Using Space Effectively: 2D

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CS 294-10: Visualization
Spring 2011

Last Time: Color

What is Color?

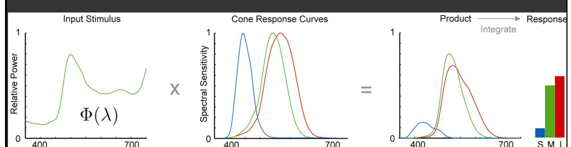
Physical World → Visual System → Mental Models

Lights, surfaces, objects → Eye, optic nerve, visual cortex → Red, green, brown

Bright, light, dark, vivid, colorful, dull

Warm, cool, bold, blah, attractive, ugly, pleasant, jarring

Computing Cone Response



$$L = \int \Phi(\lambda) L(\lambda) d\lambda$$

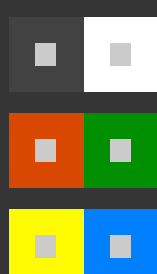
$$M = \int \Phi(\lambda) M(\lambda) d\lambda$$

$$S = \int \Phi(\lambda) S(\lambda) d\lambda$$

Simultaneous Contrast

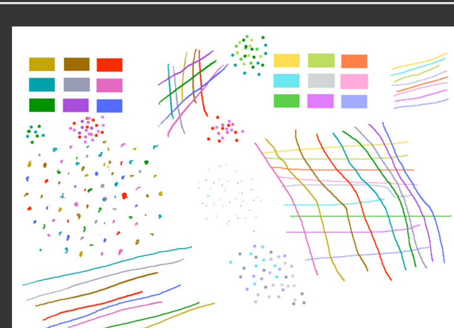
Add Opponent Color

- Dark adds light
- Red adds green
- Blue adds yellow

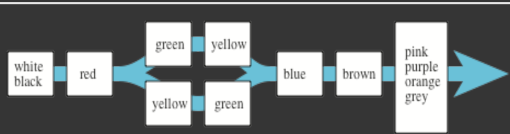


These samples will have both light/dark and hue contrast

Distinct, but hard to name



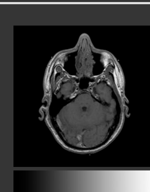
Color Names

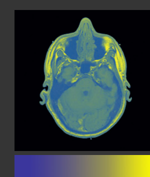


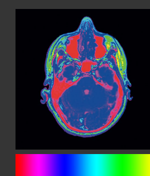
Basic names (Berlin & Kay)
- Linguistic study of names
- Similar names
- Similar evolution
- Hierarchy of names
  - Names appear in languages in order from left to right

Distinct colors = distinct names?

Density Map

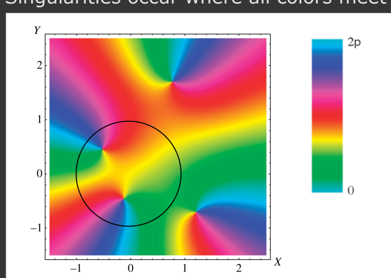

Lightness scale


Lightness scale with hue and chroma variation


Hue scale with lightness variation

Phase Diagrams (hue scale)

Singularities occur where all colors meet



The optical singularities of bianisotropic crystals, by M. V. Berry

Phases of the Tides

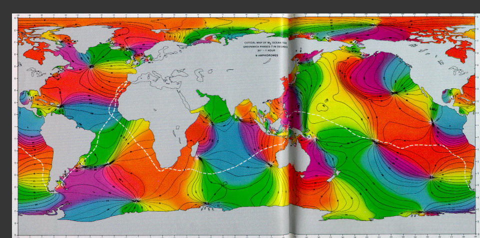
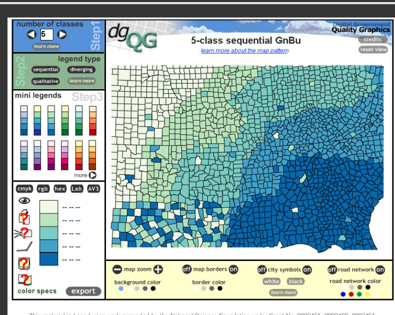


Figure 1.9. Cotidal chart. Tide phases relative to Greenwich are plotted for all the world's oceans. Phase progresses from red to orange to yellow to green to blue to purple. The lines converge on anphidromic points, singularities on the earth's surface where there is no defined tide. [Winfree, 1987 #1195 , p. 17].

