Using Space Effectively: 2D

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CS 448B: Visualization
Fall 2017

Announcements

Assignment 3: Dynamic Queries

Create a small interactive dynamic query application similar to Homefinder, but for SF Tree Data.

1. Implement interface and produce final writeup
2. Submit the application and a final writeup on canvas

Can work alone or in pairs

Due before class on Oct 30, 2017

Final project

Design new visualization method (e.g. software)

- Pose problem, Implement creative solution
- Design studies/evaluations less common but also possible (talk to us)

Deliverables

- Implementation of solution
- 6-8 page paper in format of conference paper submission
- Project progress presentations

Schedule

- Project proposal: Mon 11/6
- Project progress presentation: 11/13 and 11/15 in class (3-4 min)
- Final poster presentation: 12/6 Location: Lathrop 282
- Final paper: 12/10 11:59pm

Grading

- Groups of up to 3 people, graded individually
- Clearly report responsibilities of each member

Using Space Effectively: 2D

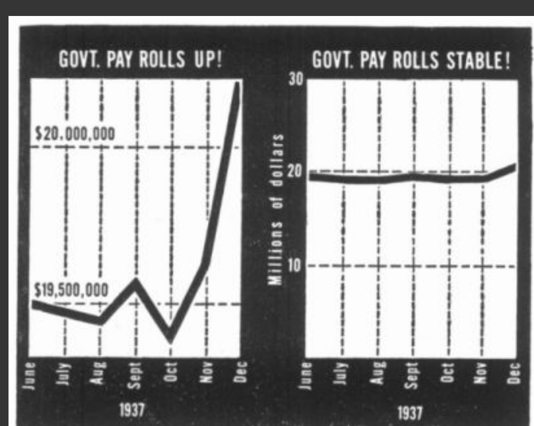
Topics

Displaying data in graphs
Selecting aspect ratio
Fitting data and depicting residuals
Graphical calculations
Zooming and Focus + Context
Cartographic distortion

Graphs and Lines

Effective use of space

Which graph is better?

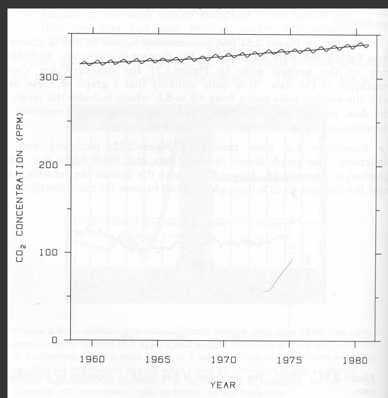


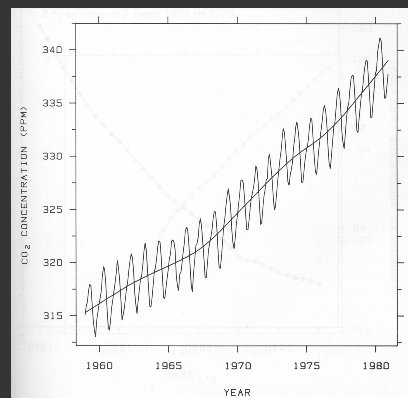
Government payrolls in 1937 [Huff 93]

Aspect ratio

Fill space with data

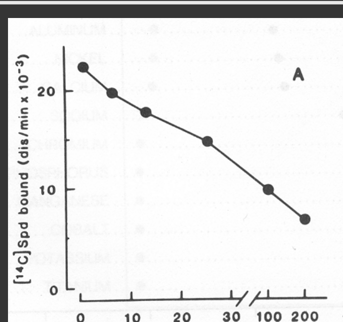
Don' t worry about showing zero



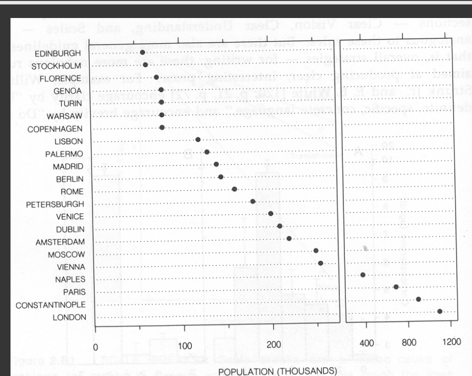


Yearly CO2 concentrations [Cleveland 85]

Clearly mark scale breaks

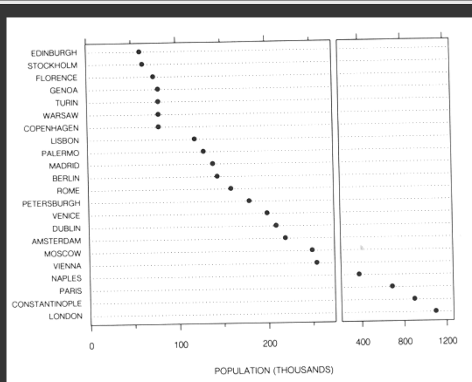


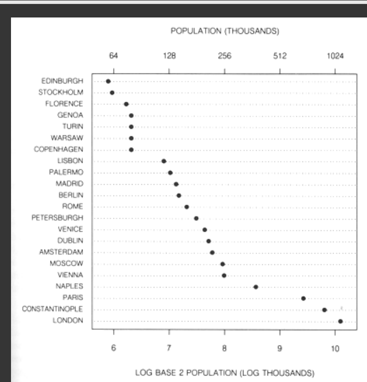
Poor scale break [Cleveland 85]



Well marked scale break [Cleveland 85]

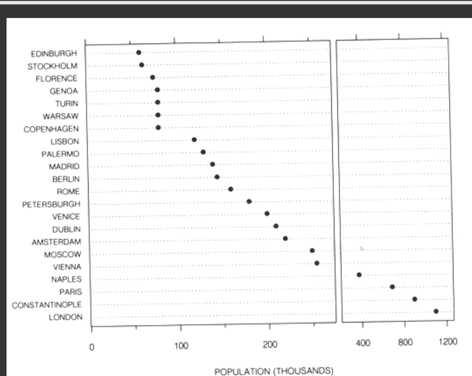
Scale break vs. Log scale

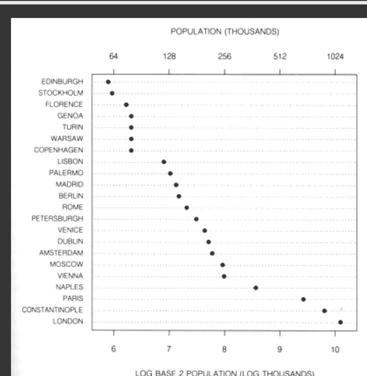




[Cleveland 85]

Scale break vs. Log scale



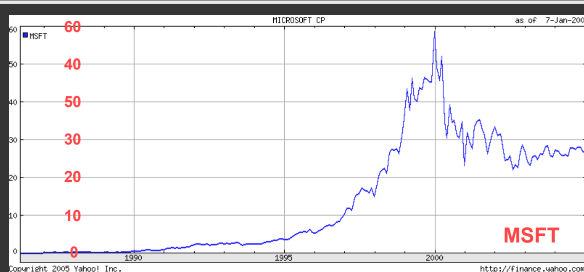


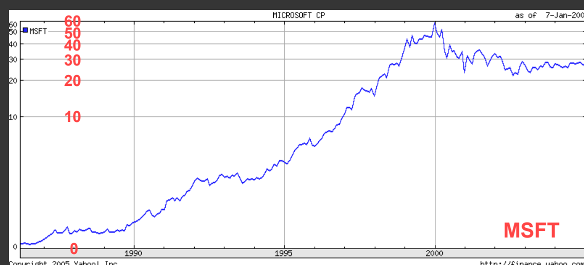
[Cleveland 85]

Both increase visual resolution

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

Linear scale vs. Log scale

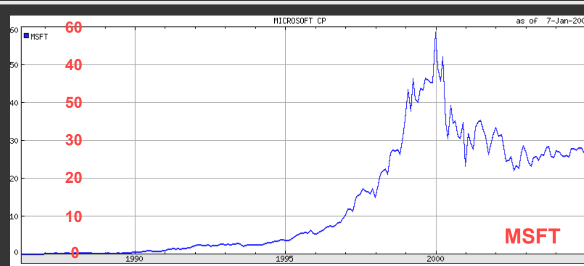




Linear scale vs. Log scale

Linear scale

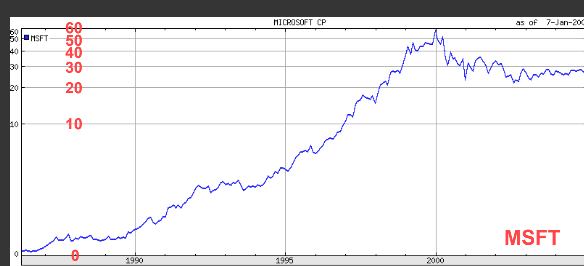
- Absolute change



Log scale

- Small fluctuations
- Percent change

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



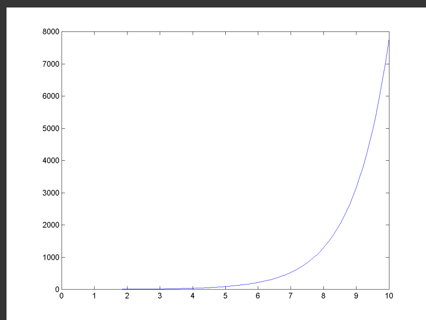
Semilog graph: Exponential growth

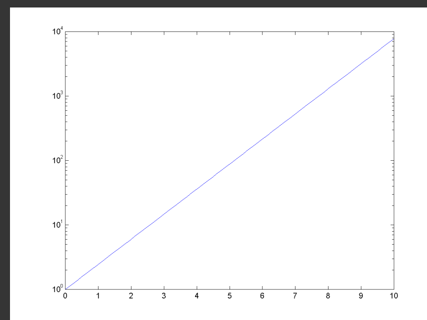
Exponential functions ($y = ka^{mx}$) transform into lines

