Using Space Effectively

Maneesh Agrawala

CS 448B: Visualization
Fall 2020

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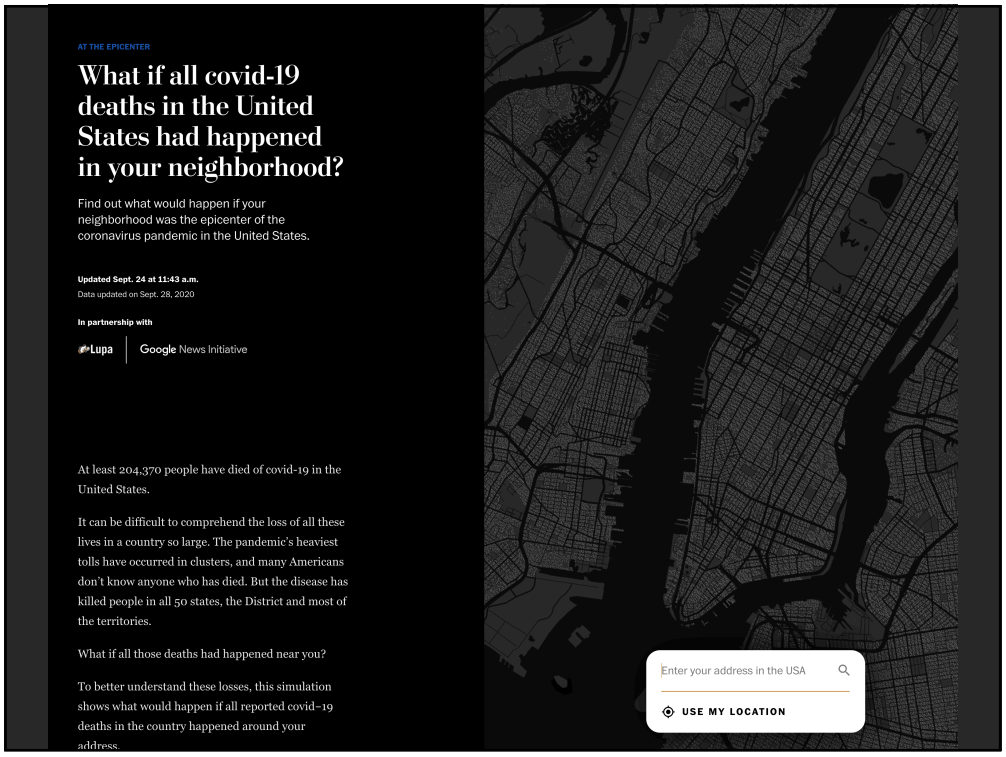

2

Last Time: EDA

3

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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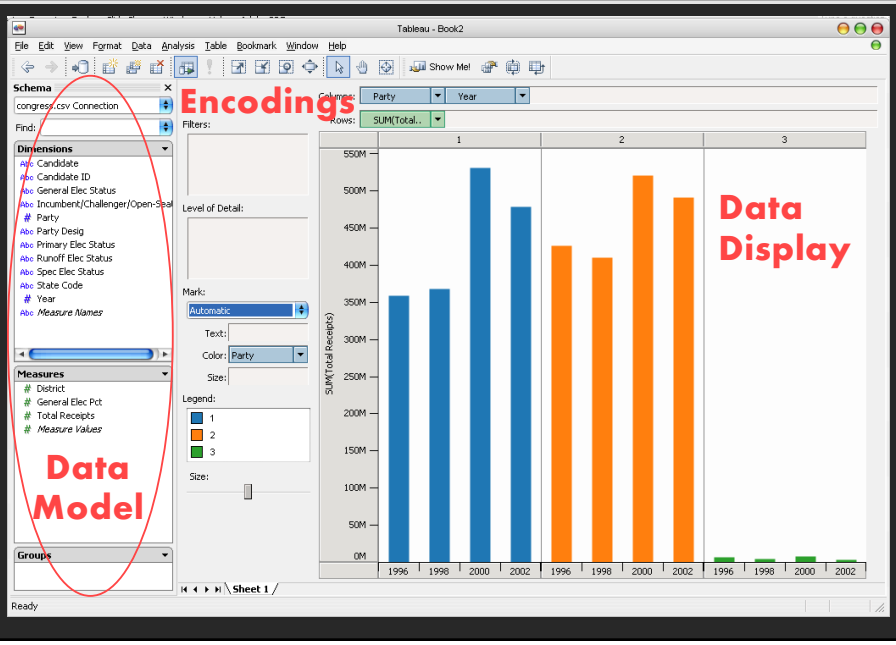
Tableau