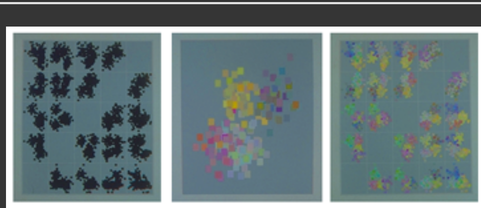
Color Brewer



www.colorbrewer.org

Multivariate Color Sequences

Multi-dimensional Scatter plot



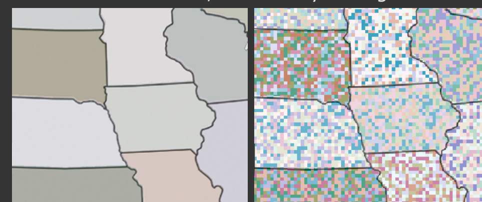
Variable 1, 2 → X, Y
Variable 3, 4, 5 → R, G, B

Do people interpret color blends as sums of variables?

Using Color Dimensions to Display Data Dimensions
Beatty and Ware

Color Weaves

6 variables = 6 hues, which vary in brightness



Additive mixture (blend) — Spatial texture (weave)

Weaving versus Blending (APGV06 and SIGGRAPH poster)
Haleh Hagh-Shenas, Victoria Interrante, Christopher Healey and Sunghee Kim

Controlling Value

Get it right in black & white

Value
- Perceived lightness/darkness
- Controlling value primary rule for design

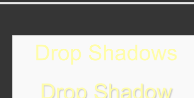
Value defines shape
- No edge without lightness difference
- No shading without lightness variation

Value difference (contrast)
- Defines legibility
- Controls attention
- Creates layering

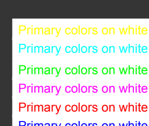
Controls Legibility

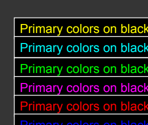
colorusage.arc.nasa.gov

Legibility



Drop shadow adds edge





Readability

If you can't use color wisely,
it is best to avoid it entirely
Above all, do no harm

If you can't use color wisely,
it is best to avoid it entirely
Above all, do no harm.

Why does the logo work?

Value Control

Legibility and Contrast

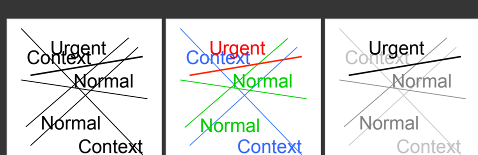
Legibility
- Function of contrast and spatial frequency
- "Psychophysics of Reading" Legge, et. al.

Legibility standards
- 5:1 contrast for legibility (ISO standard)
- 3:1 minimum legibility
- 10:1 recommended for small text

How do we specify contrast?
- Ratios of foreground to background luminance
- Different specifications for different patterns

Contrast and Layering

Value contrast creates layering



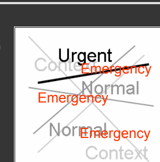
colorusage.arc.nasa.gov

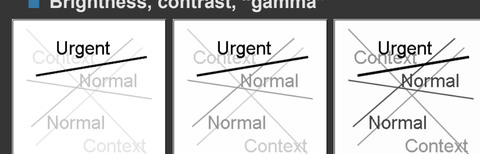
What Defines Layering?

Perceptual features
- Contrast (especially lightness)
- Color, shape and texture

Task and attention
- Attention affects perception

Display characteristics
- Brightness, contrast, "gamma"





Contrast

General formulation

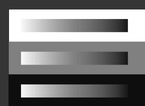
- Luminance difference (L_f, L_b)
- Depends on adaptation and size

Small symbols, solid background (Weber)

- $C = (L_f - L_b)/L_b$
- Adapted to background

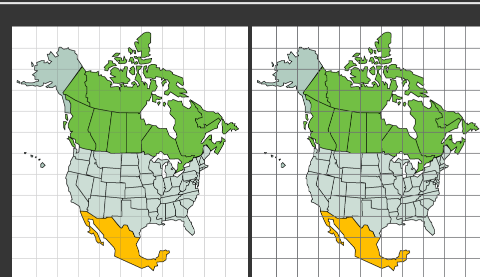
Textures, high frequency patterns (Michelson)