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

Intercept: $\log(k)$

Slope: $\log(a)m$





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

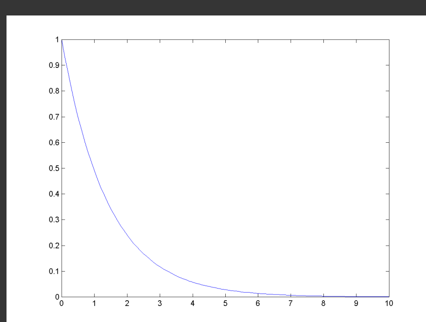
Semilog graph: Exponential decay

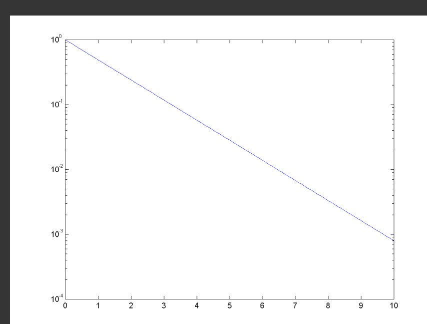
Exponential functions ($y = ka^{mx}$) transform into lines

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

Intercept: $\log(k)$

Slope: $\log(a)m$





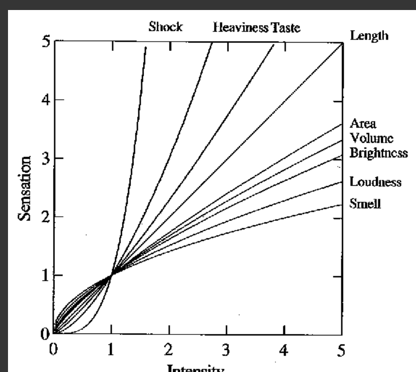
$y = 0.5^{2x}$, slope in semilog space: log(0.5)*2 = -0.602

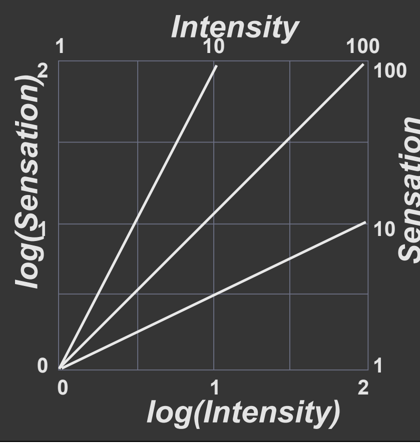
Log-Log graph

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

Example - Steven's power laws:

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



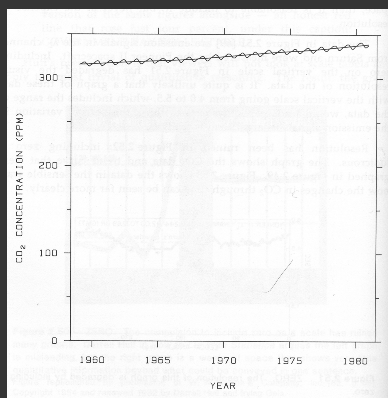


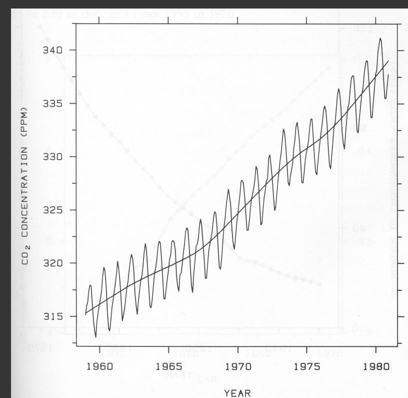
Selecting Aspect Ratio

Aspect ratio

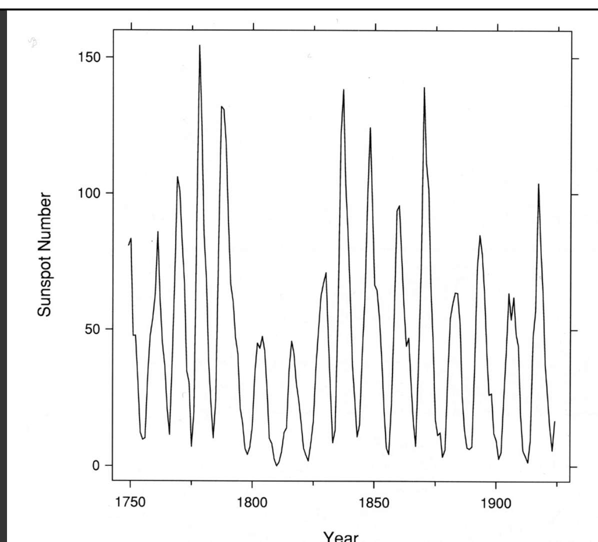
Fill space with data

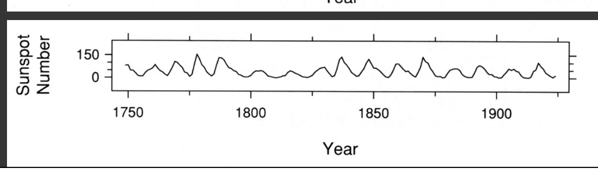
Don’t worry about showing zero





Yearly CO2 concentrations [Cleveland 85]

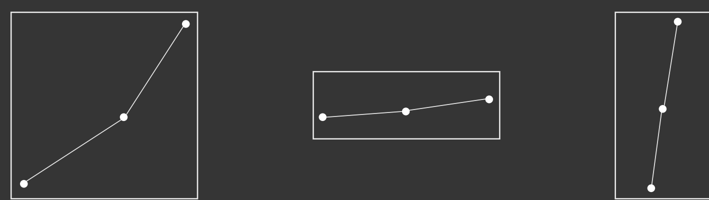




William S. Cleveland
The Elements of Graphing Data

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°

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)

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

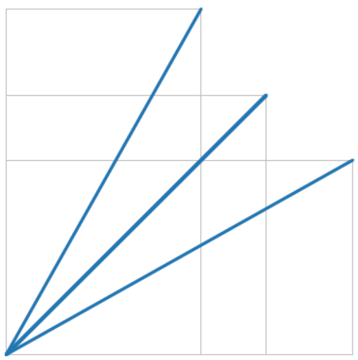
Local (over adjacent segments)

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

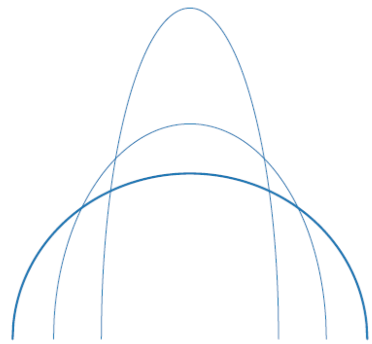
Requires Iterative Optimization

An alternate approach:

Minimize arc length (hold area constant)



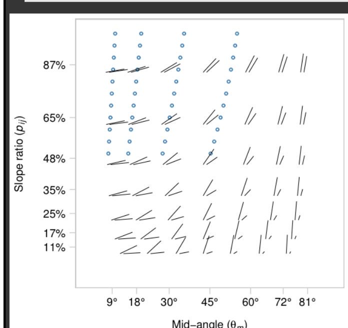
Straight line -> 45 deg

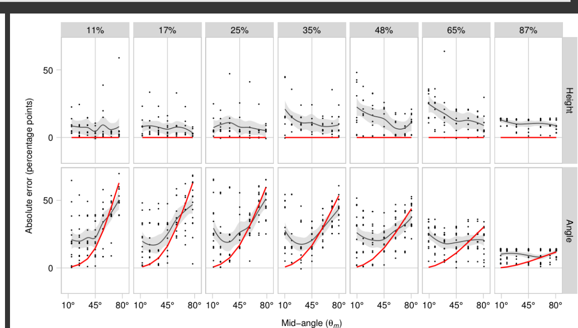


Ellipse -> Circle

[Talbot et al, 2011]

Perceptual model based aspect ratio



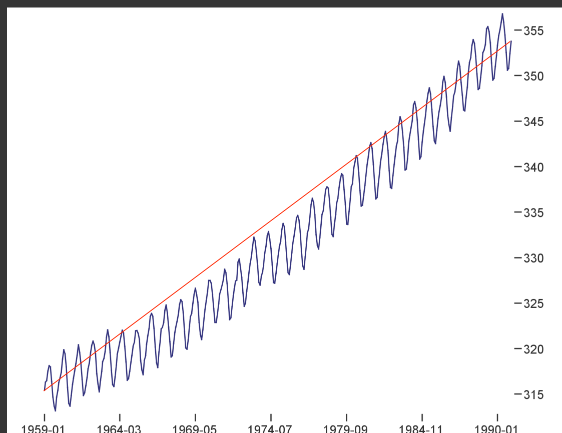


Ask people to estimate slope ratios for different conditions

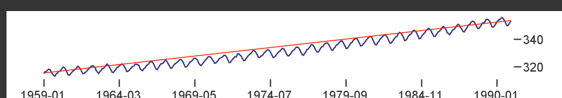
Use data to fit a model derived from perceptual theory

$$\hat{p}_{ij} = \begin{cases} \frac{\sin(\theta_i)\, l_i}{\sin(\theta_j)\, l_j} \times 100 & +\gamma & +\varepsilon^h_{ij} & \text{if HEIGHT} \\ \frac{\theta_i}{\theta_j} \times 100 & +(\mu + \beta\theta_m) & +\varepsilon^a_{ij} & \text{if ANGLE} \end{cases}$$

