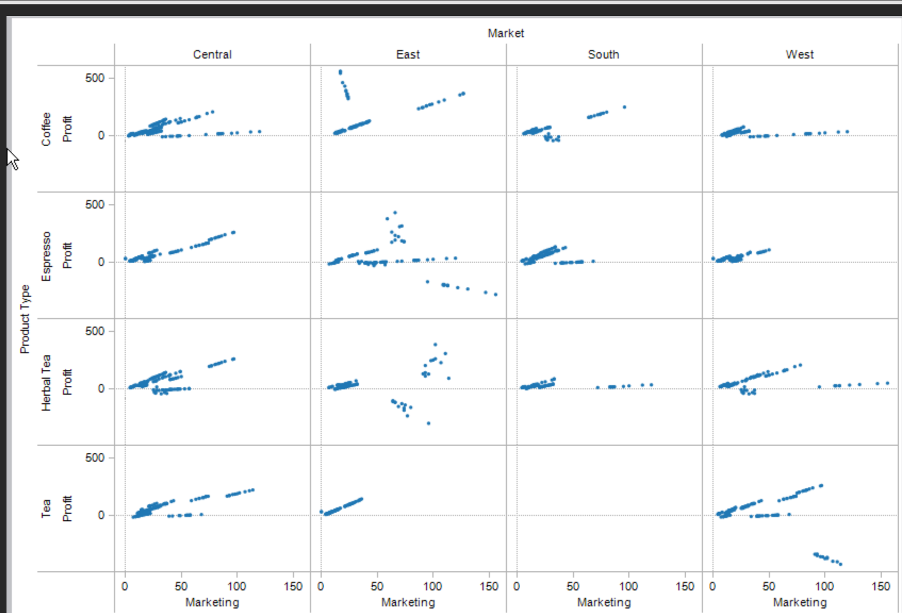
Quantitative - Quantitative



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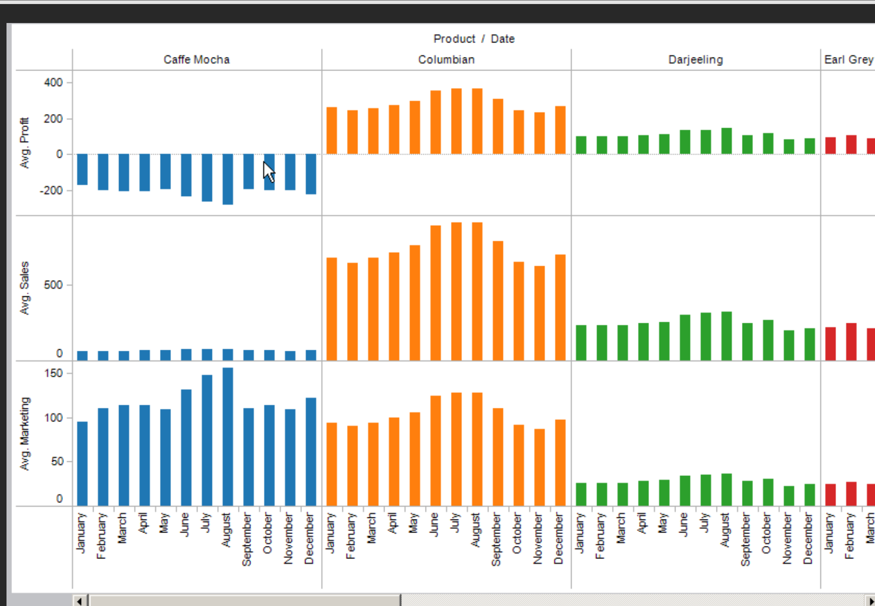
Ordinal - Quantitative



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Summary

Exploratory analysis may combine graphical methods, and statistics

Use questions to uncover more questions

Interaction is essential for exploring large multidimensional datasets

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Announcements

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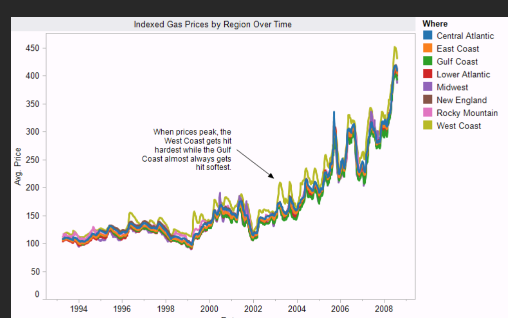
A2: Exploratory Data Analysis

Use Tableau to formulate & answer questions

First steps

Step 1: Pick domain & data
Step 2: Pose questions
Step 3: Profile data
Iterate as needed



Create visualizations

Interact with data
Refine questions

Author a report

Screenshots of most insightful views (10+)
Include titles and captions for each view

Due before class on Jan 27, 2020

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Using Space Effectively

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Topics

Graphs and lines
Selecting aspect ratio
Fitting data and depicting residuals
Graphical calculations
Cartographic distortion

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Graphs and Lines

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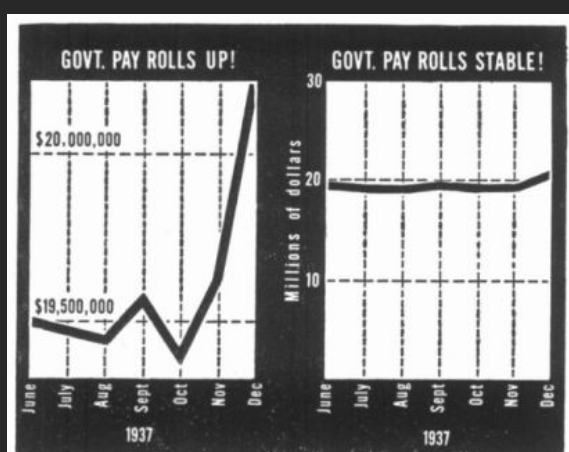
Effective use of space

Which graph is better?



Government payrolls in 1937 [Huff 93]

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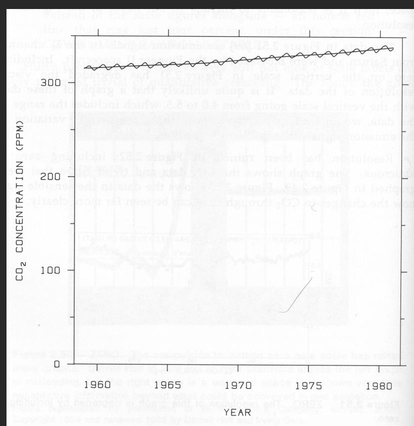
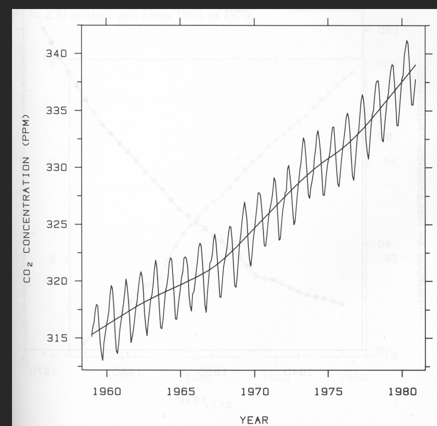
Aspect ratio

Fill space with data

Don't worry about showing zero





Yearly CO2 concentrations [Cleveland 85]

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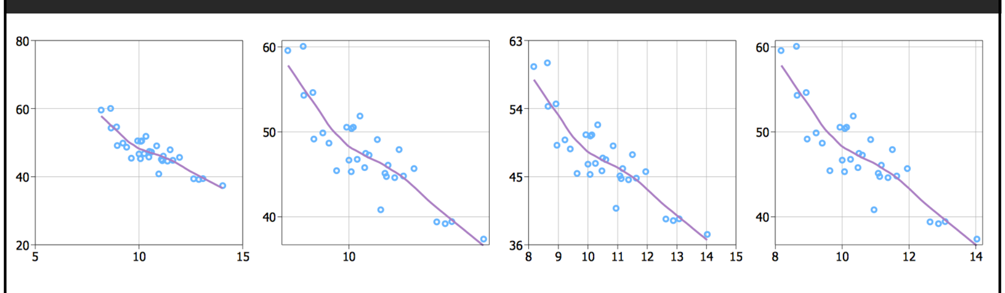
Axis Tick Mark Selection



What are some properties of "good" tick marks?