- $C = (L_f - L_b)/(L_f + L_b)$
- Adapted to average



Luminance is intensity
modulated by wavelength sensitivity

Grid Example



Grid sits unobtrusively in the background — Grid sits in foreground, obscuring map

Great Grids: How and Why? (APGV06 and SIGGRAPH poster)
Maureen Stone, Lyn Bartram and Diane Gromala

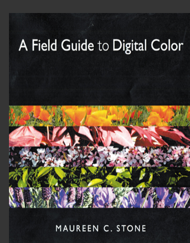
Additional Resources

Maureen Stone's website

- http://www.stonesc.com/Vis06
- Final copy of slides, references

A Field Guide to Digital Color

- A.K. Peters



Announcements

Assignment 3: Visualization Software

Create a small interactive visualization application – you choose data domain and visualization technique.

1. Describe data and storyboard interface
2. Implement interface and produce final writeup
3. Submit the application and a final writeup on the wiki

Can work alone or in pairs

Final write up due before class on Mar 7, 2011

Final project

Design new visualization method

- Pose problem, Implement creative solution

Deliverables

- Implementation of solution
- 8-12 page paper in format of conference paper submission
- 2 design discussion presentations

Schedule

- Project proposal: 3/14
- Project presentation: 4/4
- Final paper and presentation: TBD

Grading

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

Using Space Effectively: 2D

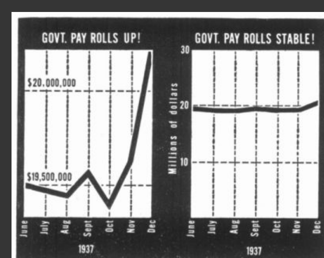
Topics

- Displaying data in graphs
- Banking to 45 degrees
- Fitting data and depicting residuals
- Graphical calculations
- Zooming and distortion

Graphs and Lines

Effective use of space

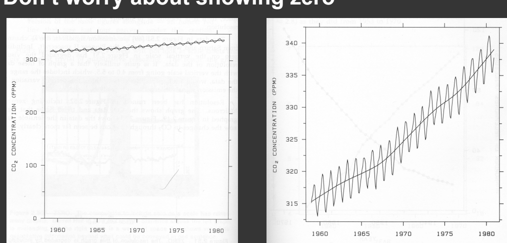
Which graph is better?



Government payrolls in 1937 [How To Lie With Statistics. Huff 93]

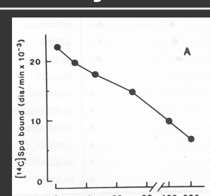
Aspect ratio

Fill space with data
Don't worry about showing zero

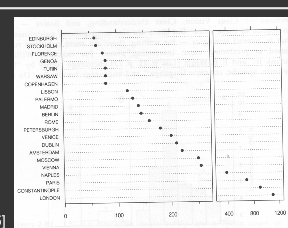


Yearly CO2 concentrations [Cleveland 85]

Clearly mark scale breaks

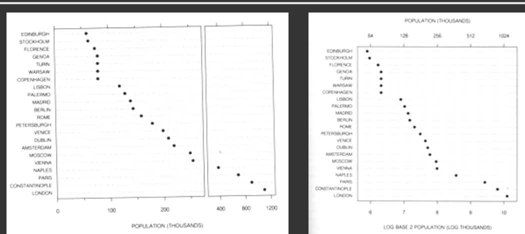


Poor scale break [Cleveland 85]



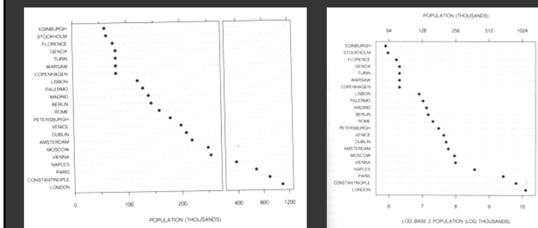
Well marked scale break [Cleveland 85]

Scale break vs. Log scale



[Cleveland 85]

Scale break vs. Log scale

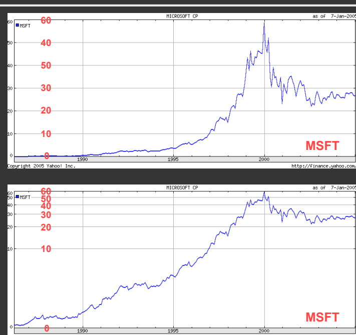


[Cleveland 85]