[Talbot 12]



Aspect Ratio = 1.17



Aspect Ratio = 7.87

CO_2 Measurements

William S. Cleveland
Visualizing Data

Multi-Scale Banking to 45°

Idea: Use Spectral Analysis to identify trends

- Find strong frequency components
- Lowpass filter to create trend lines

CO_2

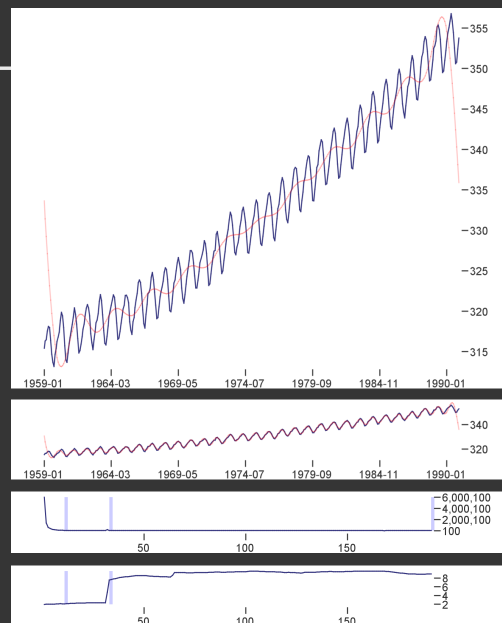
Monthly concentrations from the Mauna Loa Observatory, 1950-1990

Aspect Ratio = 1.17

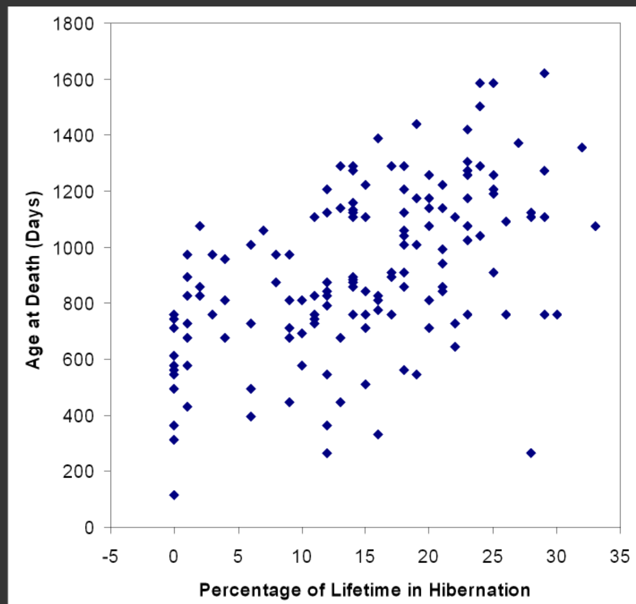
Aspect Ratio = 7.87

Power Spectrum

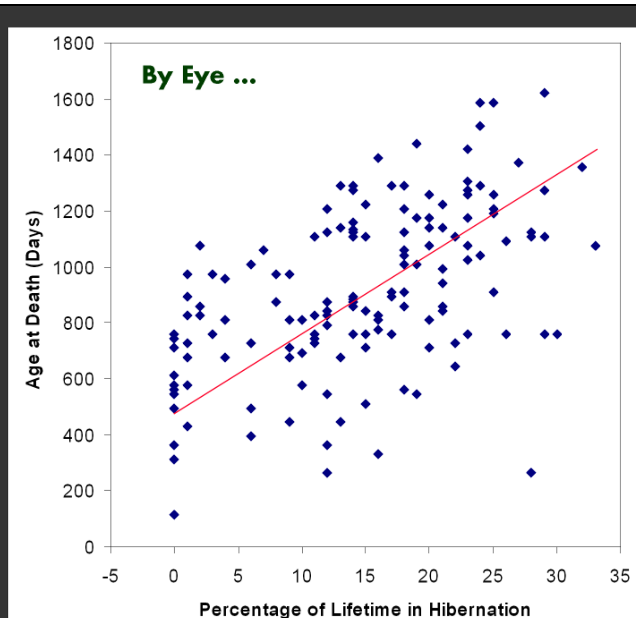
Aspect Ratios



Fitting the Data



[The Elements of Graphing Data. Cleveland 94]



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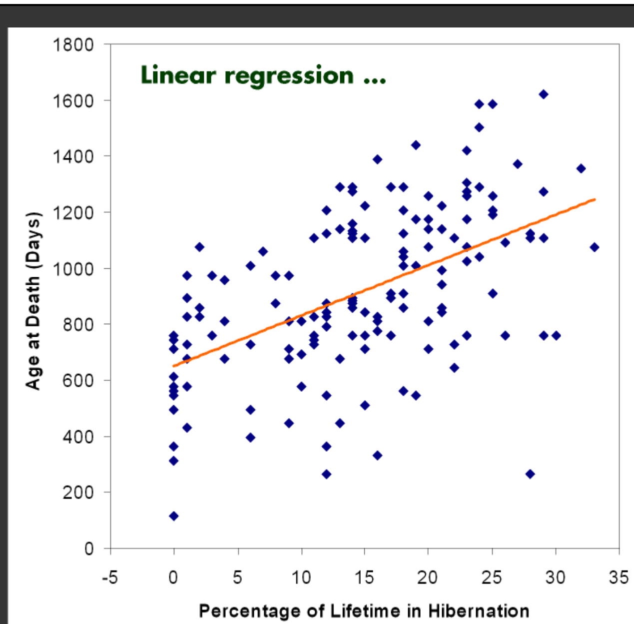

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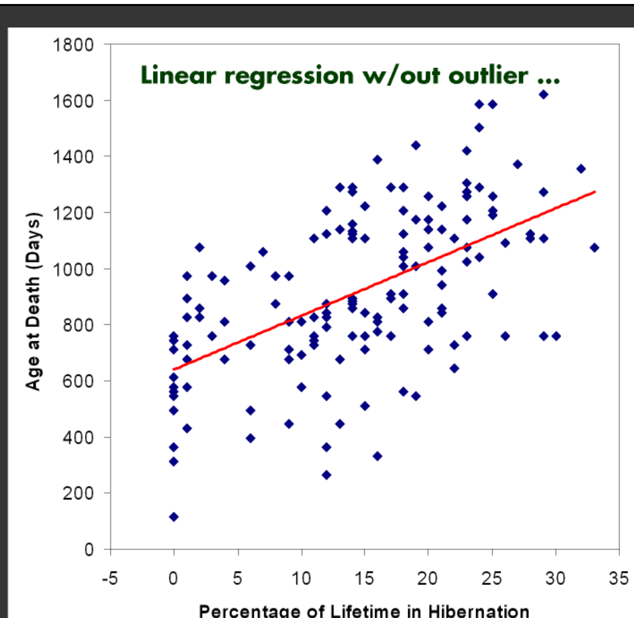
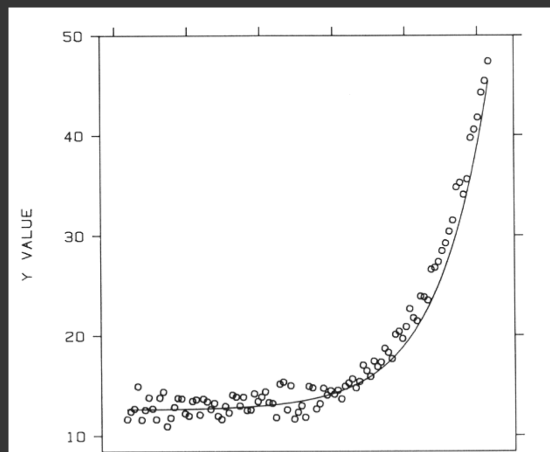


[The Elements of Graphing Data. Cleveland 94]

Transforming data

How well does curve fit data?