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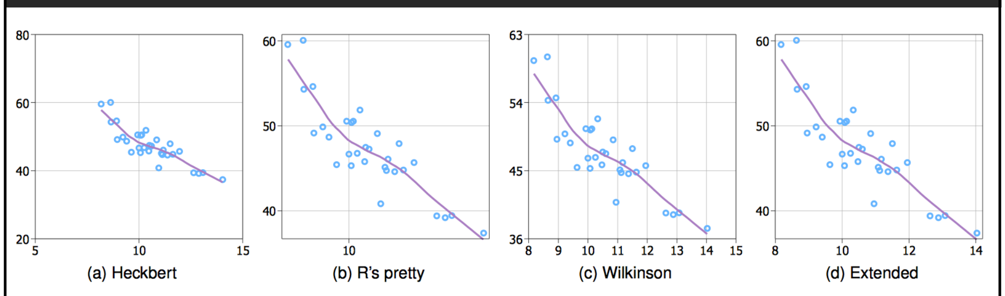
Axis Tick Mark Selection



Simplicity - numbers are multiples of 10, 5, 2

Coverage - ticks near the ends of the data

Density - not too many, nor too few

Legibility - whitespace, horizontal text, size

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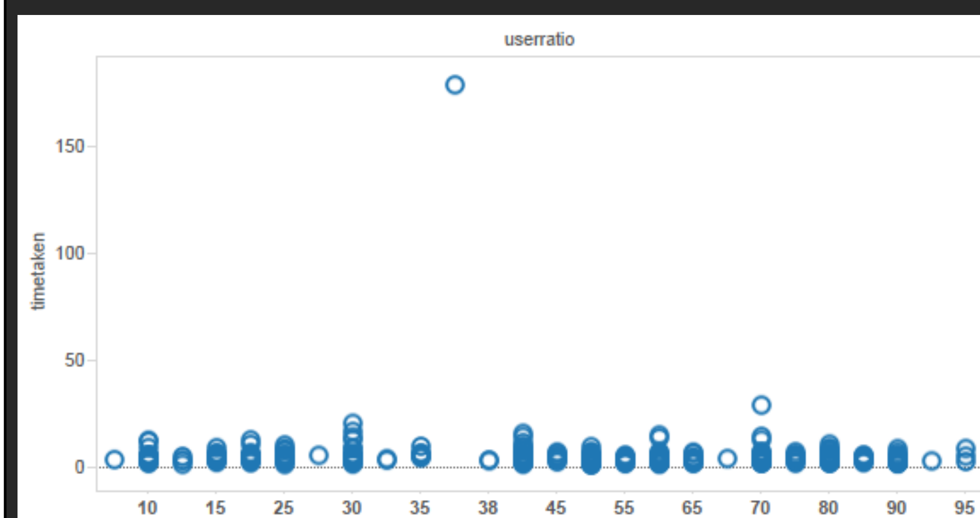
How to Scale the Axis?



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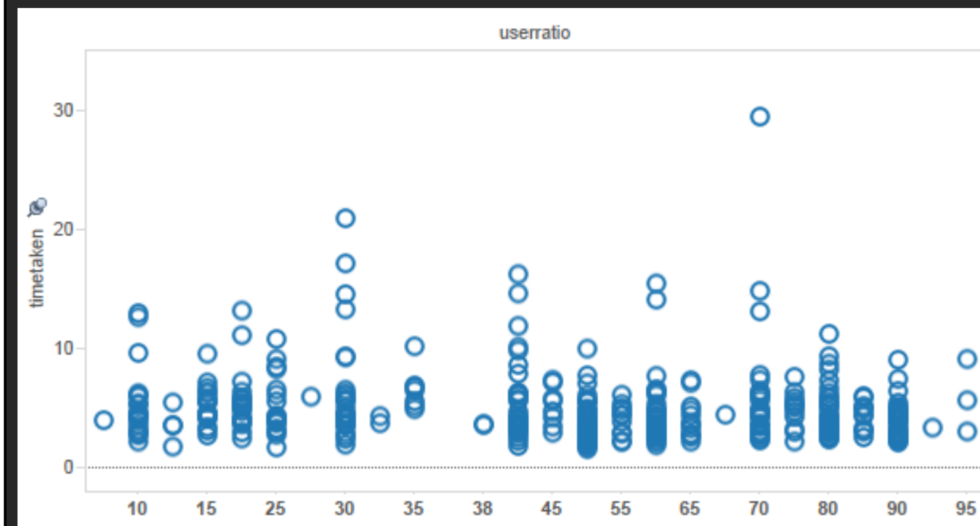
One Option: Clip Outliers



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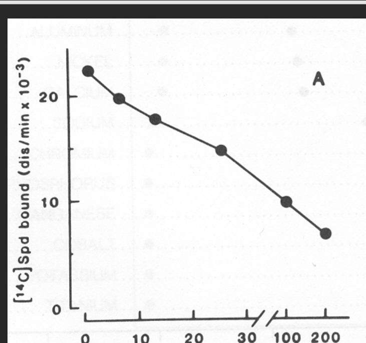
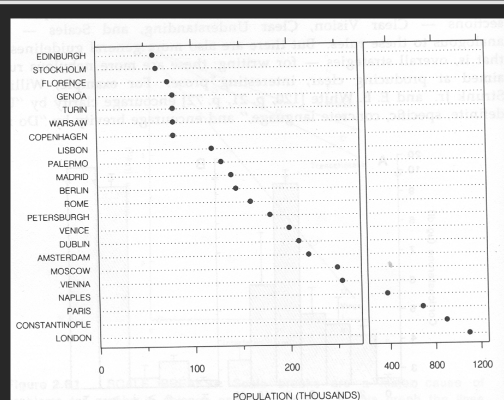
Clearly mark scale breaks



Poor scale break [Cleveland 85]



Well marked scale break [Cleveland 85]

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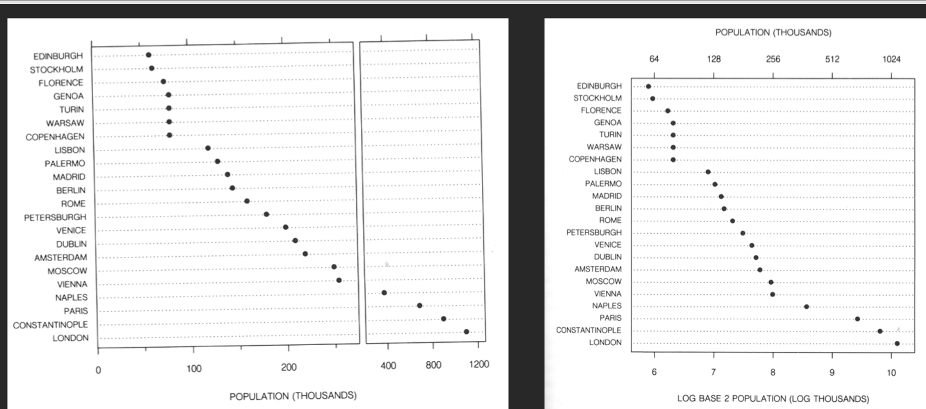
Scale break vs. Log scale



[Cleveland 85]

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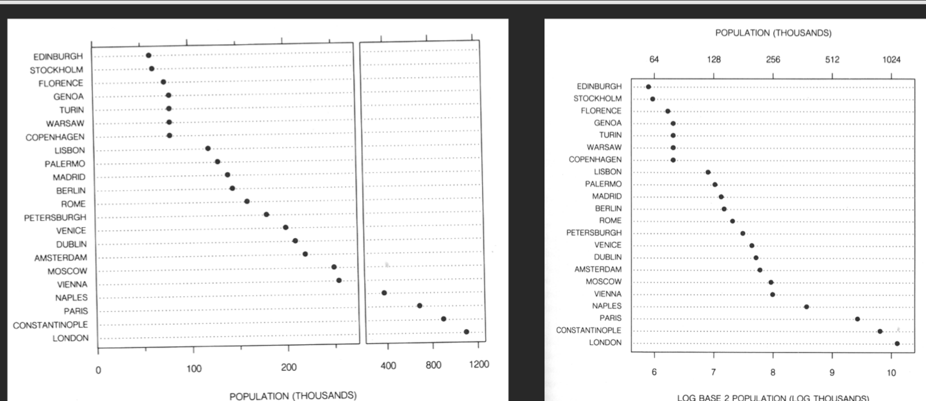
Scale break vs. Log scale



[Cleveland 85]

Both increase visual resolution

- **Log scale - easy comparisons of all data**
- **Scale break – more difficult to compare across break**

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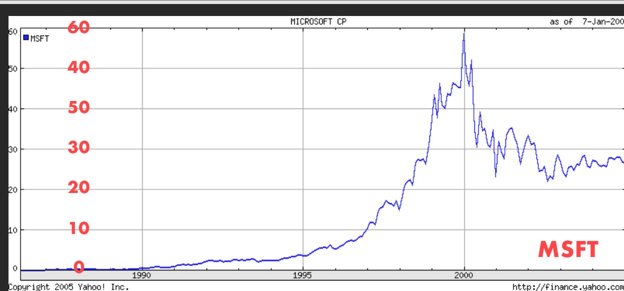
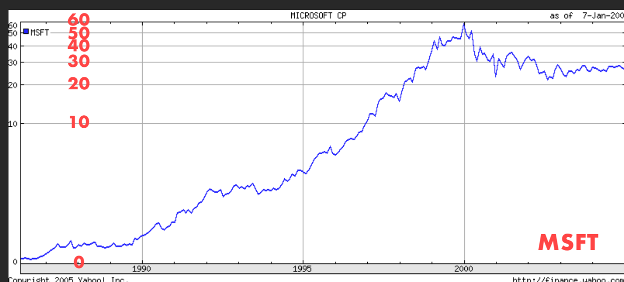
Linear scale vs. Log scale