Both increase visual resolution

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

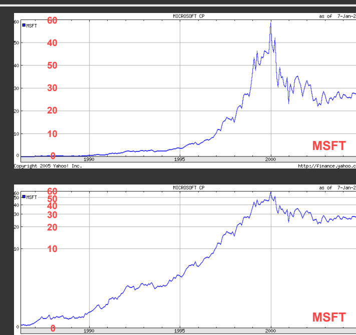
Linear scale vs. Log scale



Linear scale vs. Log scale

Linear scale

- Absolute change



Log scale

- Small fluctuations
- Percent change

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

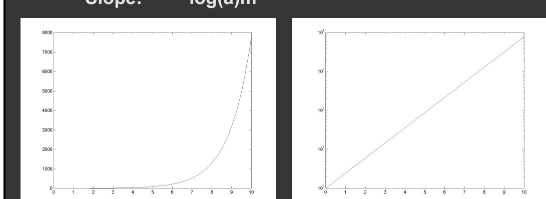
Semilog graph: Exponential growth

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

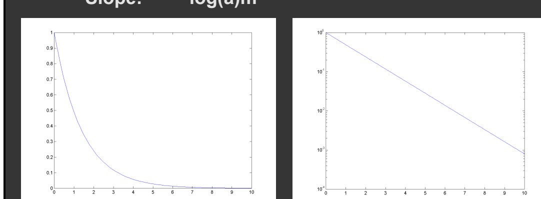
Semilog graph: Exponential decay

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

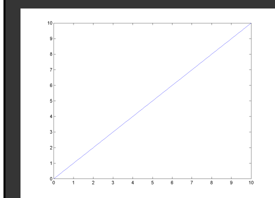
Semilog graph: Lines

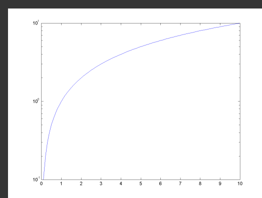
Exponential functions ($y = ka^{mx}$) transform into lines

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

Intercept: $\log(k)$

Slope: $\log(a)m$



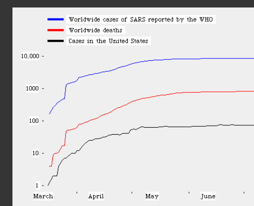


$y = x$, slope in semilog gives instantaneous : $\log(a)m$

Semilog graph

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

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



SARS cases up March – July 7, 2003

http://www.squeak.org/us/ted/sars-graph.html

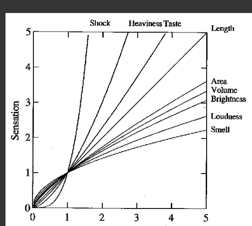
AIDS Cases: http://www.righto.com/java/statsgraph.html

Log-Log graph

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

Example - Steven's power laws:

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

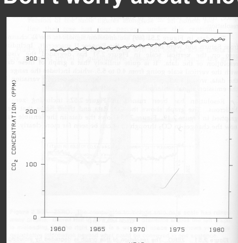


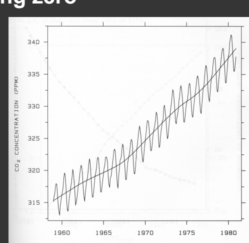
Banking to 45 Degrees

Aspect ratio

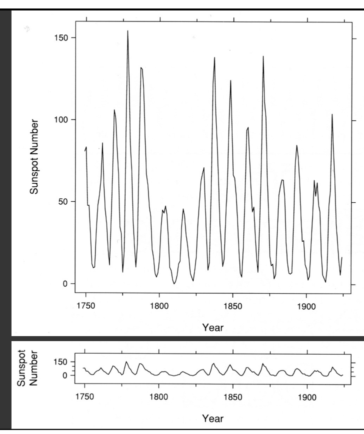
Fill space with data

Don't worry about showing zero





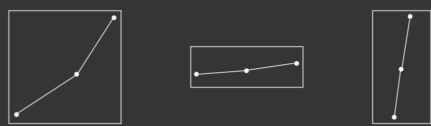
Yearly CO2 concentrations [Cleveland 85]



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 their average absolute angle 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)