5

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

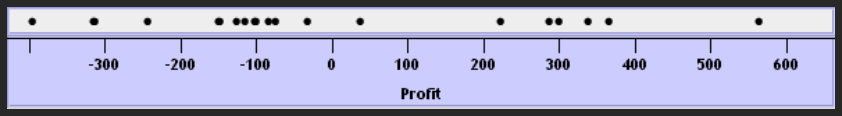
Ordinal fields: interpret domain as a set that partitions table into rows and columns

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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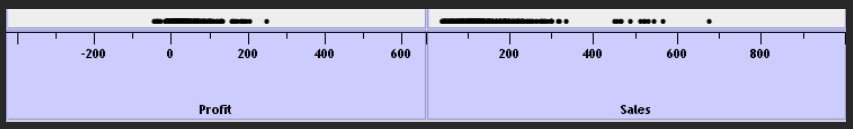
Concatenation (+) Operator

Ordered union of sets

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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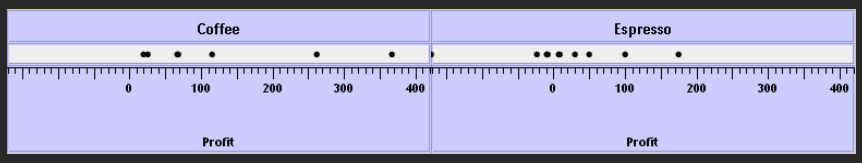
Cross (x) Operator

Cross-product of sets

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 =



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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)

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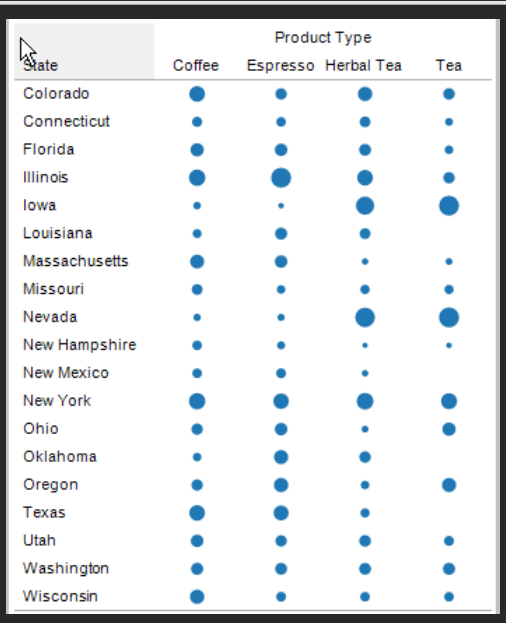
Ordinal - Ordinal



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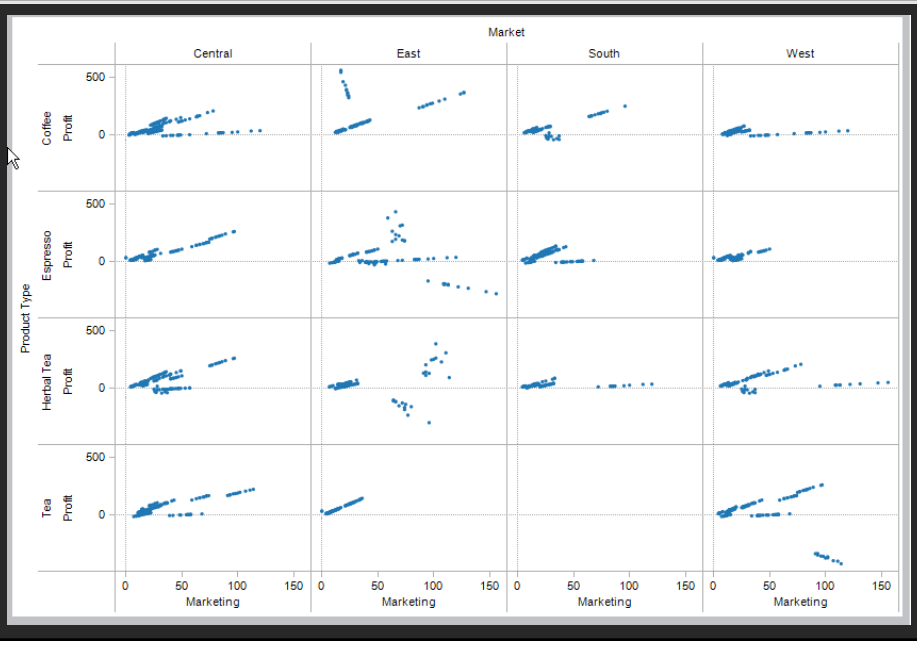
Quantitative - Quantitative