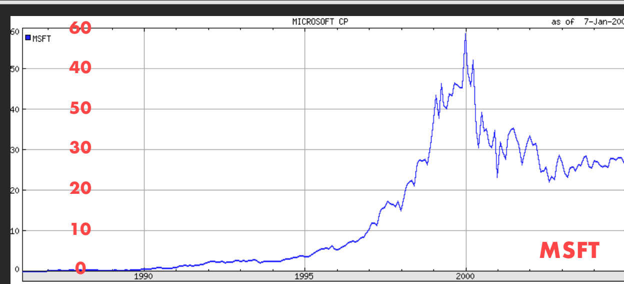




Linear scale vs. Log scale

Linear scale

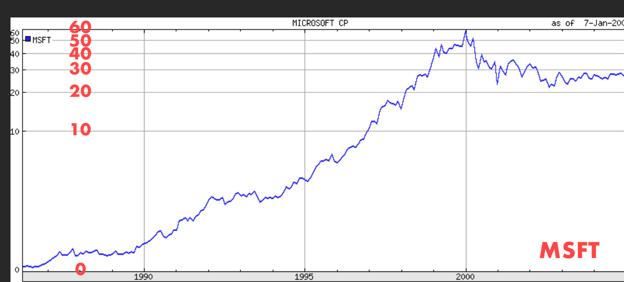
- Absolute change



Log scale

- Small fluctuations
- Percent change

  $d(10,20) = d(30,60)$



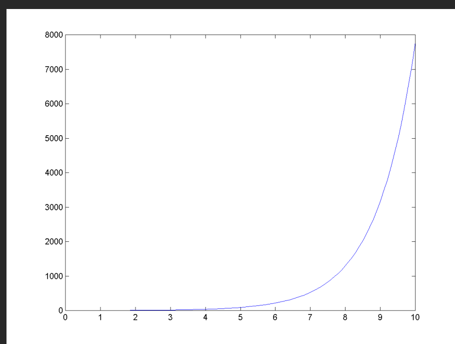
Semilog graph: Exponential growth

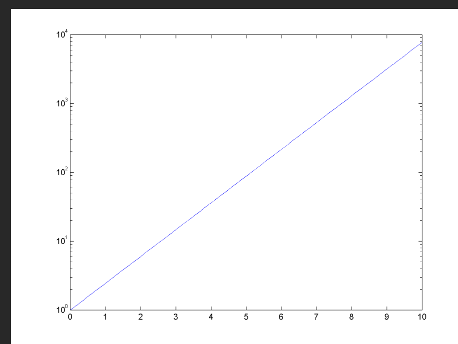
Exponential functions ($y = ka^{mx}$) transform into lines

$\log(y) = \log(k) + \log(a)mx$

Intercept: $\log(k)$

Slope: $\log(a)m$





$y = 6^{0.5x}$, **slope in semilog space:** $\log(6) * 0.5 = 0.3891$

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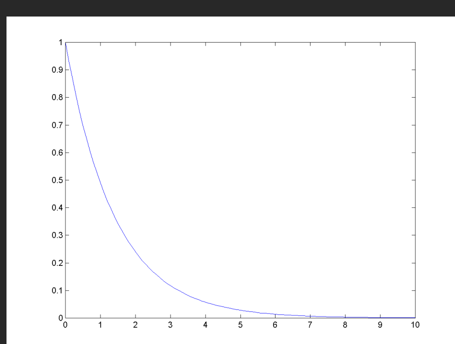
Semilog graph: Exponential decay

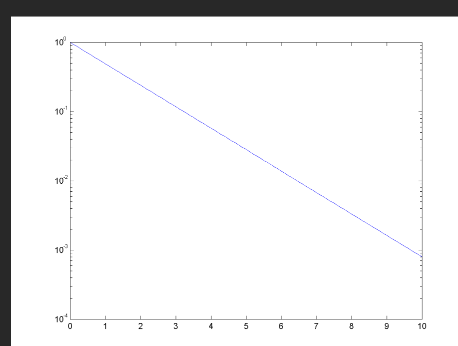
Exponential functions ($y = ka^{mx}$) transform into lines

$\log(y) = \log(k) + \log(a)mx$

Intercept: $\log(k)$

Slope: $\log(a)m$





$y = 0.5^{2x}$, **slope in semilog space:** $\log(0.5) * 2 = -0.602$

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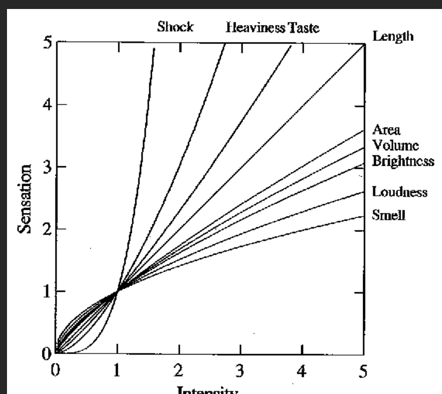
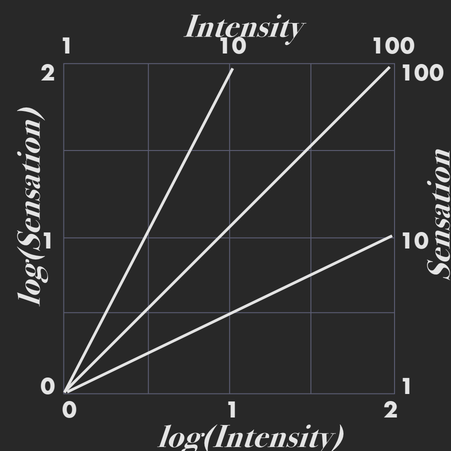
Log-Log graph

Power functions ($y = kx^a$) transform into lines

Example - Steven's power laws:

$$S = kI^p \rightarrow \log S = \log k + p \log I$$





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Selecting Aspect Ratio

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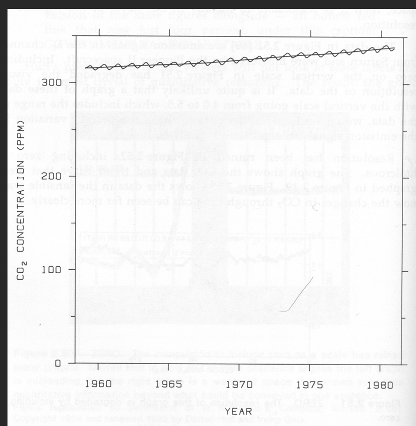
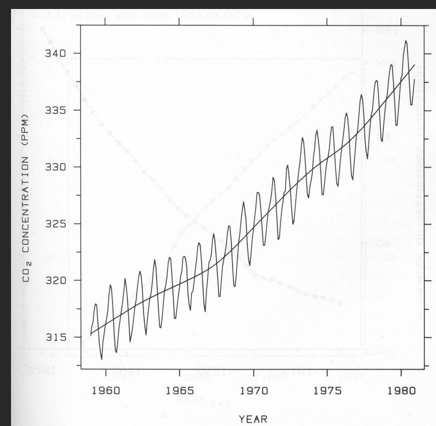
Aspect ratio

Fill space with data
Don't worry about showing zero





Yearly CO2 concentrations [Cleveland 85]

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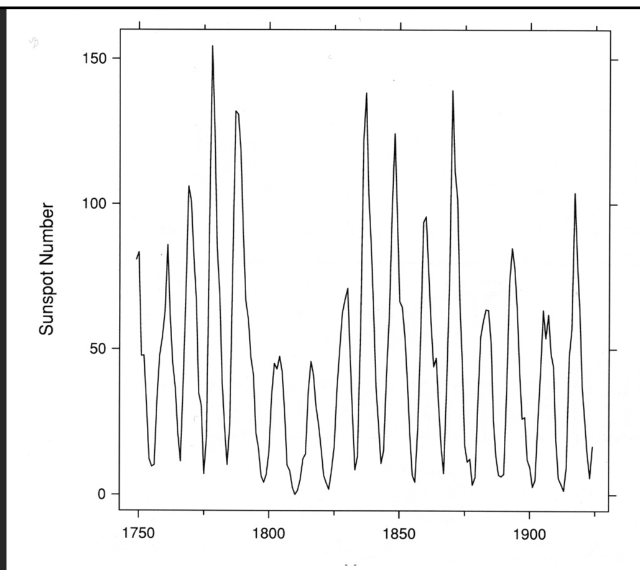

William S. Cleveland
The Elements of Graphing Data

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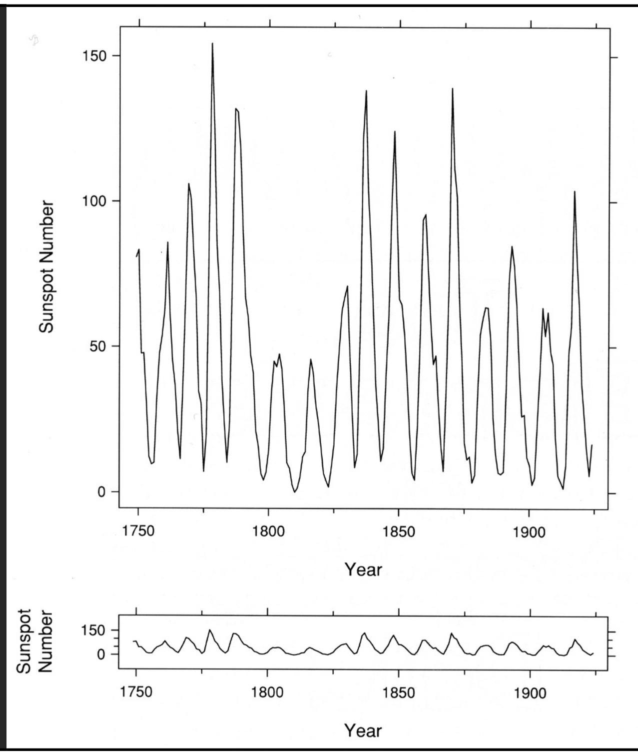

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The Elements of Graphing Data

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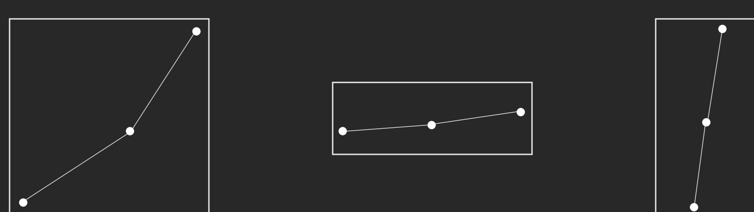
Banking to 45° [Cleveland]