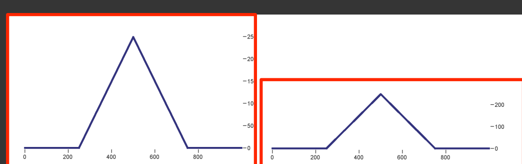
$$\sum_i \sum_j |\theta_i(\alpha) - \theta_j(\alpha)|^2$$

Local (over adjacent segments)

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

Requires Iterative Optimization

Slopeless line culling



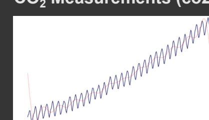
Standard, Aspect Ratio = 1.97

Culled, Aspect Ratio = 4.00

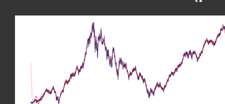
Exclude line segments with zero or infinite slope

Comparison data sets

CO_2 Measurements (co2)

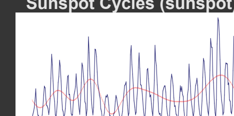


PRMTX Mutual Fund (prmtx)

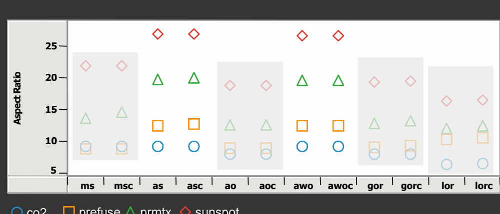


Prefuse Downloads

Sunspot Cycles (sunspot)

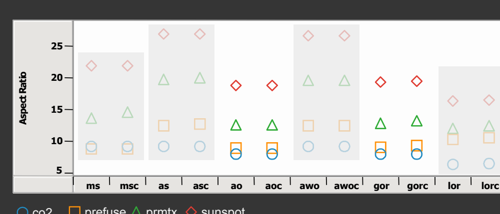


Comparison (Results)



Average-slope (as) and Average-weighted-orientation (awo) provide similar ratios

Comparison (Results)



Average-orientation (ao) and Global-orientation-resolution (gor) provide similar ratios

Discussion

Due to computational complexity…

Prefer avg-slope to avg-weighted-orient

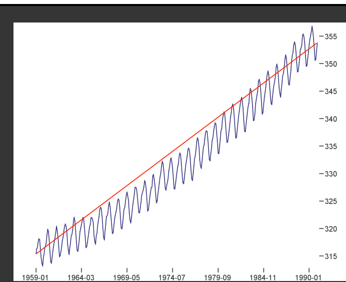
Prefer avg-orient to global-orient-resolution

But due to perceptual effectiveness… ?

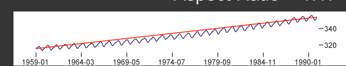
Cleveland recommends weighted-avg-orient