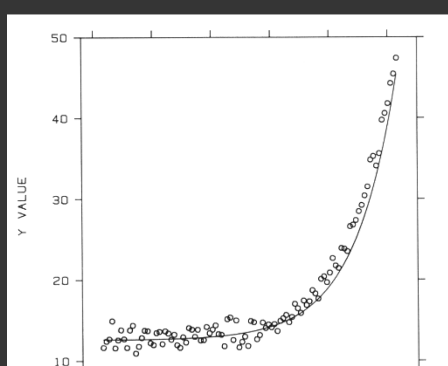


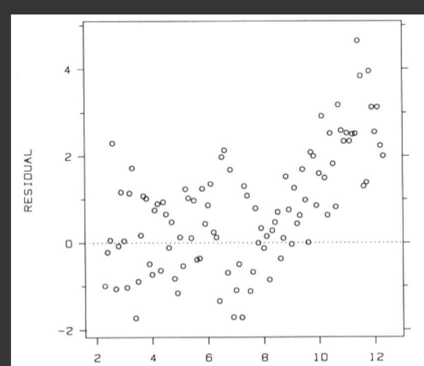
[Cleveland 85]

Transforming data

Residual graph

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

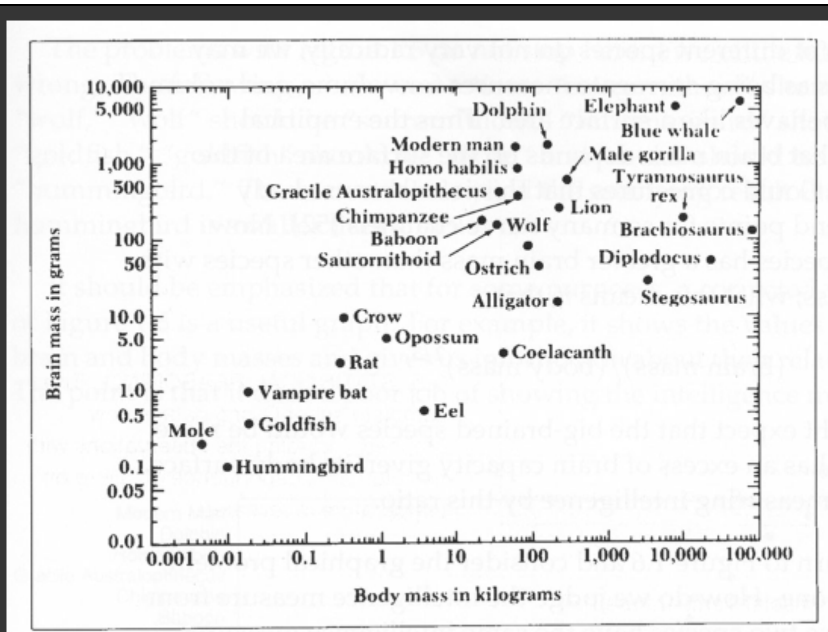




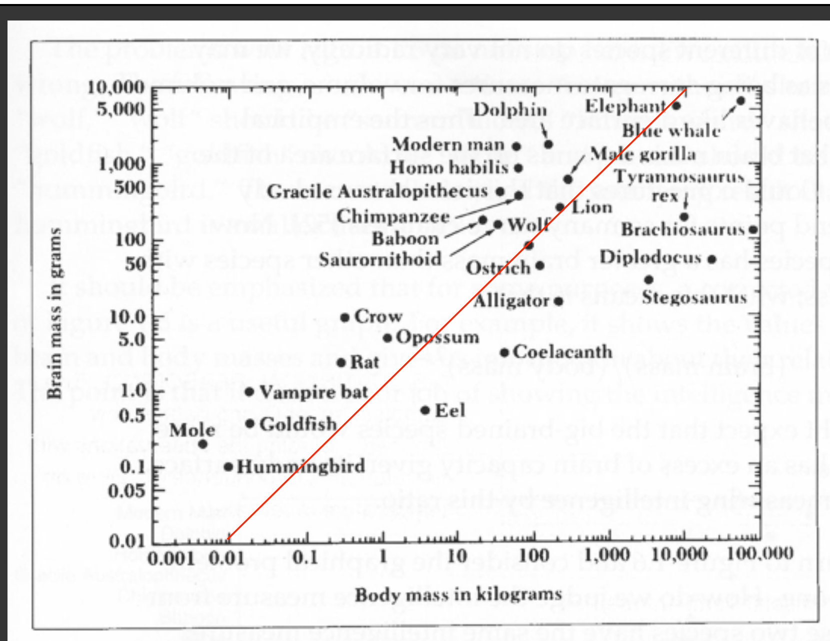
[Cleveland 85]

Most powerful brain?

ID	Name	Body Weight	Brain Weight
1	Lesser Short-tailed Shrew	5	0.14
2	Little Brown Bat	10	0.25
3	Mouse	23	0.3
4	Big Brown Bat	23	0.4
5	Musk Shrew	48	0.33
6	Star Nosed Mole	60	1
7	Eastern American Mole	75	1.2
8	Ground Squirrel	101	4
9	Tree Shrew	104	2.5
10	Golden Hamster	120	1
11	Mole Rate	122	3
12	Galago	200	5
13	Rat	280	1.9
14	Chinchilla	425	6.4
15	Desert Hedgehog	550	2.4
16	Rock Hyrax (a)	750	12.3
17	European Hedgehog	785	3.5
18	Tenrec	900	2.6
19	Arctic Ground Squirrel	920	5.7
20	African Giant Pouched Rat	1000	6.6
21	Guinea Pig	1040	5.5
22	Mountain Beaver	1350	8.1
23	Slow Loris	1400	12.5
24	Genet	1410	17.5
25	Phalanger	1620	11.4



The Dragons of Eden [Carl Sagan]



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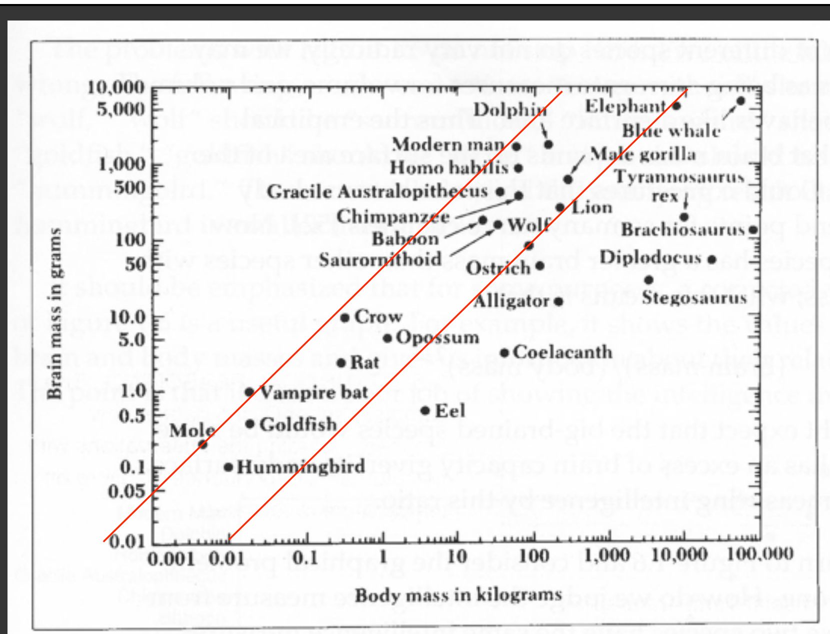

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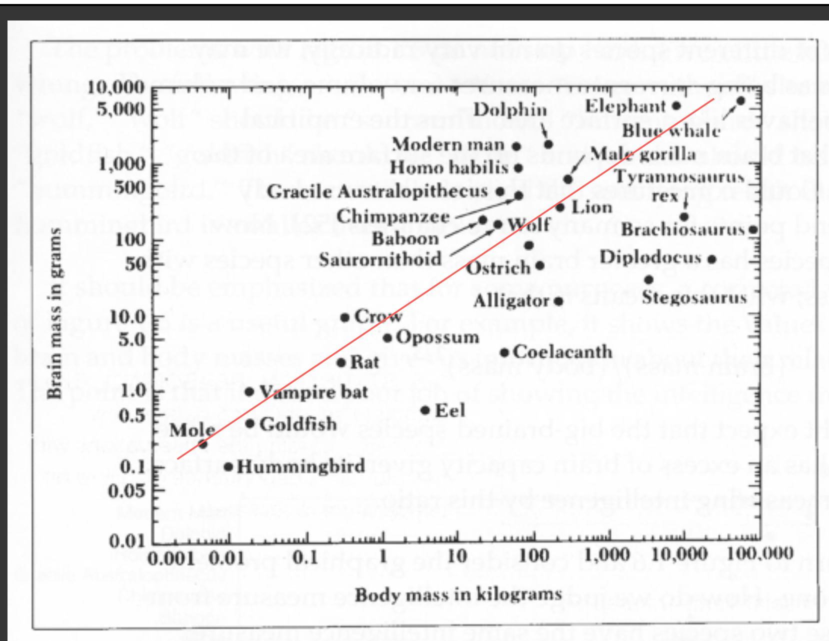

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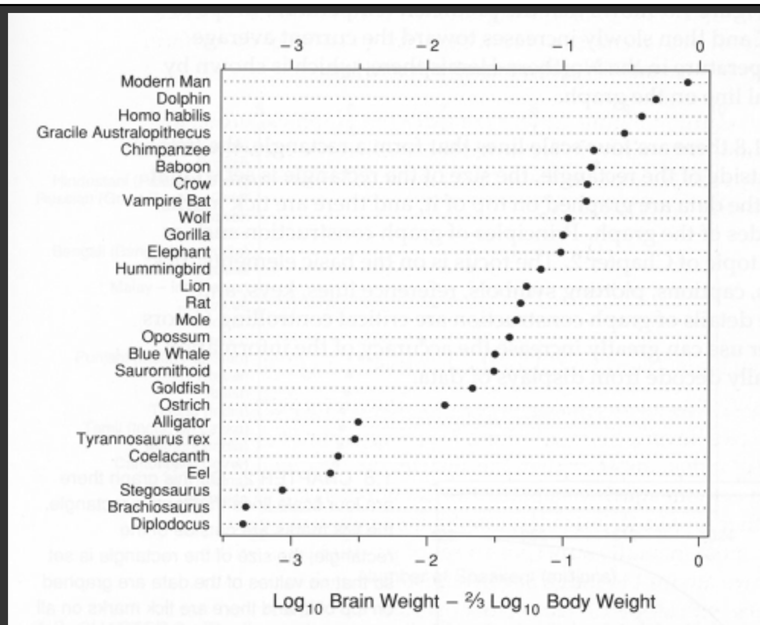
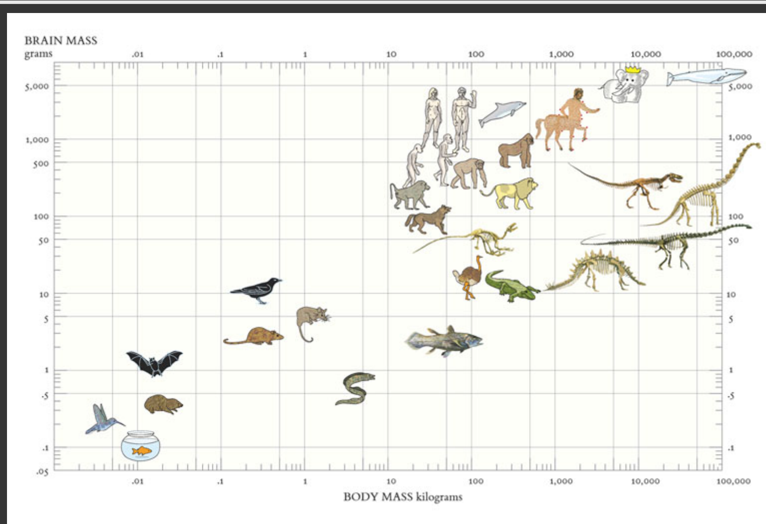