To facilitate perception of trends, maximize the discriminability of line segment orientations



Two line segments are maximally discriminable when avg. absolute angle between them is 45°

Optimize the *aspect ratio* to bank to 45°

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Aspect-ratio banking techniques

Median-Absolute-Slope

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

Average-Absolute-Slope

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

Has Closed Form Solution

Average-Absolute-Orientation

Unweighted

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

Weighted

$$\frac{\sum_i |\theta_i(\alpha)|\, l_i(\alpha)}{\sum_i l_i(\alpha)} = 45°$$

Max-Orientation-Resolution

Global (over all i, j s.t. i≠j)

$$\sum_i \sum_j |\theta_i(\alpha) - \theta_j(\alpha)|^2$$

Local (over adjacent segments)

$$\sum_i |\theta_i(\alpha) - \theta_{i+1}(\alpha)|^2$$

Requires Iterative Optimization

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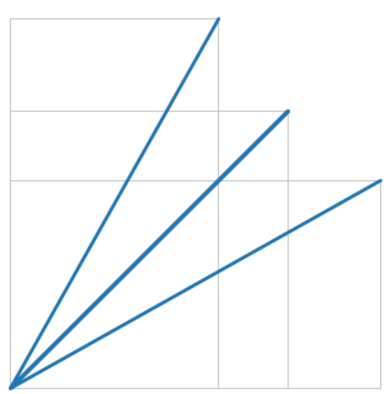
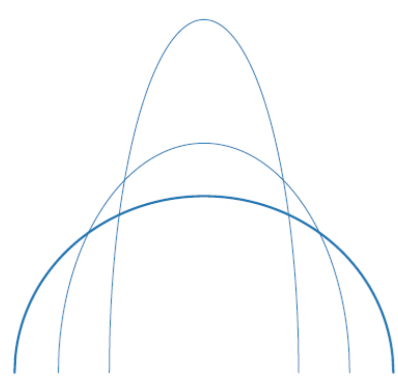
An alternate approach:

Minimize arc length (hold area constant)



Straight line -> 45 deg



Ellipse -> Circle

[Talbot et al, 2011]

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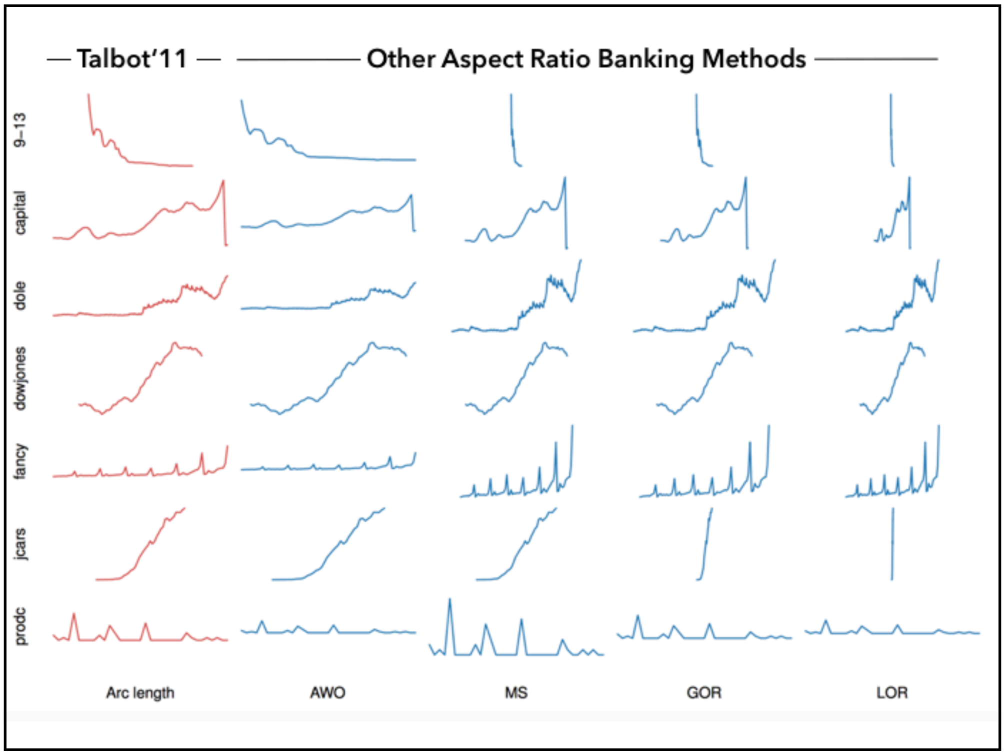

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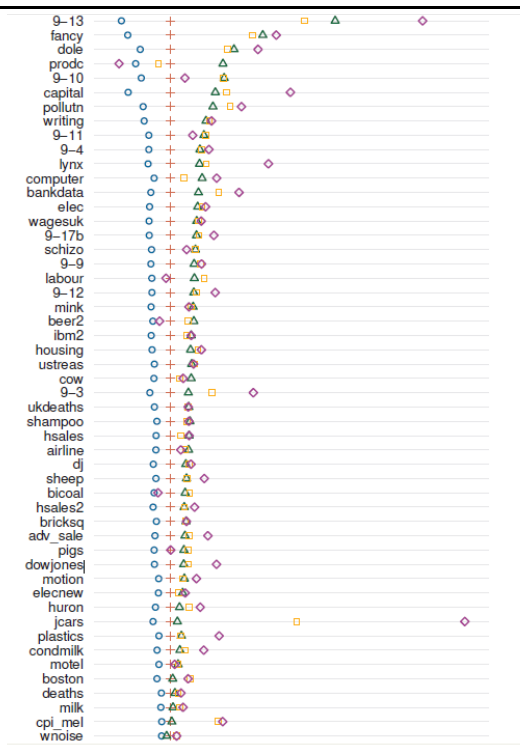

Compromise

Arc-length banking produces aspect ratios in-between those produced by other methods.

[Talbot et al, 2011]

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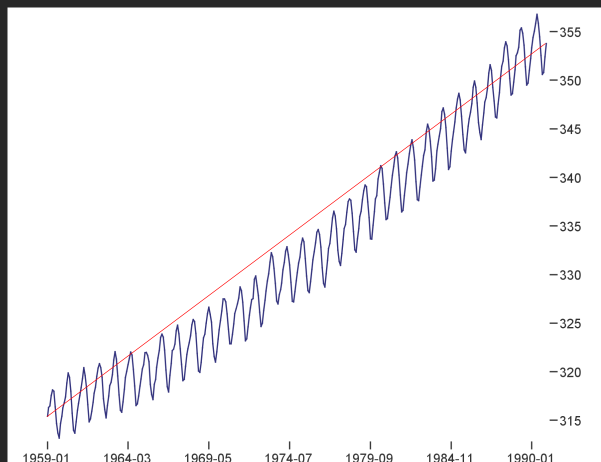
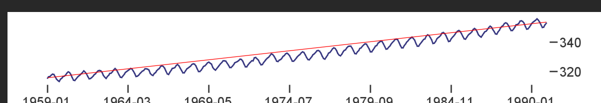


Aspect Ratio = 1.17



Aspect Ratio = 7.87

Trends may occur at different scales!

Apply banking to the original data or to fitted trend lines.

[Heer & Agrawala '06]

CO_2 Measurements

William S. Cleveland
Visualizing Data

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Fitting the Data

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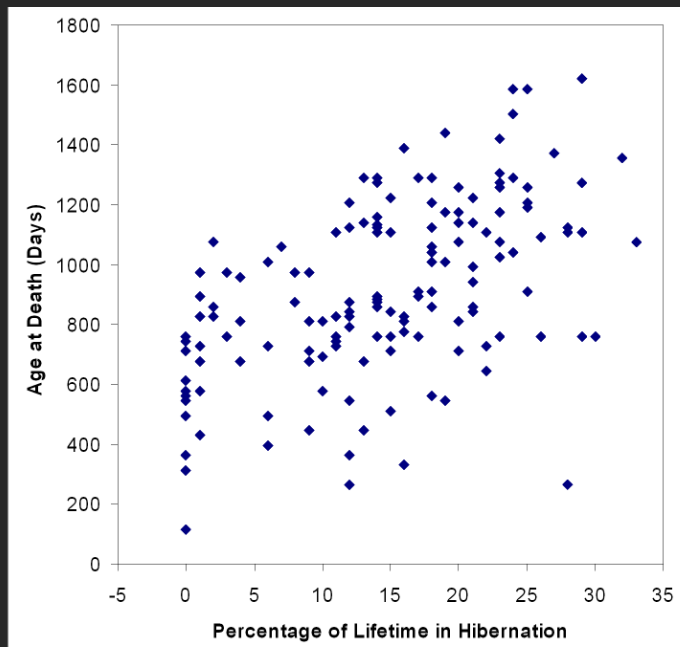

[The Elements of Graphing Data. Cleveland 94]