But, goal is to maximize discriminability

Perceptual experiments needed to clarify



Aspect Ratio = 1.17



Aspect Ratio = 7.87

CO_2 Measurements

William S. Cleveland
Visualizing Data

Multi-Scale Banking to 45°

Goal

Optimized aspect ratios for varying scales

Approach

Identify Scales of Interest

Generate Scale-Specific Trend Lines

Bank Trend Lines to 45°

Filter Resulting Aspect Ratios

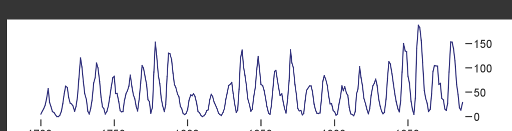
Multi-Scale Banking to 45°

Use Spectral Analysis to identify trends

Find strong frequency components

Lowpass filter to create trend lines

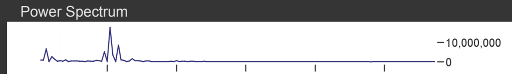
Compute Power Spectrum



Take Discrete Fourier Transform

Compute squared magnitudes

Power Spectrum



Smooth the Spectrum

Convolve with Gaussian filter

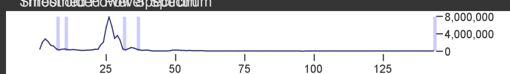
window size = 3, σ = 1

Smoothed Power Spectrum

Threshold the Spectrum

Threshold at mean of power spectrum
Retain last values of contiguous runs

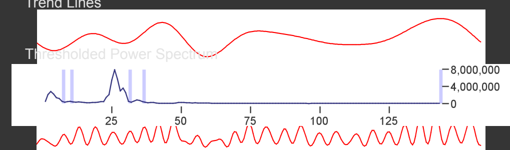
Thresholded Power Spectrum



Generate Trend Lines

Generate trend lines with lowpass filter

Trend Lines

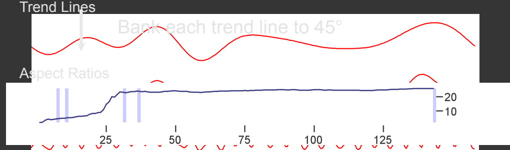


Bank Trend Lines to 45°

Trend Lines

Bank each trend line to 45°

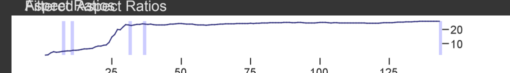
Aspect Ratios



Filter Aspect Ratios

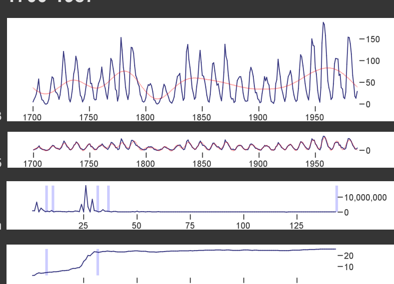
Filter similar aspect ratios
Keep if $\alpha_{i+1} > c\alpha_i$ (c=1.25 by default)

Filtered Aspect Ratios



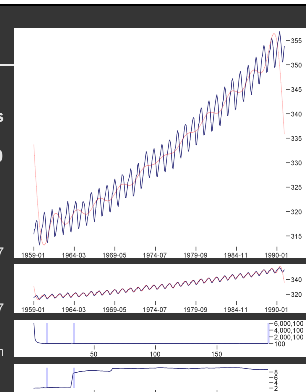
Sunspot Cycles

Yearly values 1700-1987



CO_2

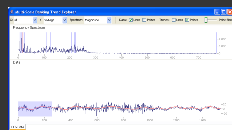
Monthly concentrations from the Mauna Loa Observatory, 1950-1990

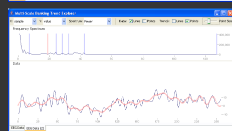


Applications

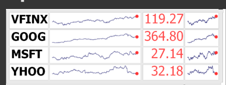
Small Multiples

Trend Explorer

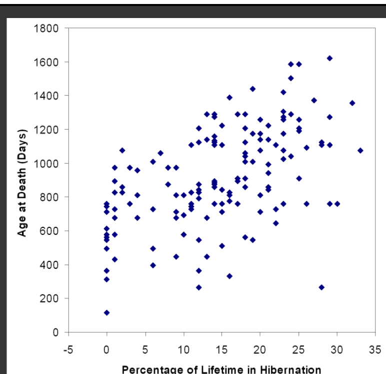




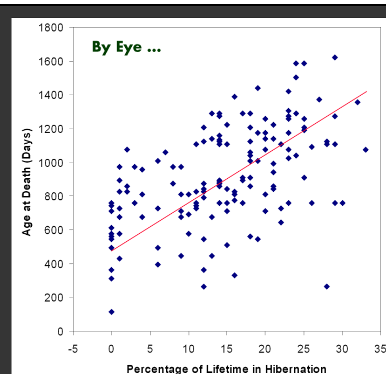
Sparklines



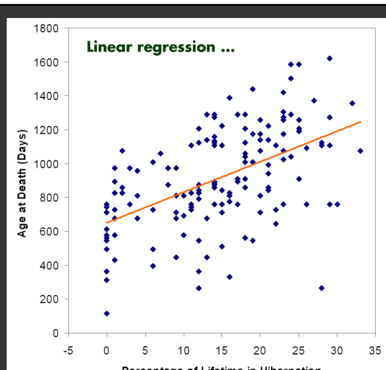
Fitting the Data



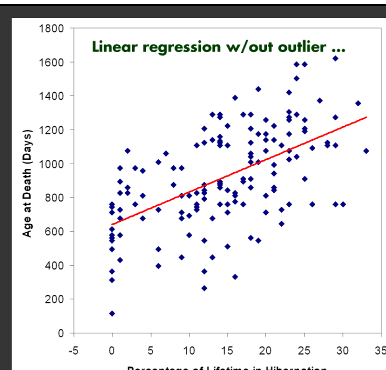
[The Elements of Graphing Data. Cleveland 94]



[The Elements of Graphing Data. Cleveland 94]



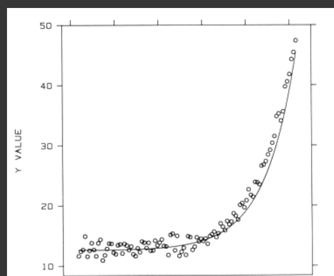
[The Elements of Graphing Data. Cleveland 94]



[The Elements of Graphing Data. Cleveland 94]

Transforming data

How well does curve fit data?