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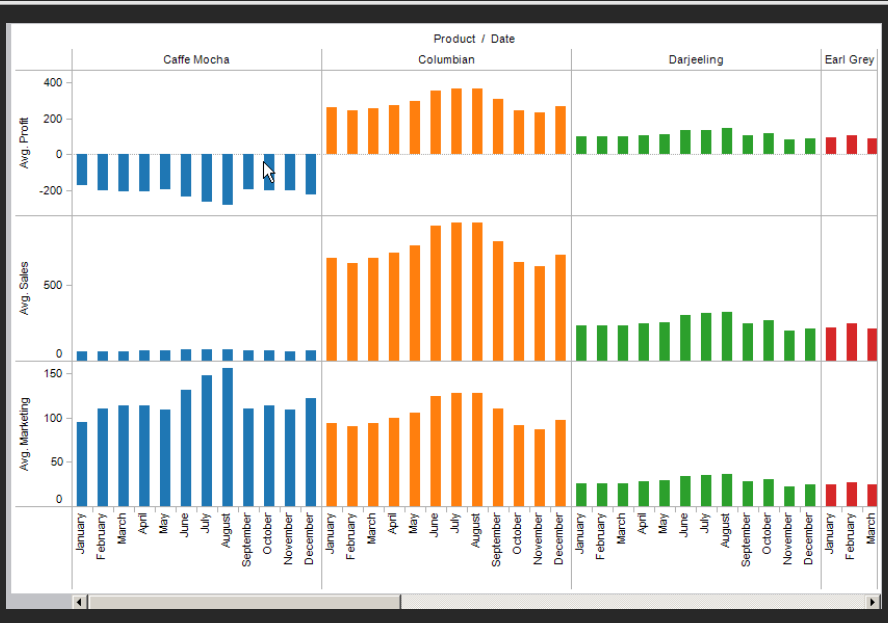
Ordinal - Quantitative



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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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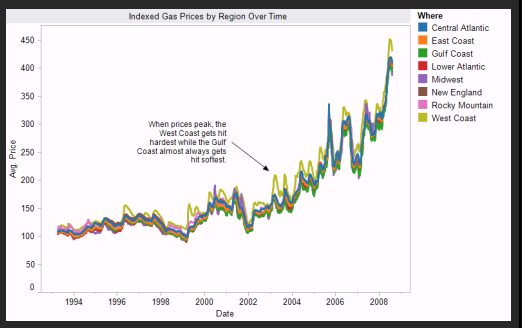
A2: Exploratory Data Analysis

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 Oct 6, 2020

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Using Space Effectively

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Topics

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

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Graphs and Lines

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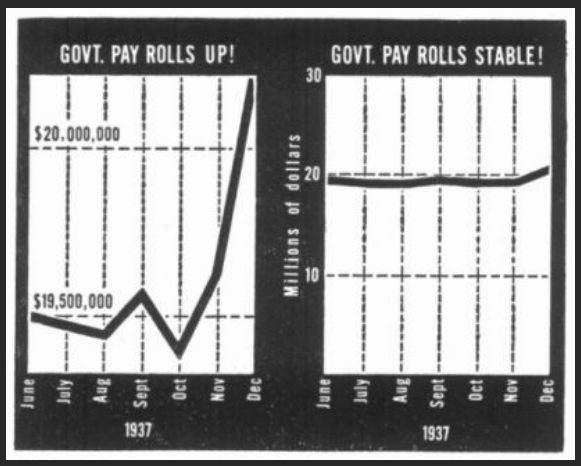
Effective use of space

Which graph is better?