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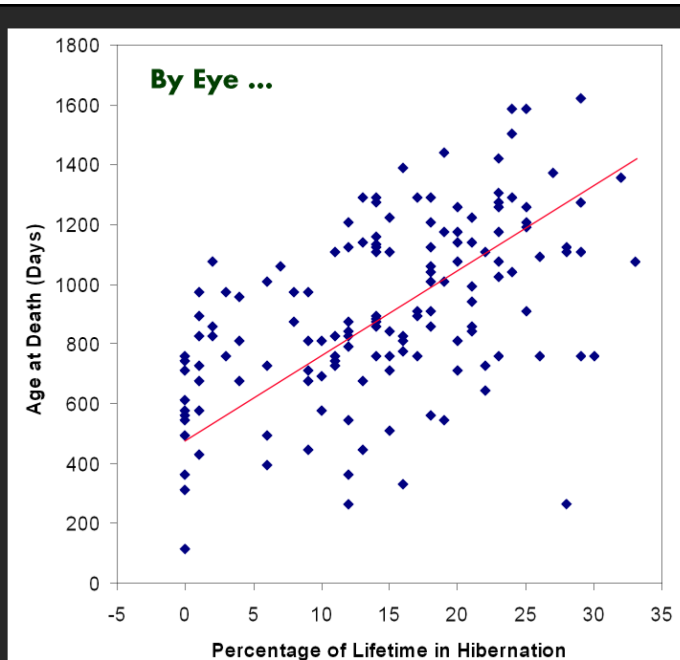

[The Elements of Graphing Data. Cleveland 94]

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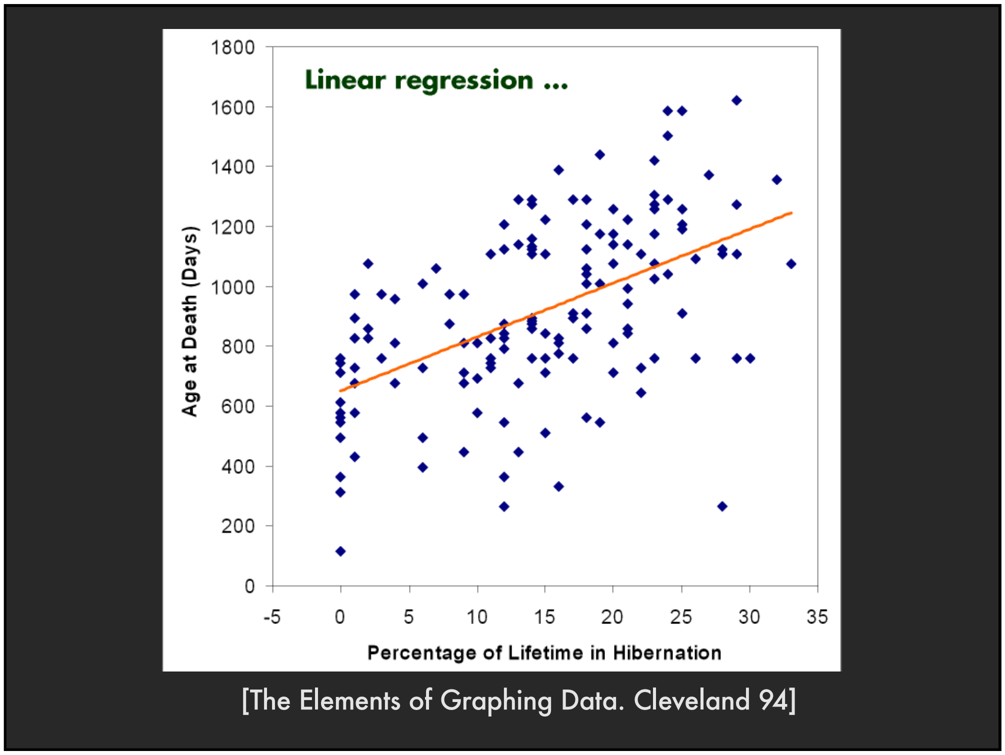
Linear regression ...
1800
1600
1400
1200
1000
800
600
400
200
0
-5
0
5
10
15
20
25
30
35
Age at Death (Days)
Percentage of Lifetime in Hibernation
[The Elements of Graphing Data. Cleveland 94]

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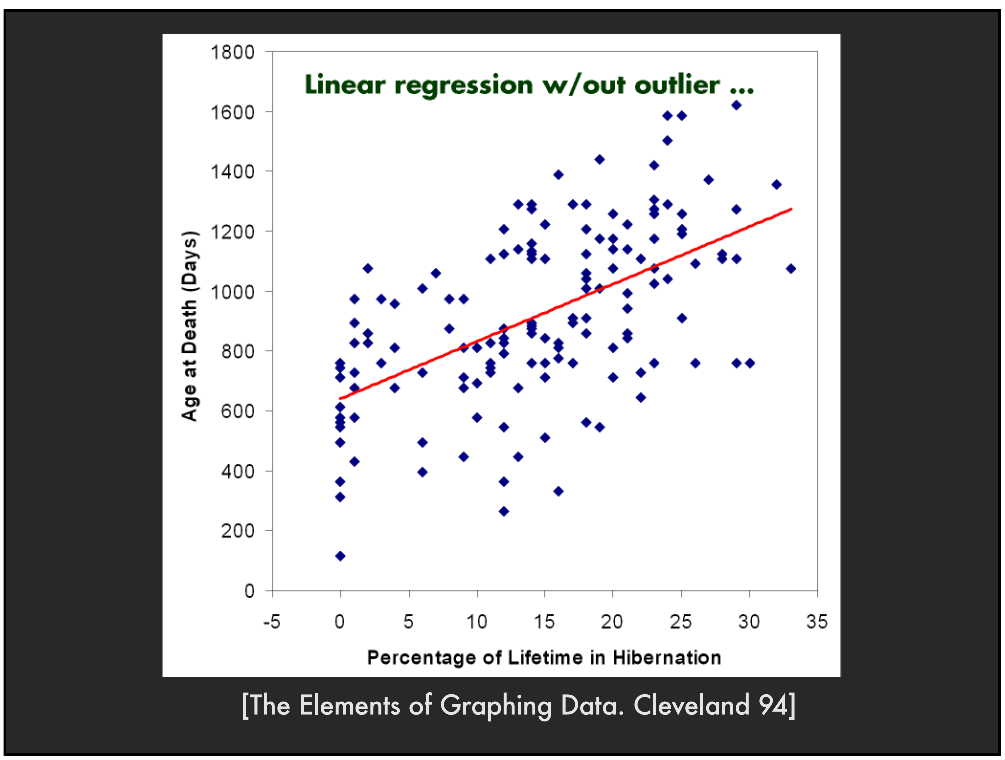
Linear regression w/out outlier ...
1800
1600
1400
1200
1000
800
600
400
200
0
-5
0
5
10
15
20
25
30
35
Age at Death (Days)
Percentage of Lifetime in Hibernation
[The Elements of Graphing Data. Cleveland 94]

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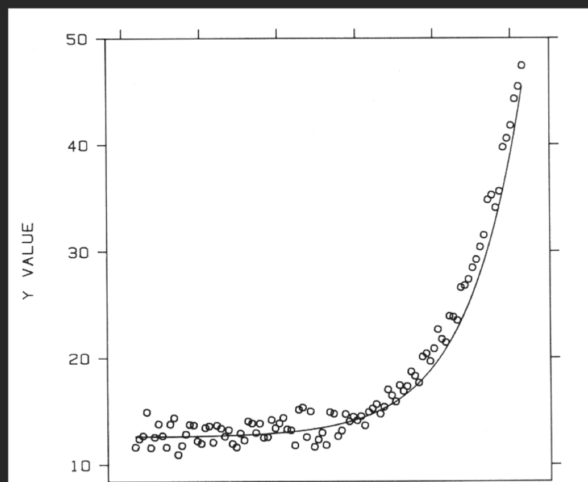
Transforming data

How well does curve fit data?



[Cleveland 85]

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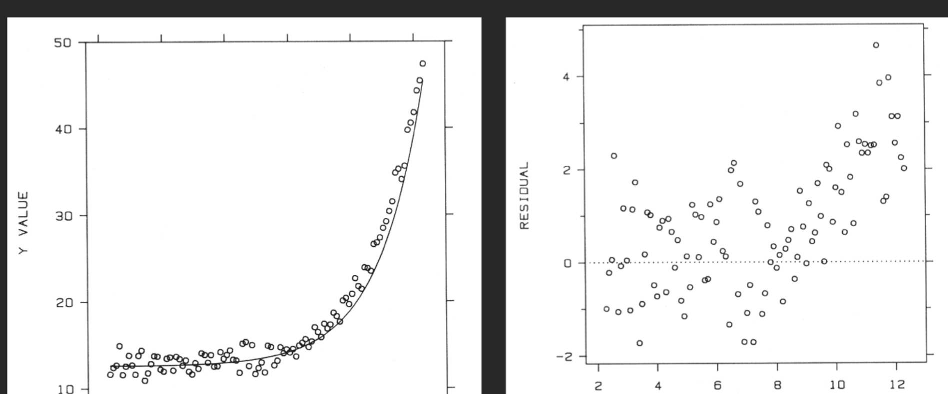
Transforming data

Residual graph

- Plot vertical distance from best fit curve
- Residual graph shows accuracy of fit



[Cleveland 85]

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Graphical Calculations

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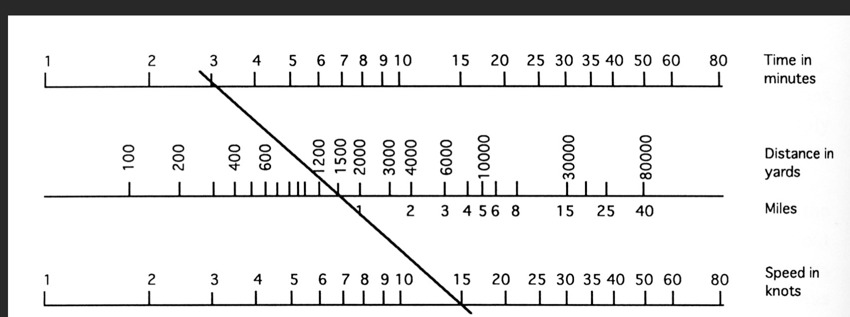
Nomograms