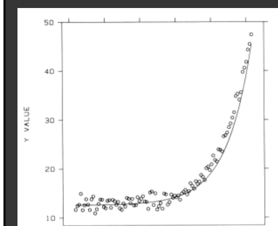


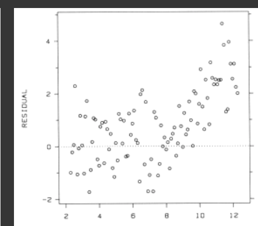
[Cleveland 85]

Transforming data

Residual graph

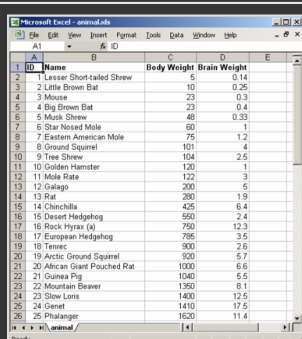
- Plot vertical distance from best fit curve
- Residual graph shows accuracy of fit





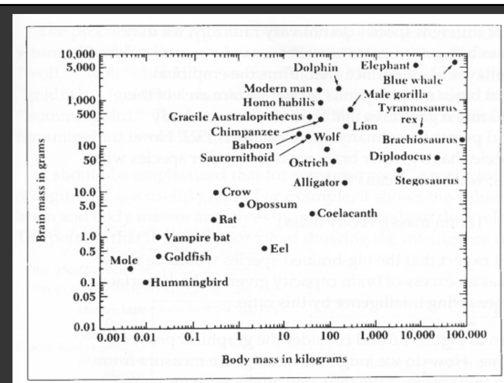
[Cleveland 85]

Most powerful brain?

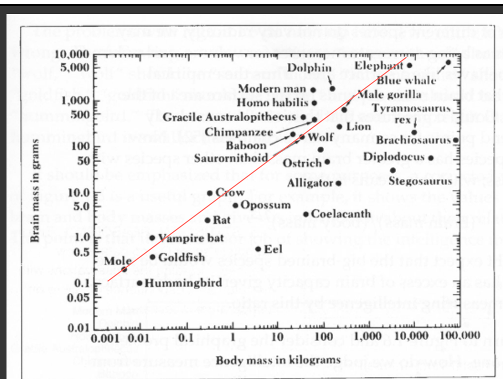


Microsoft Excel - animal.xls

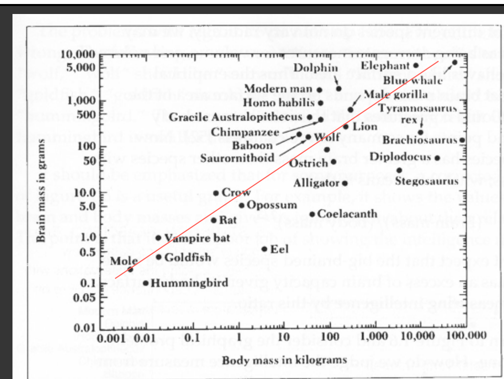
ID	Name	Body Weight	Brain Weight
1	Lesser Short-tailed Shrew	5	0.14
2	Little Brown Bat	10	0.25
3	Mouse	23	0.3
4	Big Brown Bat	23	0.4
5	Musk Shrew	48	0.33
6	Star Nosed Mole	60	1
7	Eastern American Mole	75	1.2
8	Ground Squirrel	101	4
9	Tree Shrew	104	2.5
10	Golden Hamster	120	1
11	Mole Rate	122	3
12	Galago	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



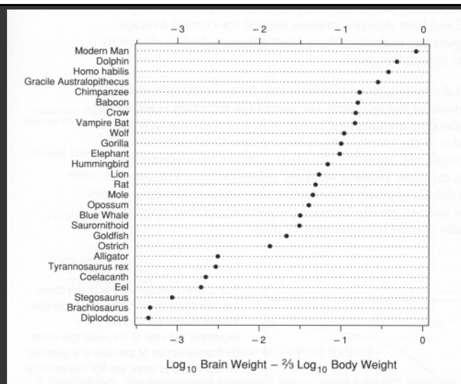
The Dragons of Eden [Carl Sagan]