Government payrolls in 1937 [Huff 93]

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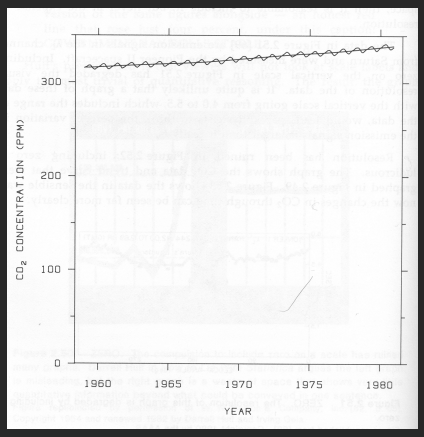
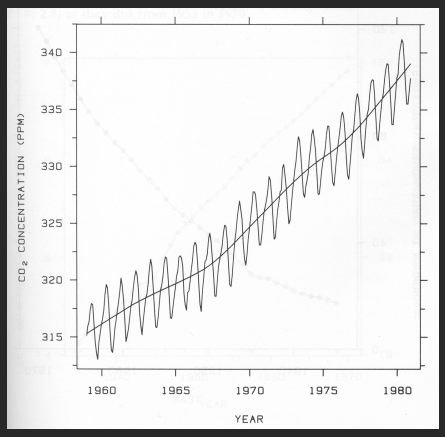
Fill space

Show data with as much resolution as possible
Don't worry about showing zero





Yearly CO2 concentrations [Cleveland 85]

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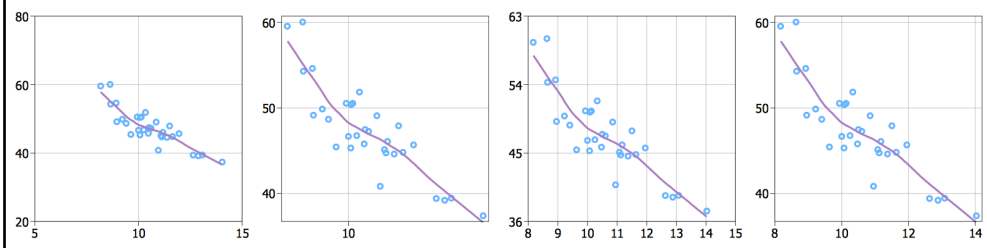
Axis Tick Mark Selection



What are some properties of "good" tick marks?

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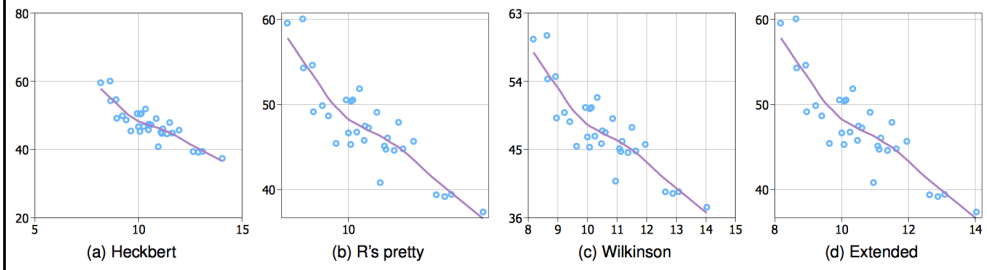
Axis Tick Mark Selection



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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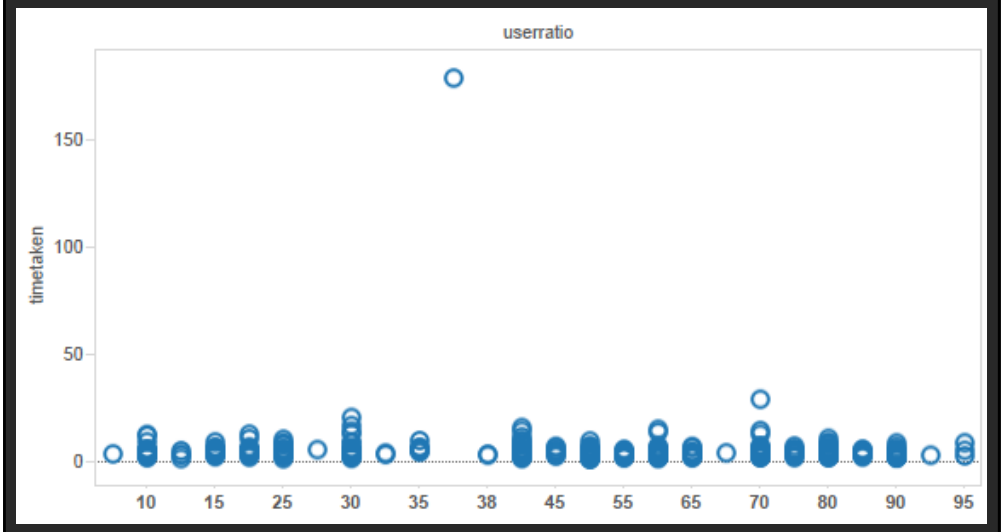
How to Scale the Axis?