Sailing: The Rule of Three

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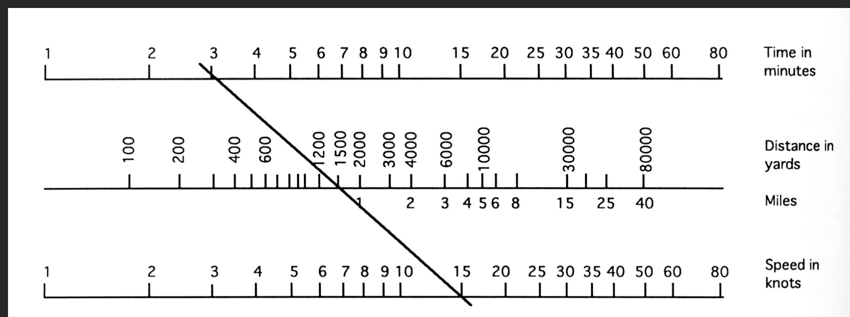
Nomograms



1. **Compute in any direction;** fix n-1 params and read nth param
2. **Illustrate sensitivity to perturbation of inputs**
3. **Clearly show domain of validity of computation**

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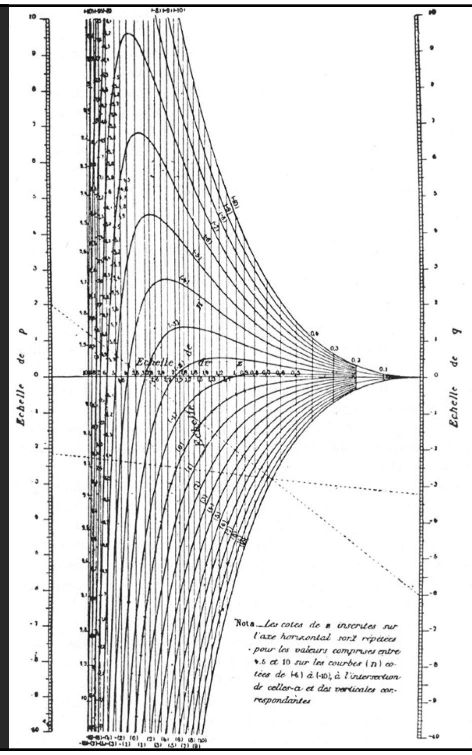
Slide rule

Model 1474-66 Electrotechnica 18 Scales

Tehnolemn Timisoara Slide Rule Archive
http://pubpages.unh.edu/~jwc/tehnolemn/

94



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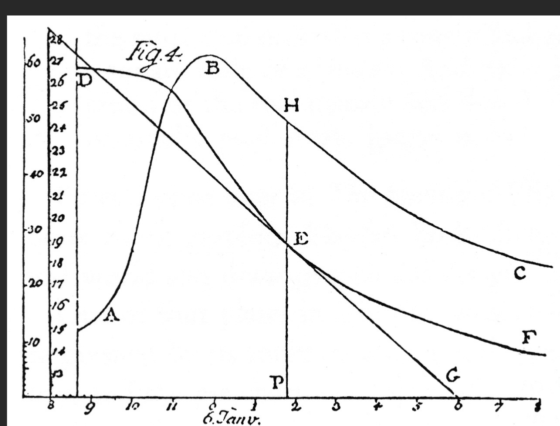
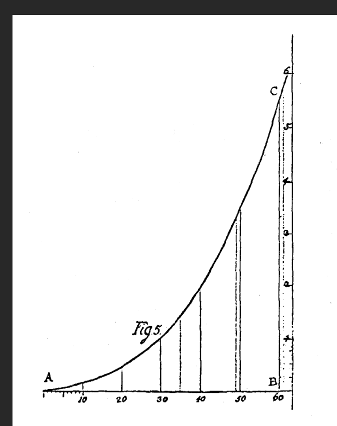
Lambert's graphical construction





Johannes Lambert used graphs to study the rate of water evaporation as function of temperature [from Tufte 83]

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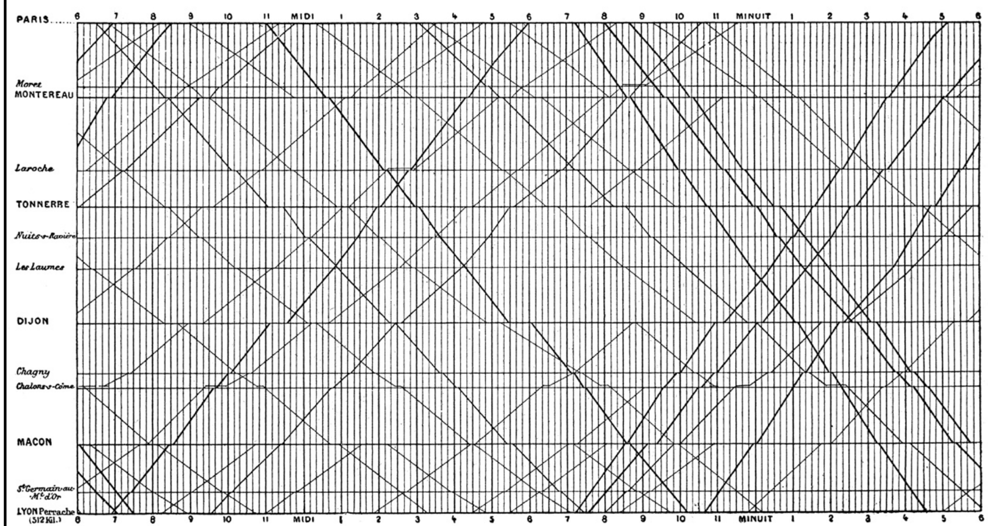

E. J. Marey, *La Méthode Graphique* (Paris, 1885), p. 20. The method is attributed to the French engineer, Ibry.

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Cartographic Distortion

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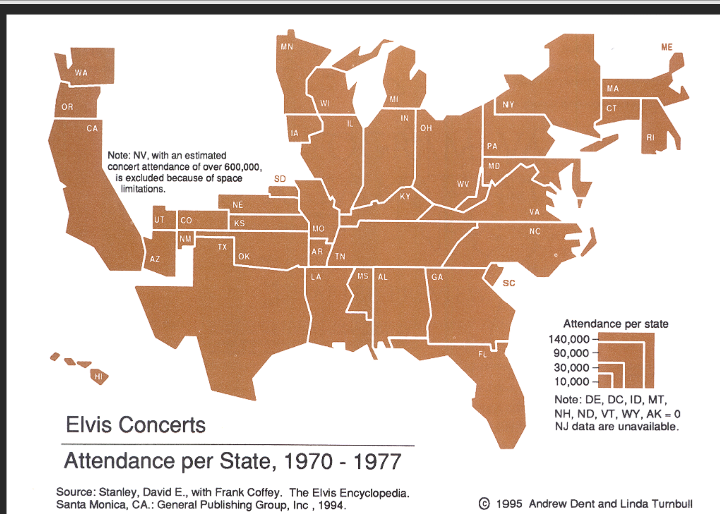
Cartograms: Distort areas



Scale area by data

[From *Cartography*, Dent]

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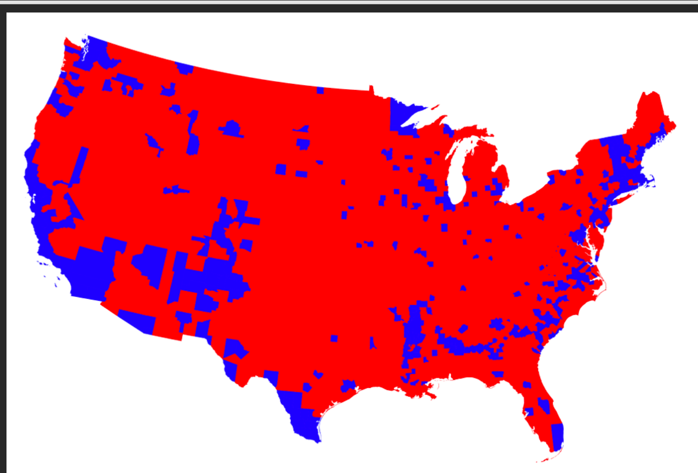
Election 2016 map