The Dragons of Eden [Carl Sagan]



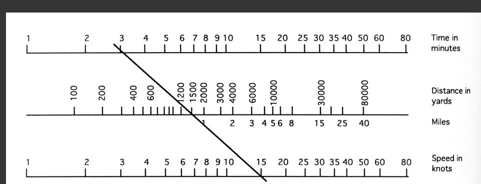
The Dragons of Eden [Carl Sagan]



The Elements of Graphing Data [Cleveland]

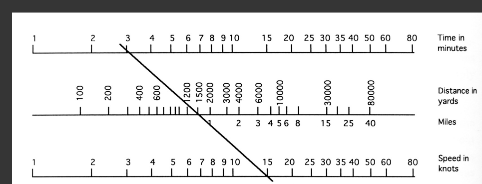
Graphical Calculations

Nomograms



Sailing: The Rule of Three

Nomograms

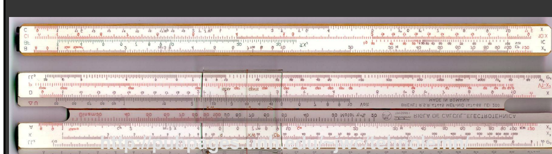


1. **Compute in any direction; fix n-1 params and read nth param**
2. **Illustrate sensitivity to perturbation of inputs**
3. **Clearly show domain of validity of computation**

Theory

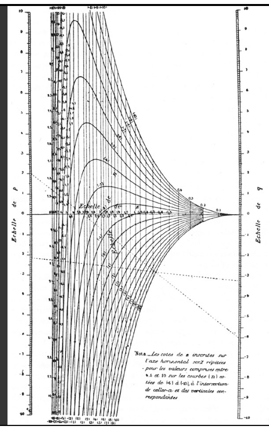
$$\begin{vmatrix} x_1(u) & y_1(u) & w_1(u) \\ x_2(v) & y_2(v) & w_2(v) \\ x_3(s,t) & y_3(s,t) & w_3(s,t) \end{vmatrix} = 0$$

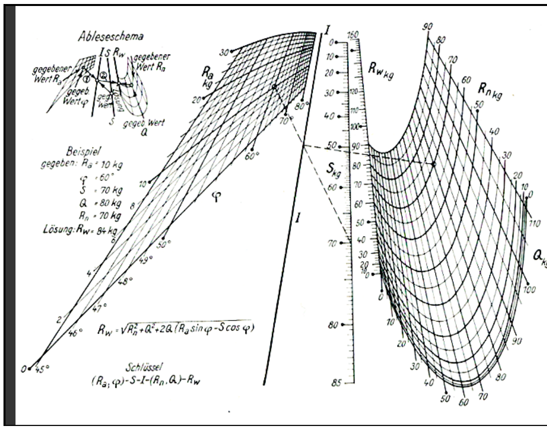
Slide rule



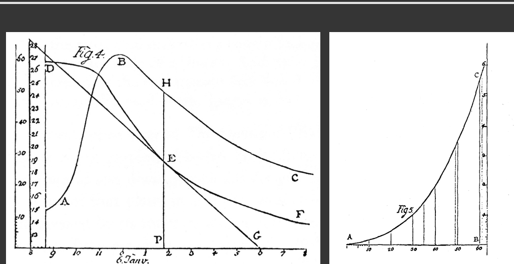
Model 1474-66 Electrotechnica 18 Scales

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

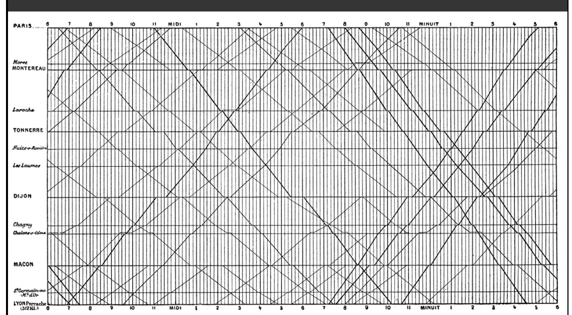




Lambert's graphical construction



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.