The Elements of Graphing Data [Cleveland]

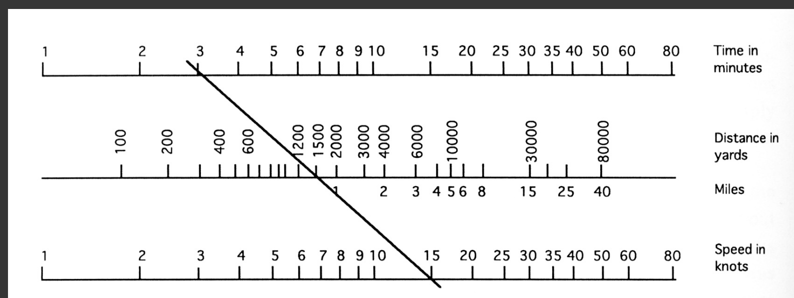
Most powerful brain



Beautiful Evidence [Tufte]

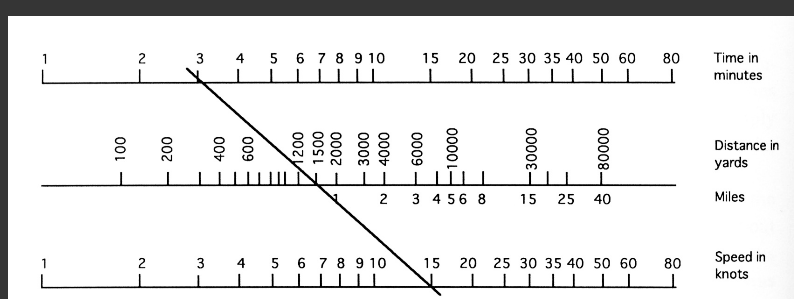
Graphical Calculations

Nomograms



Sailing: The Rule of Three

Nomograms

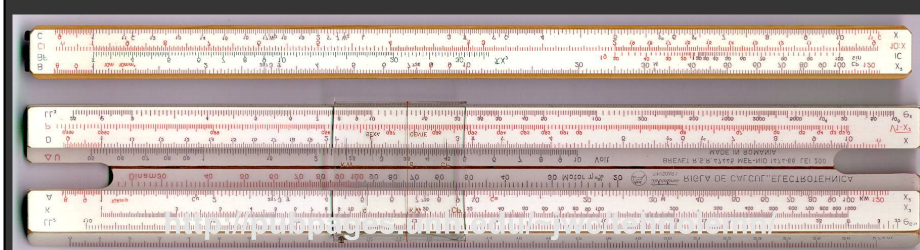


1. Compute in any direction; fix n-1 params and read nth param
2. Illustrate sensitivity to perturbation of inputs
3. Clearly show domain of validity of computation

Theory

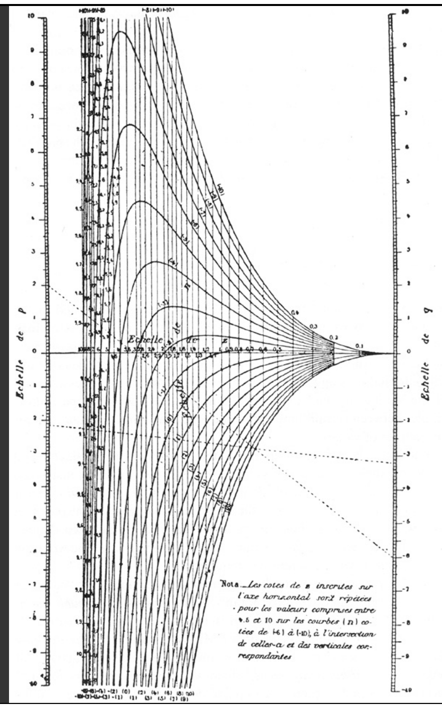
$$\begin{vmatrix} x_1(u) & y_1(u) & w_1(u) \\ x_2(v) & y_2(v) & w_2(v) \\ x_3(s,t) & y_3(s,t) & w_3(s,t) \end{vmatrix} = 0$$

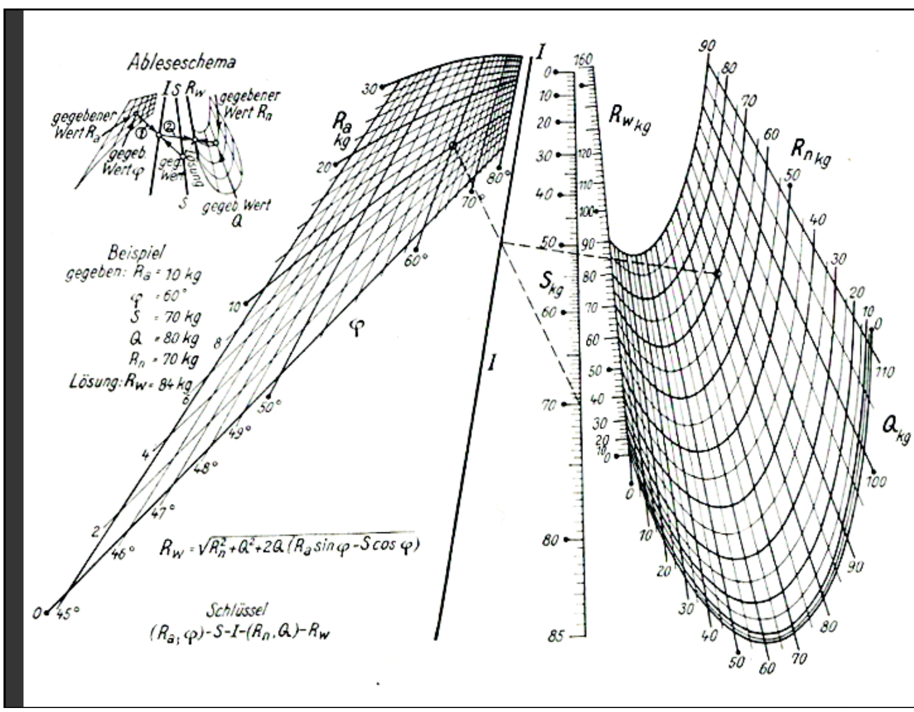
Slide rule



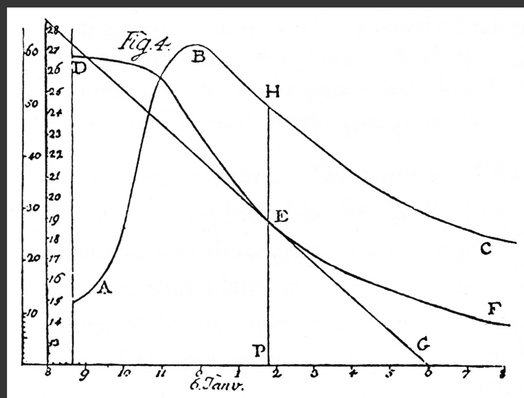
Model 1474-66 Electrotechnica 18 Scales

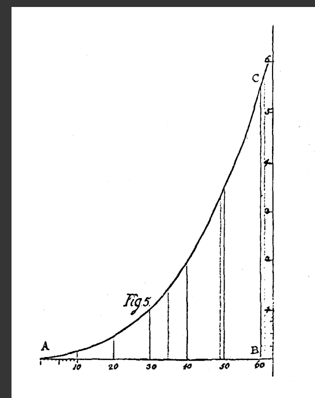
Tehnolemn Timisoara Slide Rule Archive
http://pubpages.unh.edu/~jwc/tehnolemn/


Echelle de p
Echelle de q
Echelle de n
Nota _ Les cotes de n inscrites sur l'axe horizontal sont répétées pour les valeurs comprises entre 4.5 et 10 sur les courbes (n) cotées de (-6) à (-10), à l'intersection de celles-ci et des verticales correspondantes