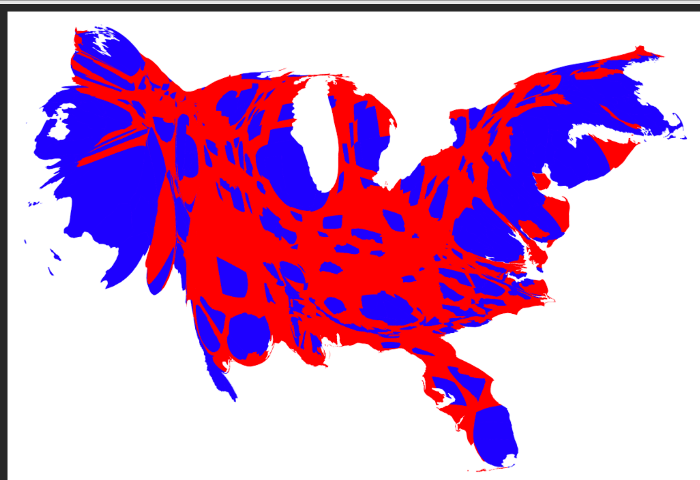
% voted democrat

% voted republican

http://www-personal.umich.edu/~mejn/election/

131

Election 2016 map

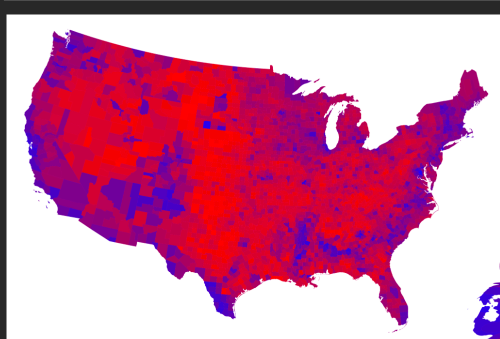


% voted democrat
% voted republican

http://www-personal.umich.edu/~mejn/election/

132

Election 2016 map



http://www-personal.umich.edu/~mejn/election/

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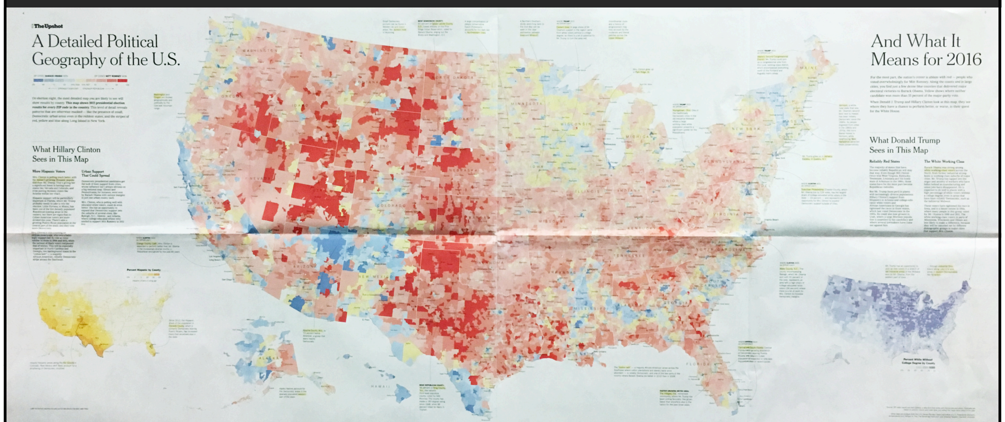
NYT Election 2016 (based on 2012)



Statistical map with shading

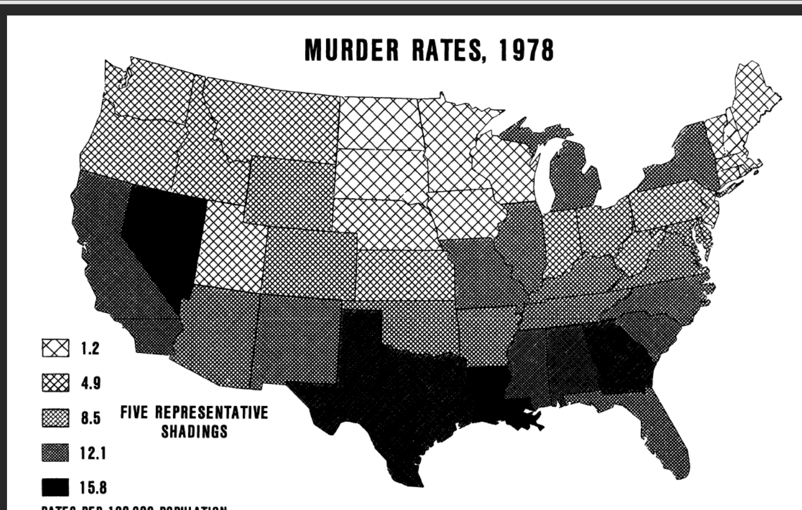
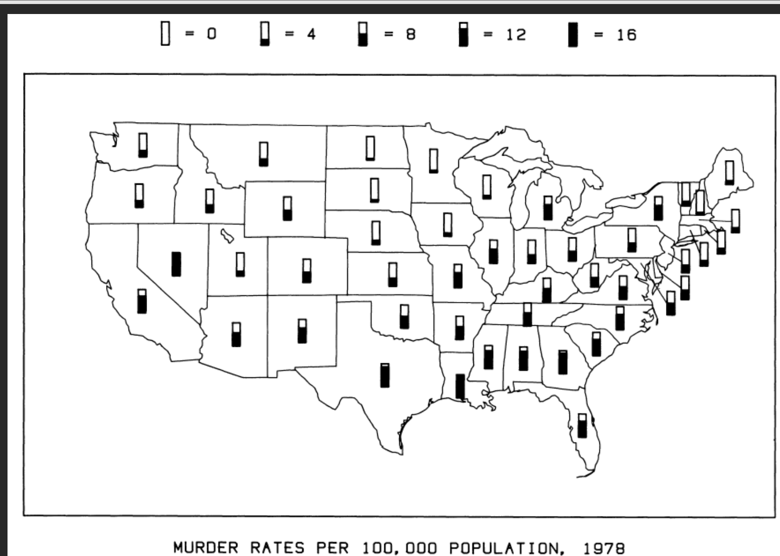


Figure 5. Statistical map with shading.

[Cleveland and McGill 84]

Framed rectangle chart



[Cleveland and McGill 84]

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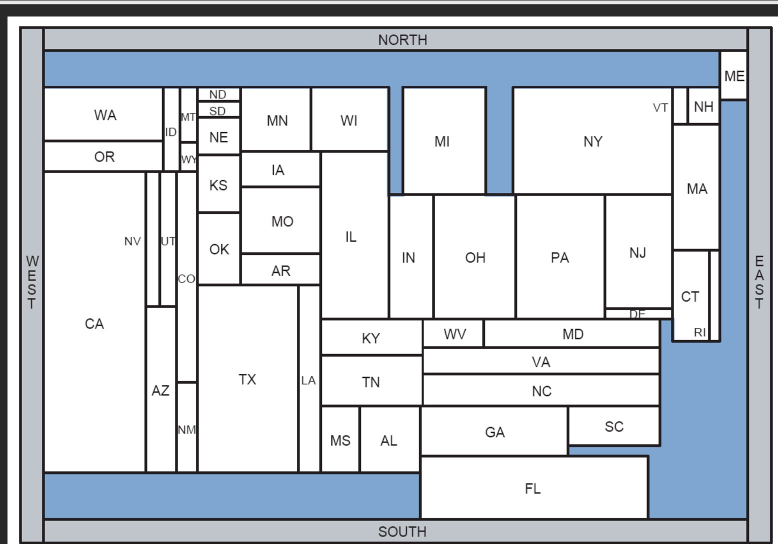
Rectangular cartogram



American population [van Kreveld and Speckmann 04]

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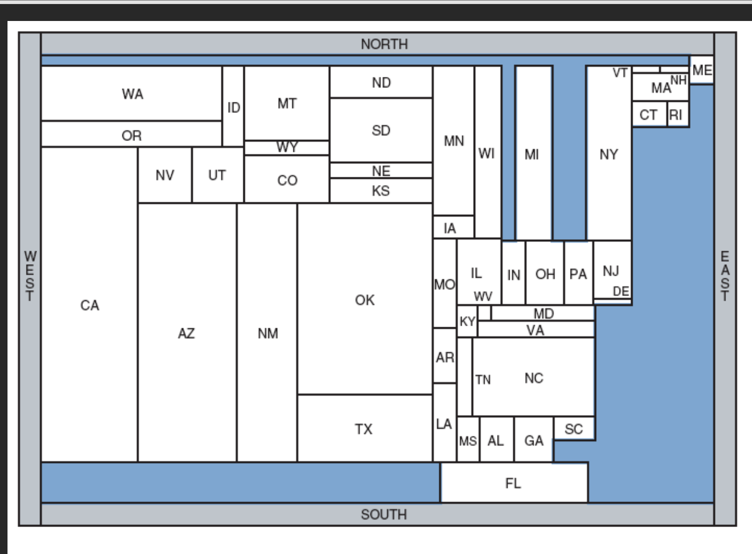
Rectangular cartogram



Native American population [van Kreveld and Speckmann 04]

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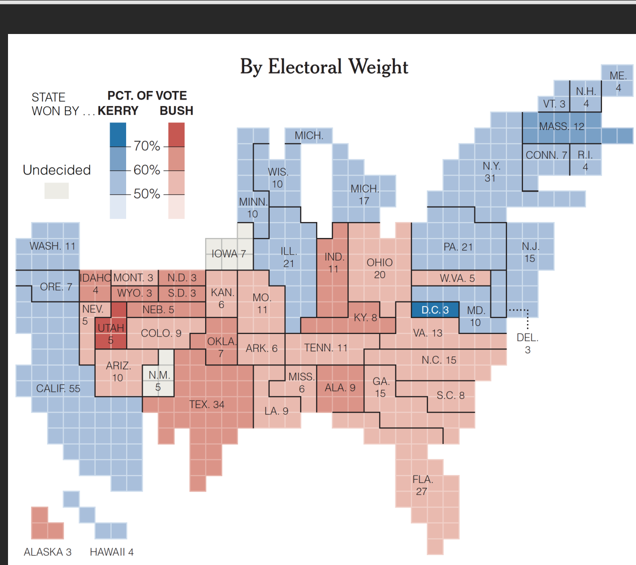
New York Times Election 2004