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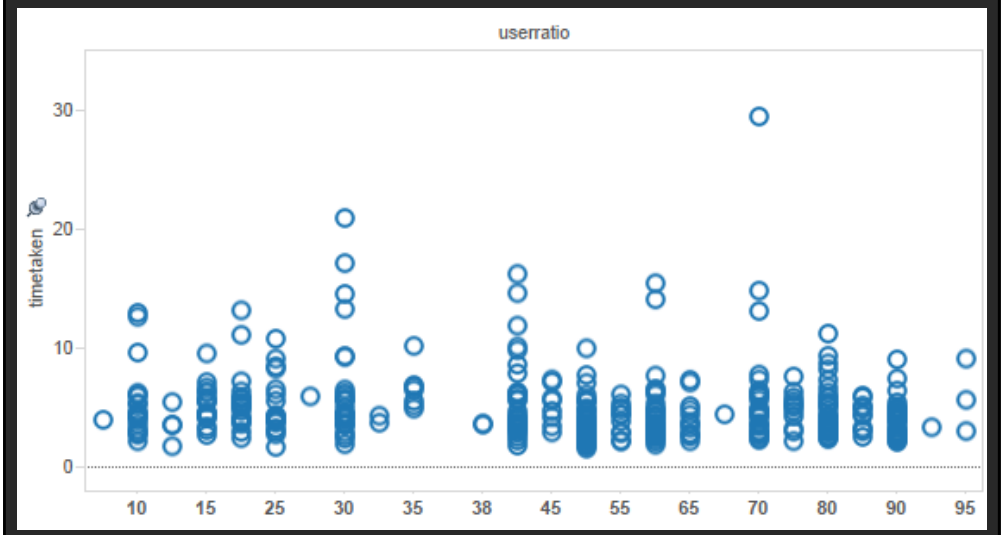
One Option: Clip Outliers



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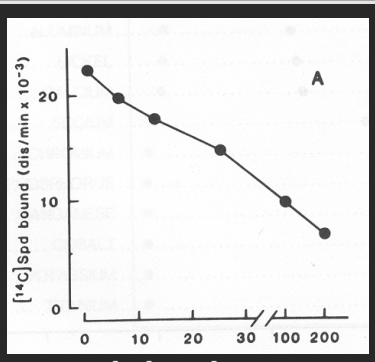
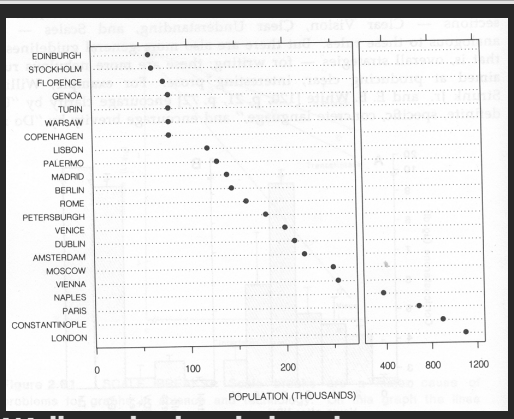
Clearly mark scale breaks



Poor scale break [Cleveland 85]



Well marked scale break [Cleveland 85]

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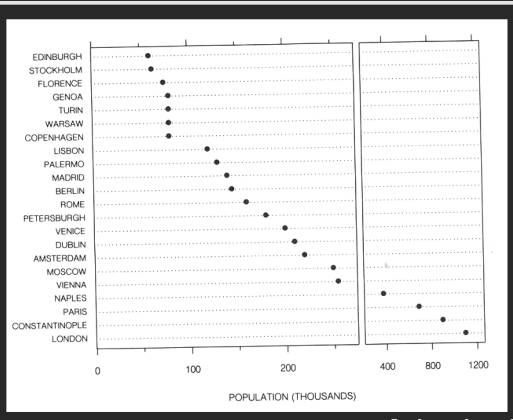
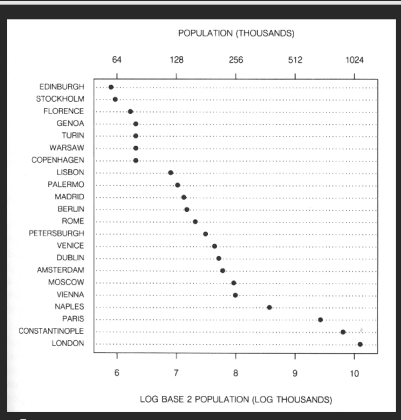
Scale break vs. Log scale