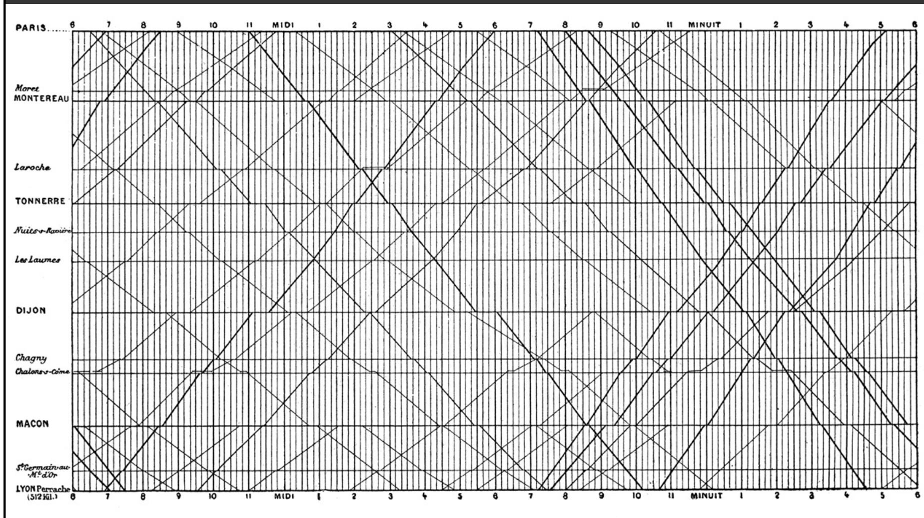

Ableseschema
gegebener Wert R_a
gegeb. Wert φ
gegebener Wert R_n
gegeb. Wert
Lösung
gegeb. Wert Q
Beispiel
gegeben: R_a = 10 kg
φ = 60°
S = 70 kg
Q = 80 kg
R_n = 70 kg
Lösung: R_w = 84 kg
$R_w = \sqrt{R_n^2 + Q^2 + 2Q(R_a \sin\varphi - S\cos\varphi)}$
Schlüssel
$(R_a; \varphi)-S-I-(R_n, Q)-R_w$
R_a kg
R_w kg
S_{kg}
R_n kg
Q_{kg}
I

Lambert's graphical construction





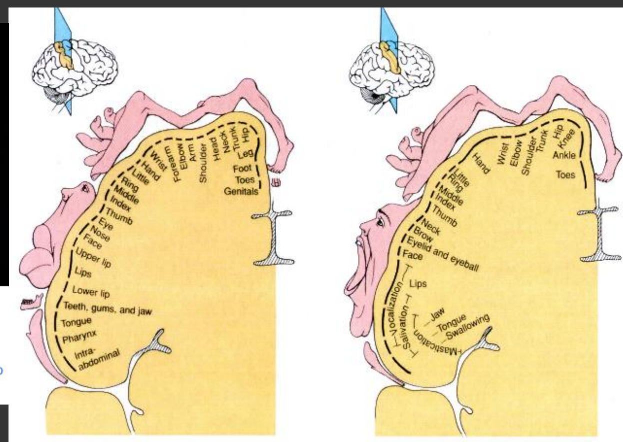
Johannes Lambert used graphs to study the rate of water evaporation as function of temperature [from Tufte 83]



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

Focus + Context

This model shows what a man's body would look like if each part grew in proportion to the area of the cortex of the brain concerned with its sensory perception. The hands and lips dominate — but the feet are also disproportionately large, indicating their sensory importance.



(a) Somatosensory cortex in right cerebral hemisphere

(b) Motor cortex in right cerebral hemisphere

Degree-of-Interest [Furnas 81, 06]

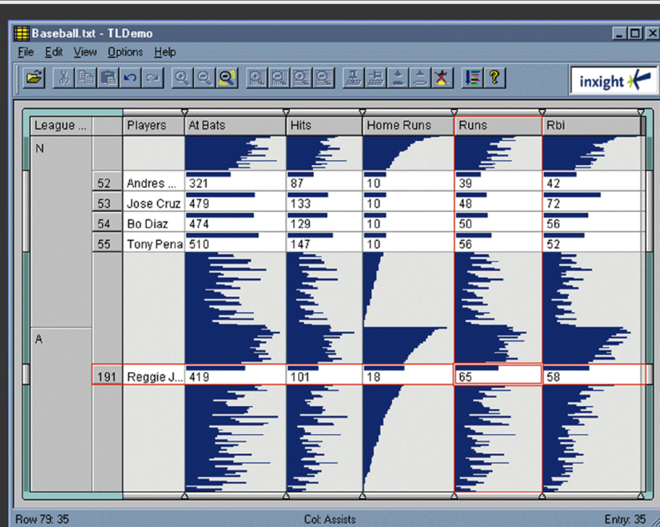
Estimate the saliency of information to display
Can affect *what* is shown and/or *how* to show it

DOI ~ f(Current Focus, A Priori Importance)

Example: Google Search

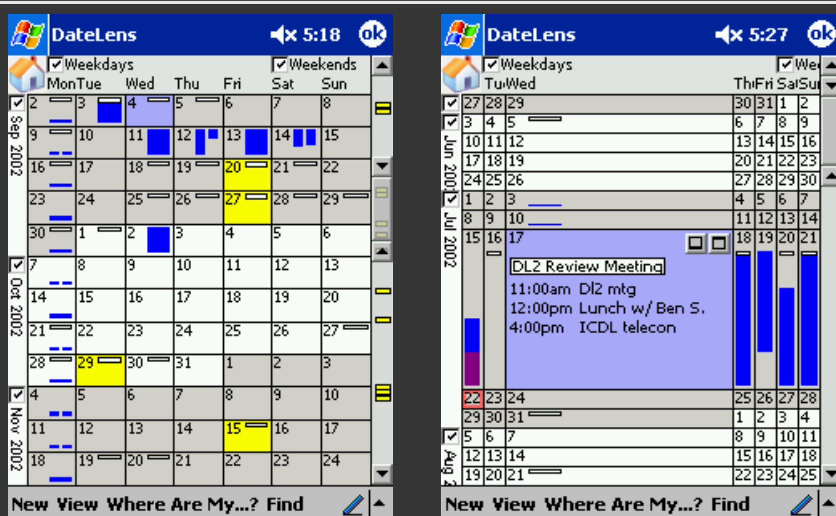
- **Current Focus = Query Hits (e.g., TF.IDF score)**
- **A Priori Importance = PageRank**
- ***What*: Top N results, *How*: List**

TableLens [Rao & Card 94]



http://www.youtube.com/watch?v=qWqTrRAC52U

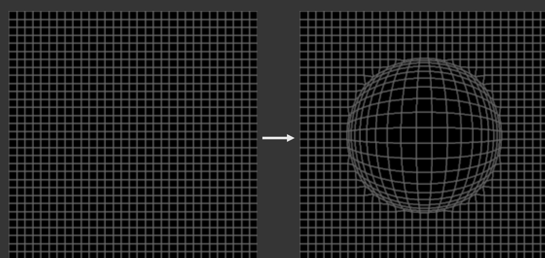
Datelens

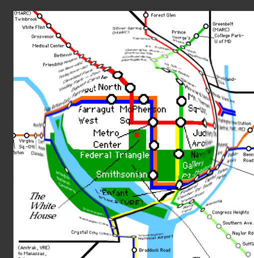


[Bederson et al. 04]

Single view detail + context

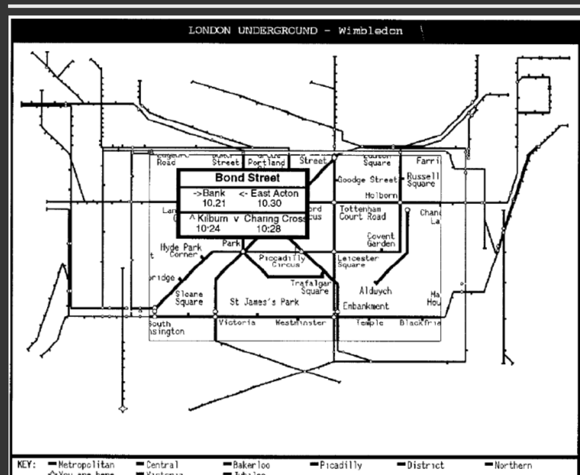
- Focus area – local details
- De-magnified area – surrounding context
- Like a rubber sheet with borders tacked down

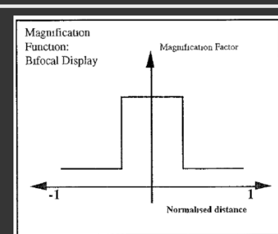


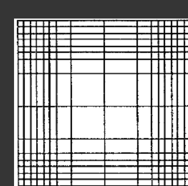


Nonlinear Magnification Infocenter [http://www.cs.indiana.edu/%7Etkeahey/research/nlm/nlm.html]

Bifocal display [Leung and Apperley 94]

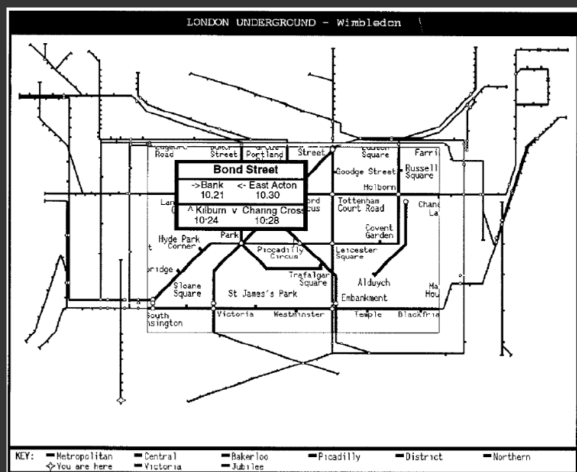


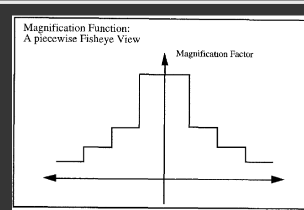




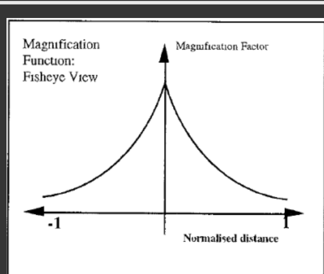
2D distortion

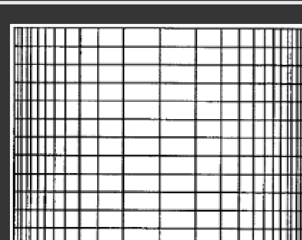
Multifocal display [Leung and Apperley 94]