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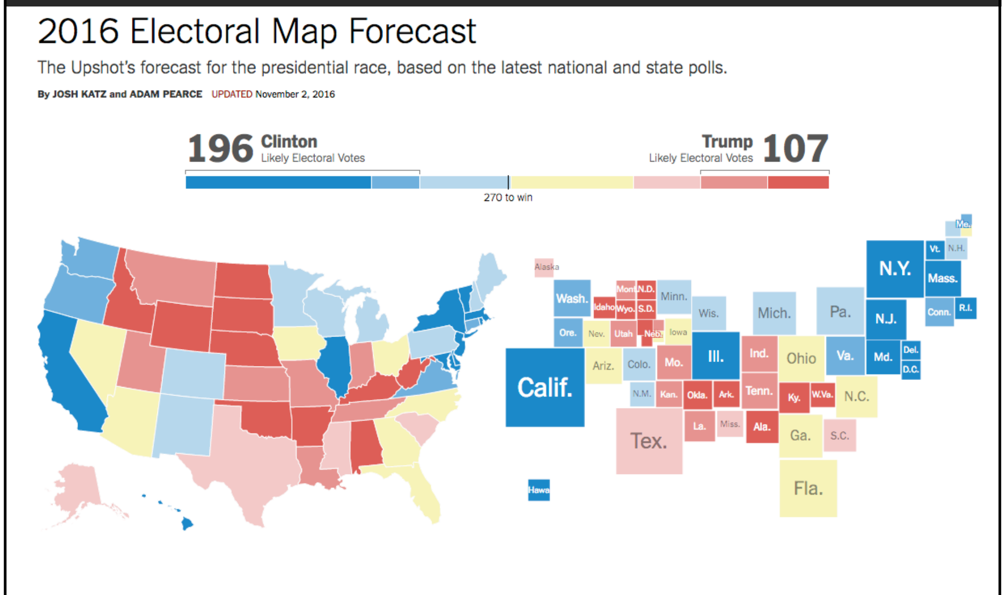
New York Times Election 2016



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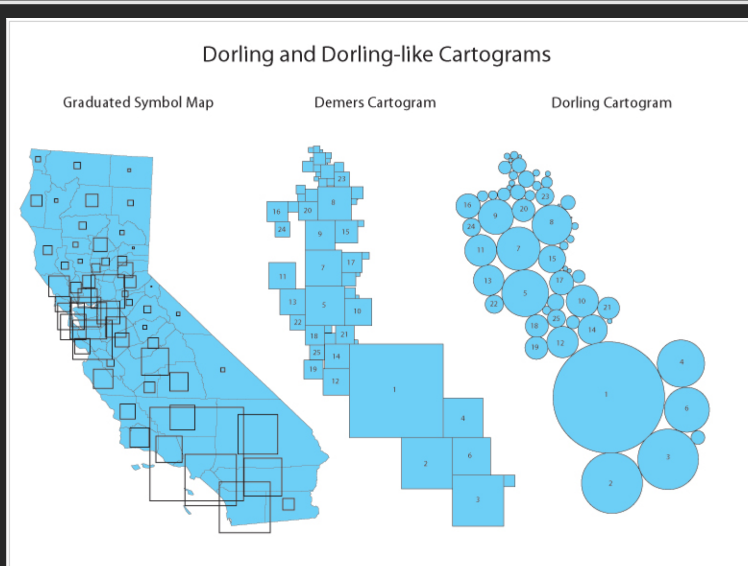
Dorling cartogram



http://www.ncgia.ucsb.edu/projects/Cartogram_Central/types.html

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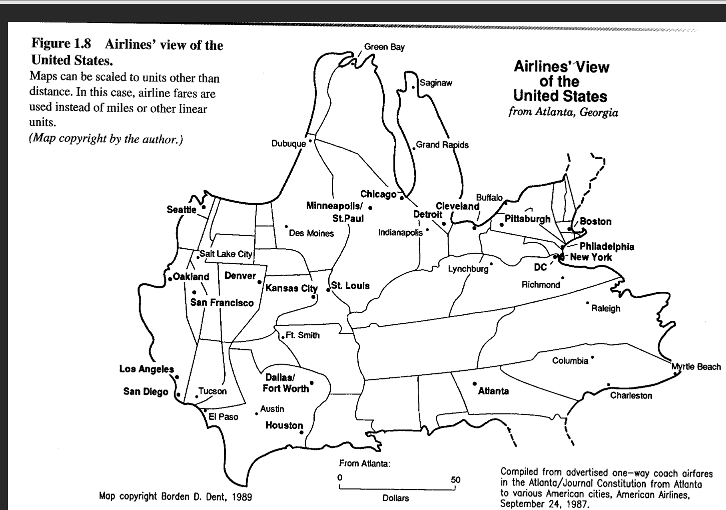
Distorting distances



Scale distance by data (airline fare)

[From *Cartography*, Dent]

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London underground

http://www.thetube.com/content/history/map.asp

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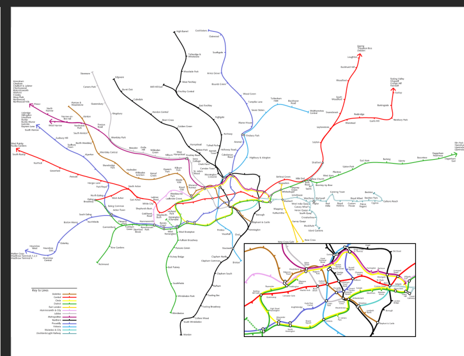
Comparison to geographic map

Distorted



Undistorted

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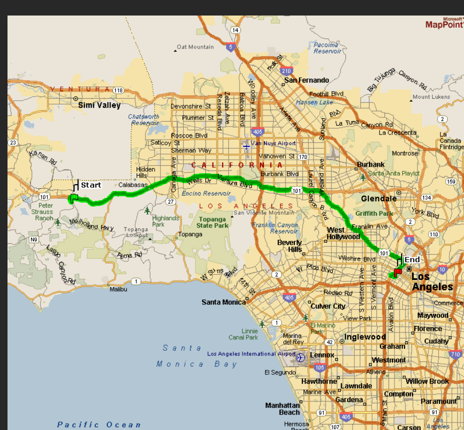
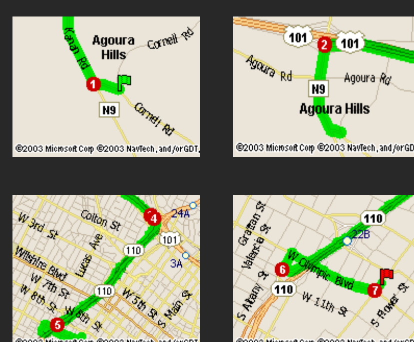
Visualizing Routes





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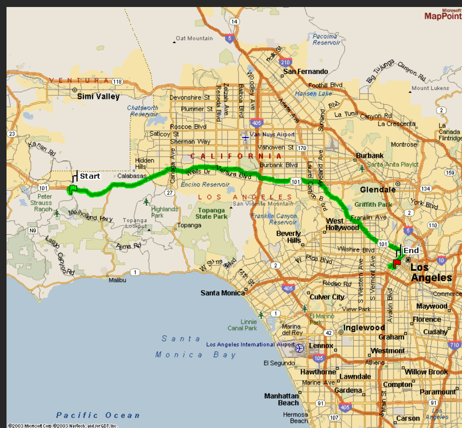
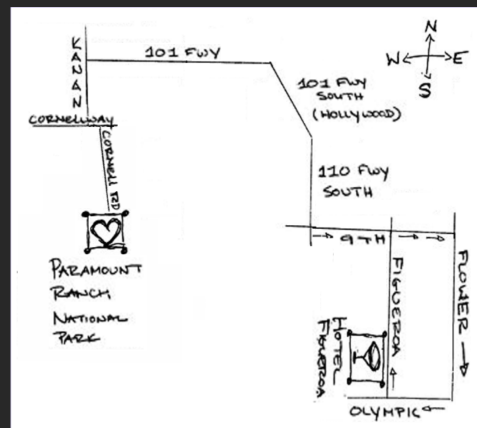
A Better Visualization





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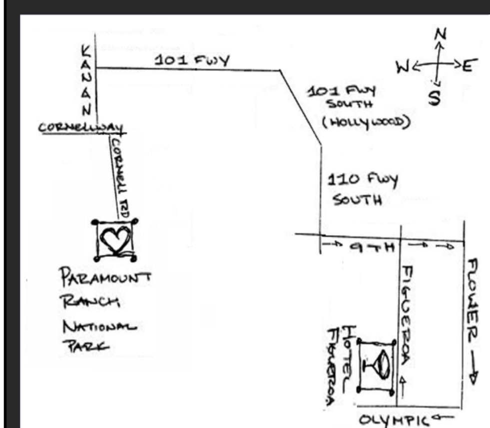
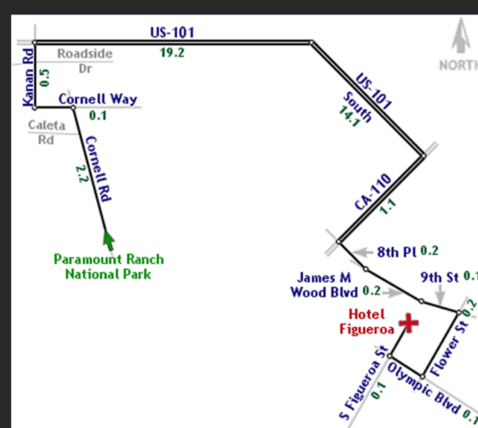
LineDrive [Agrawala & Stolte 2001]



Hand-drawn route map



LineDrive route map

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Summary

- Space is the most important visual encoding
- Geometric properties of spatial transforms support geometric reasoning
- Show data with as much resolution as possible
- Use distortions to emphasize important information

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