[Cleveland 85]

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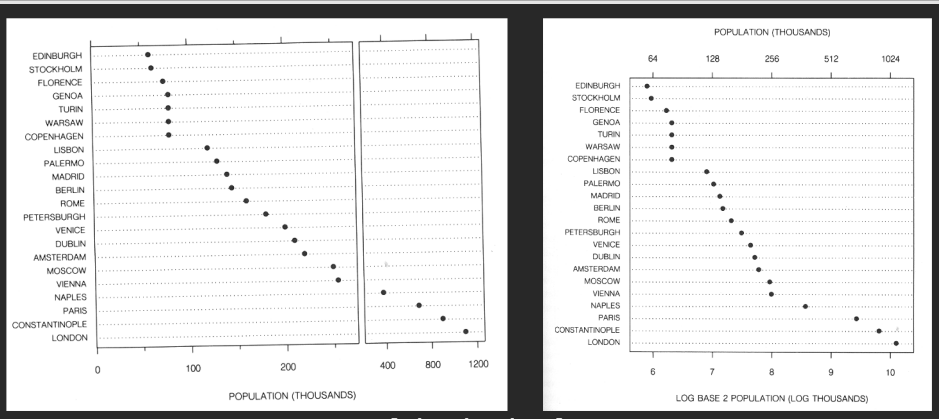
Scale break vs. Log scale



[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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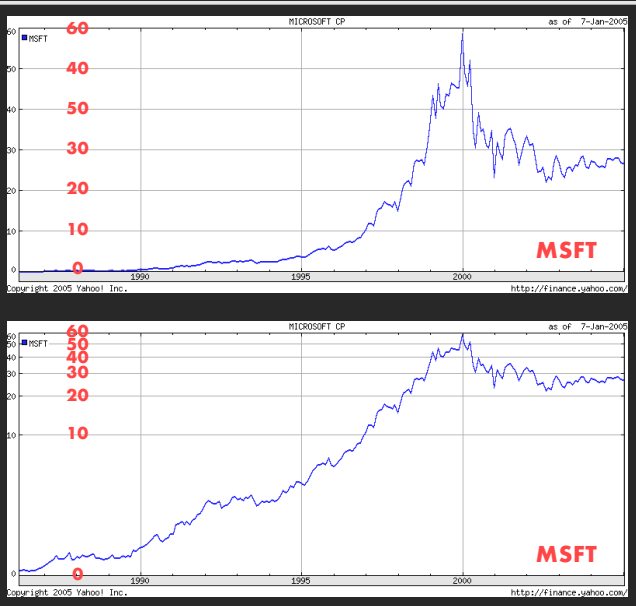
Linear scale vs. Log scale



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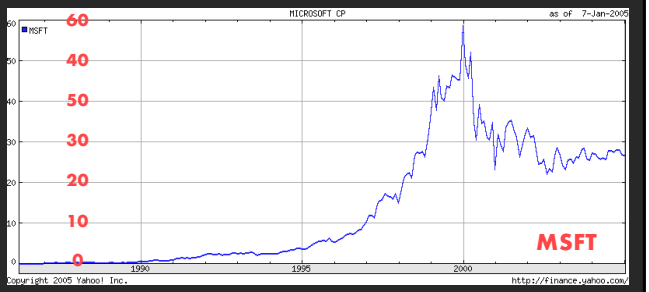
Linear scale vs. Log scale