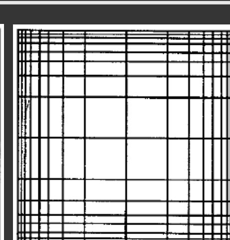


Fisheye [Leung and Apperley 94]

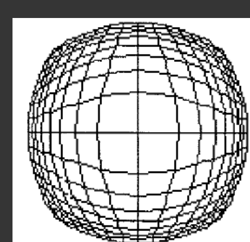




1D

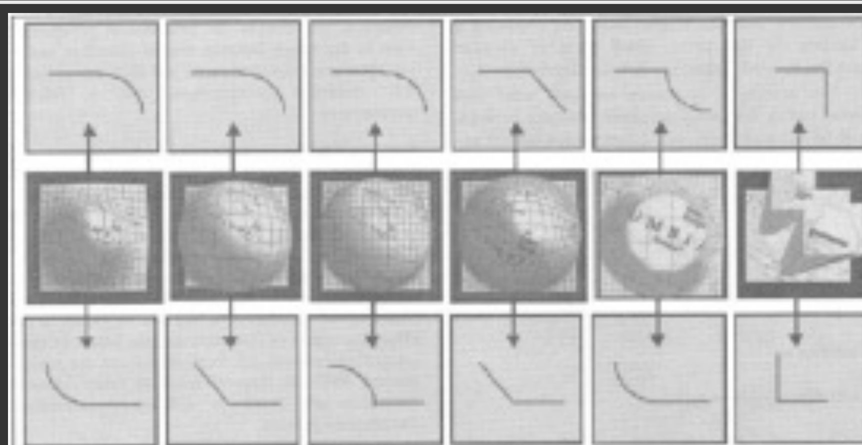


2D



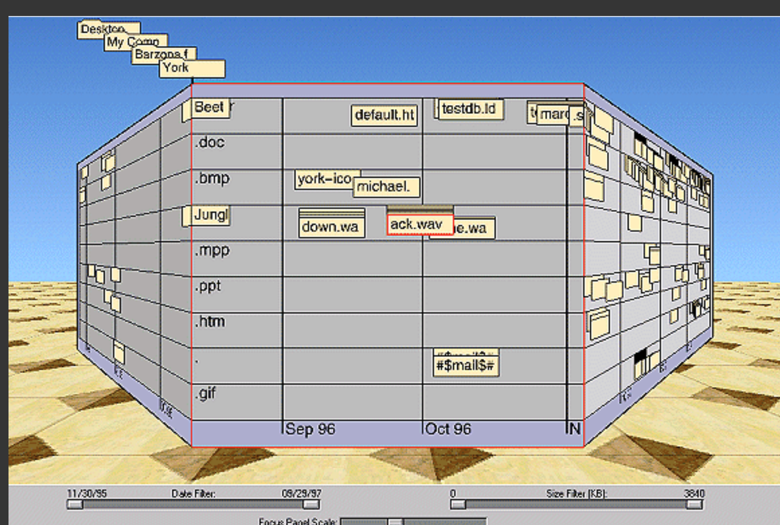
Polar

6 types of distortions [Carpendale & Montagnese 01]



Gaussian, Cosine, Hemisphere, Linear, Inverse Cosine and Manhattan. Top row shows transition from focus to distortion, bottom row from distortion to context.

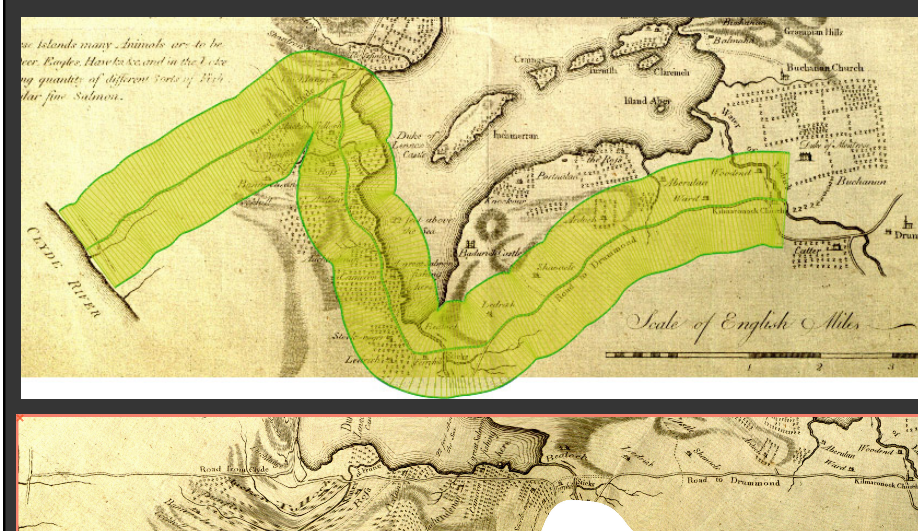
Perspective allows more context



Perspective Wall [Mackinlay et al. 91]

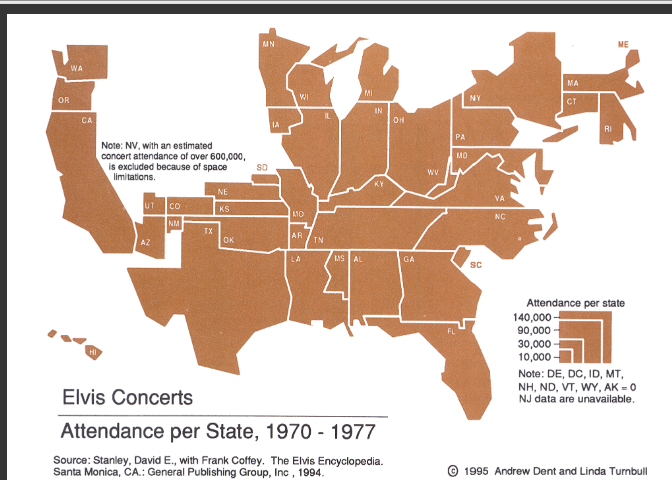
Distortions

Transmogrifiiers [Brosz et al. 13]



http://www.transmogrifiers.org/

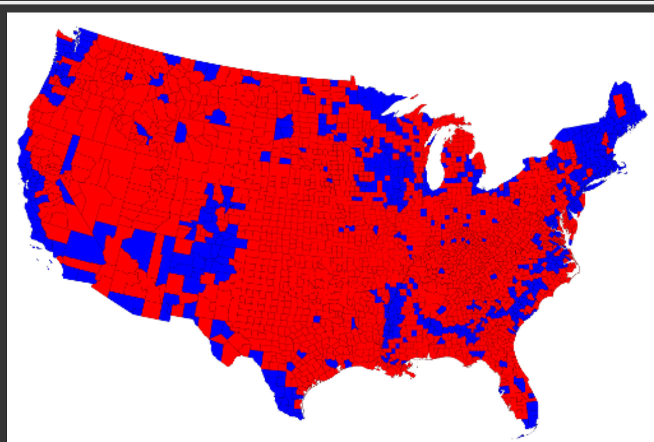
Cartograms: Distort areas



Scale area by data

[From *Cartography*, Dent]