Linear scale

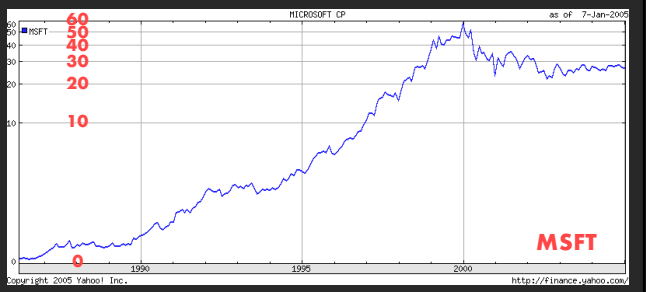
- Absolute change



Log scale

- Small fluctuations
- Percent change

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



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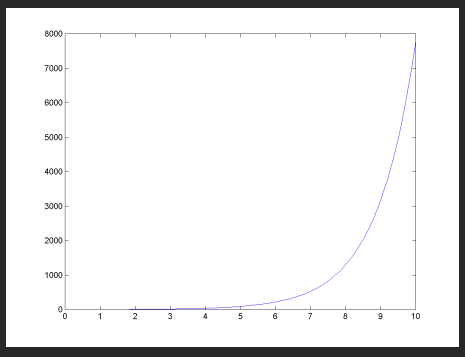
Semilog graph: Exponential growth

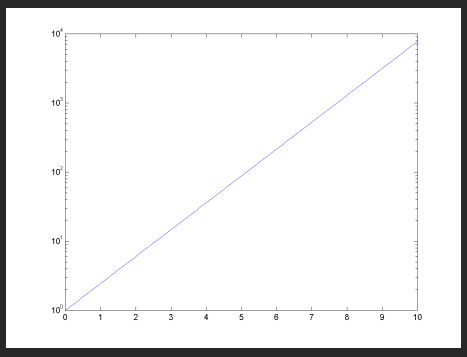
Exponential functions ($y = ka^{mx}$) transform into lines

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

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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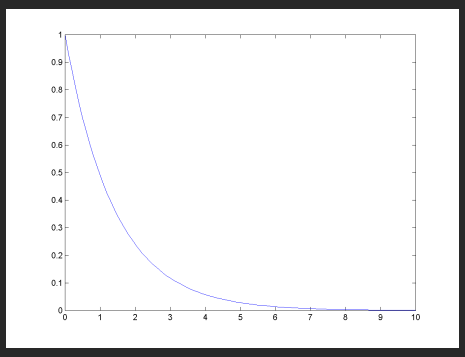
Semilog graph: Exponential decay

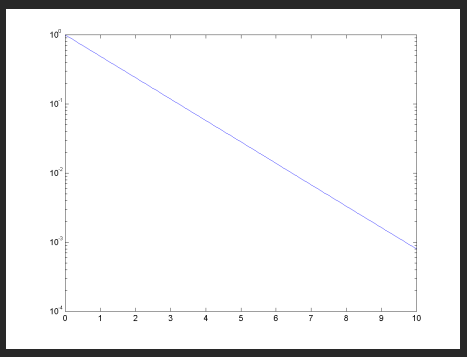
Exponential functions ($y = ka^{mx}$) transform into lines

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

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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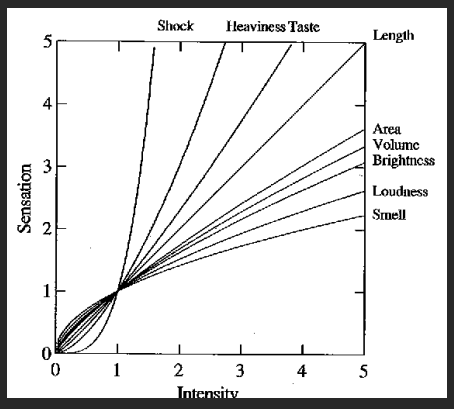
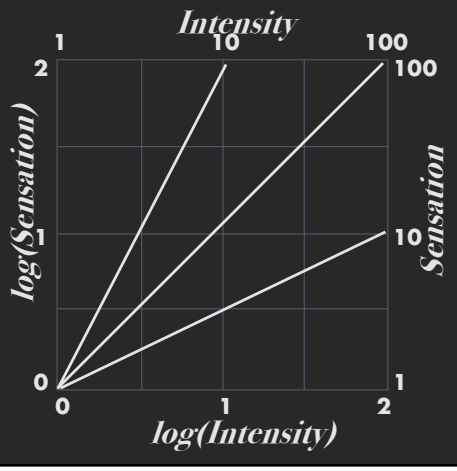
Log-Log graph