Election 2012 map

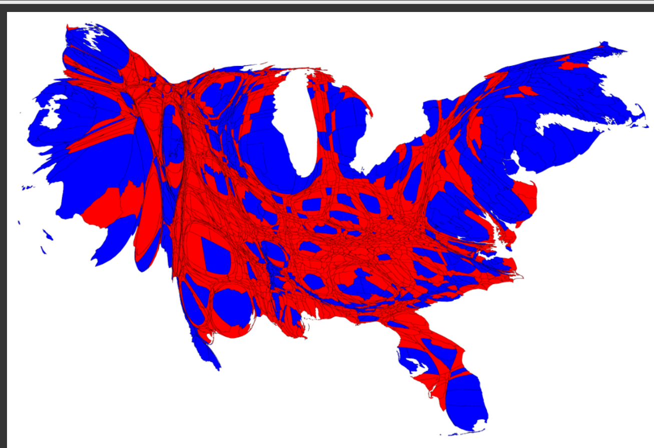


% voted democrat

% voted republican

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

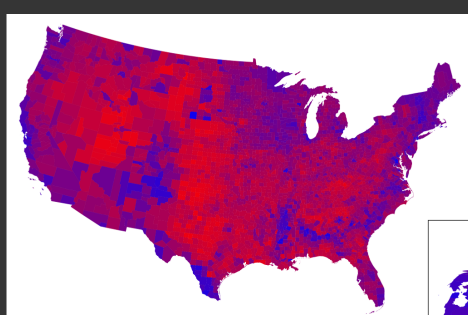
Election 2012 map

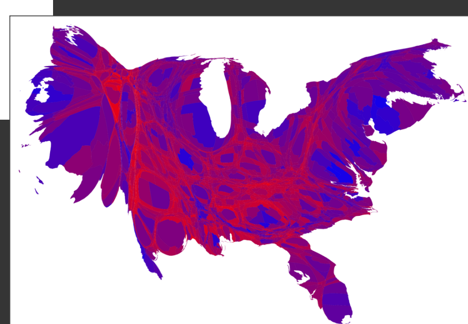


% voted democrat
% voted republican

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

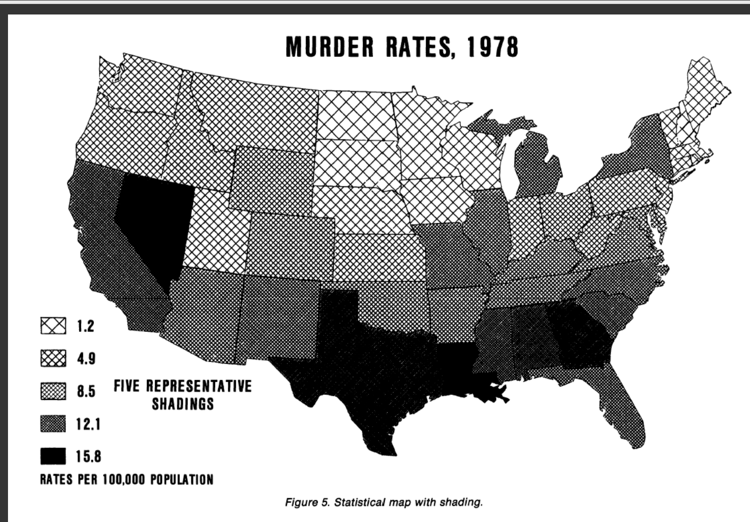
Election 2012 map





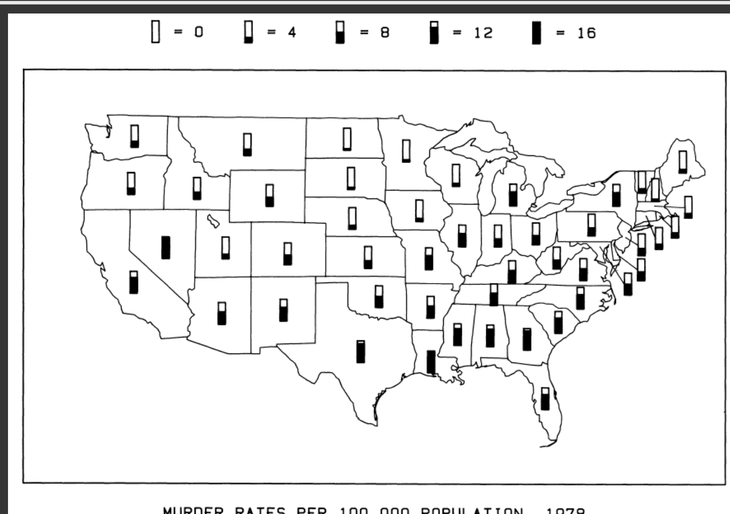
http://www-personal.umich.edu/~mejn/election/

Statistical map with shading



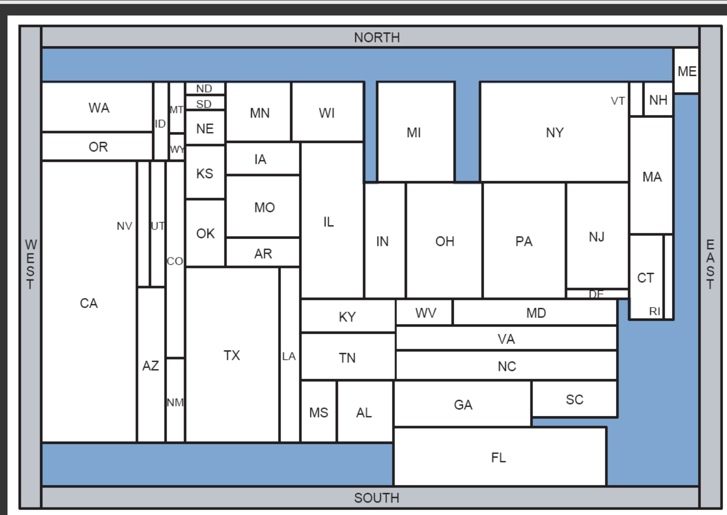
[Cleveland and McGill 84]

Framed rectangle chart



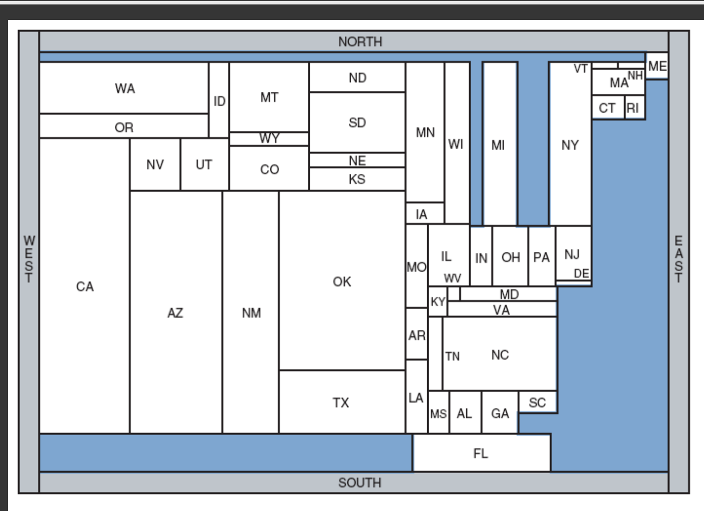
[Cleveland and McGill 84]

Rectangular cartogram



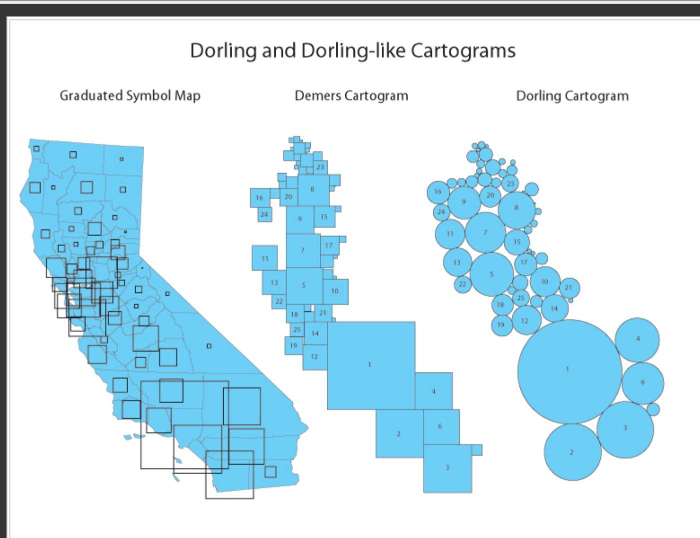
American population [van Kreveld and Speckmann 04]

Rectangular cartogram



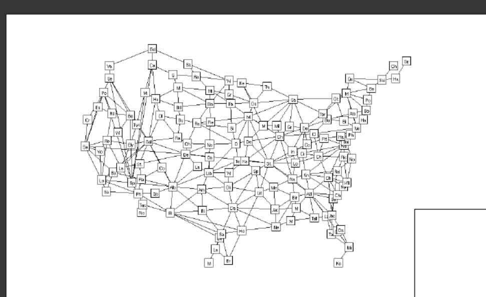
Native American population [van Kreveld and Speckmann 04]

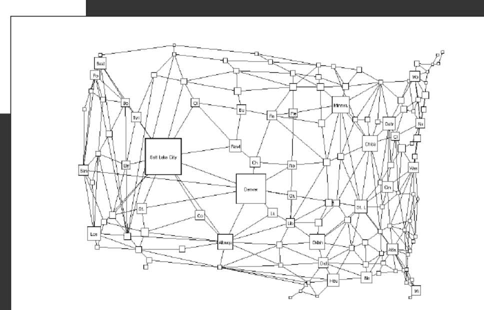
Dorling cartogram



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

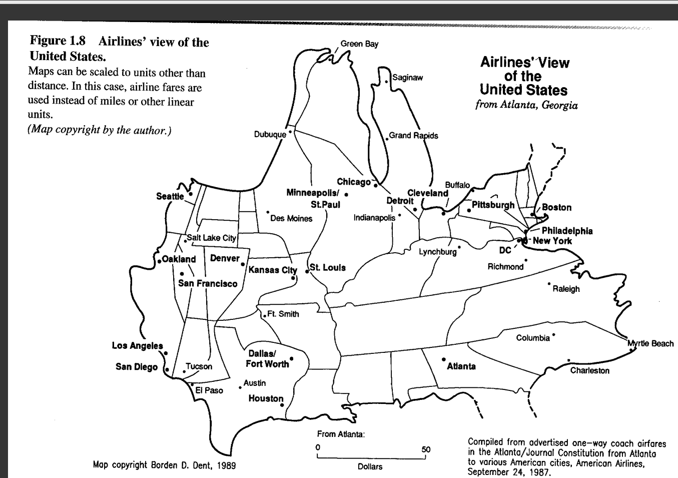
States as nodes in a graph





Graphical fisheye views of graphs [Sarkar & Brown 92]

Distorting distances



Scale distance by data (airline fare)

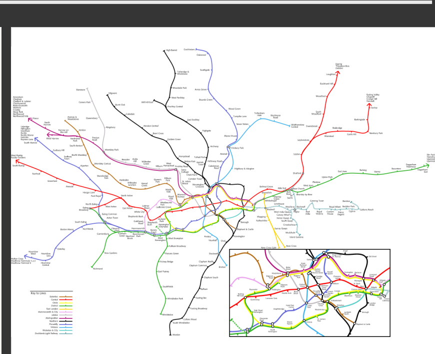
[From *Cartography*, Dent]

London underground

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

Comparison to geographic map

Distorted



Undistorted

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