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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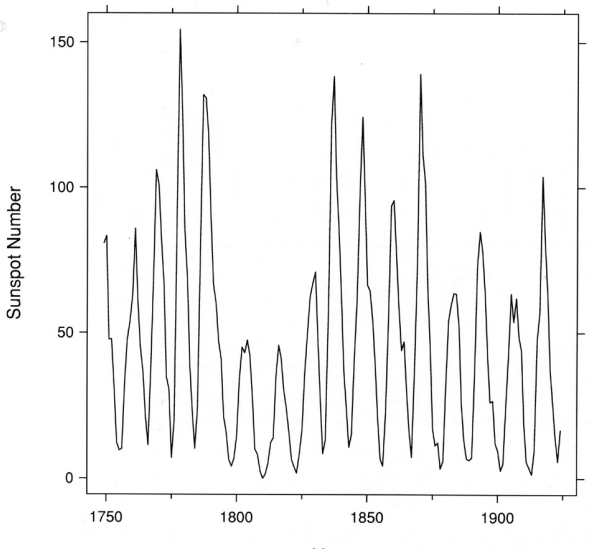

William S. Cleveland
The Elements of Graphing Data

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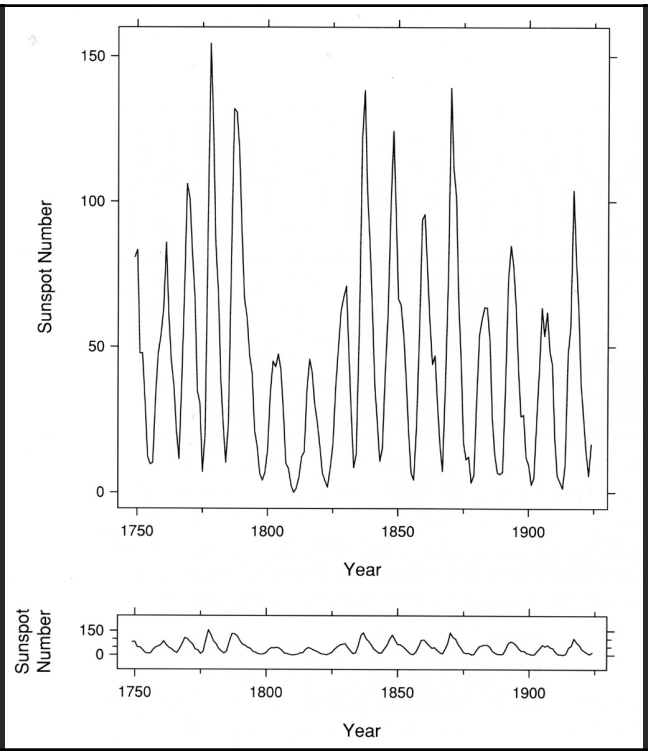

William S. Cleveland
The Elements of Graphing Data

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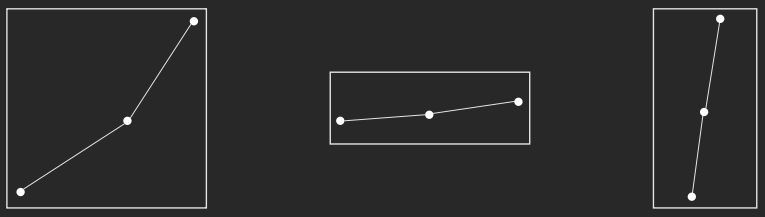
Banking to 45° [Cleveland]

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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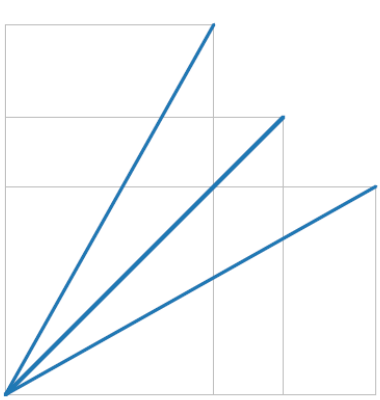
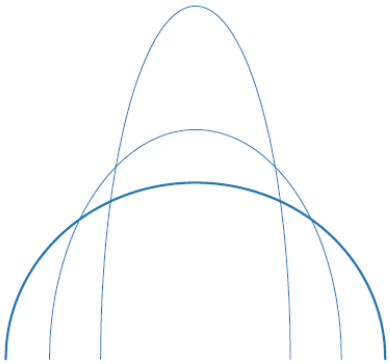
An alternate approach:
Minimize arc length (hold area constant)



Straight line -> 45 deg



Ellipse -> Circle

[Talbot et al, 2011]

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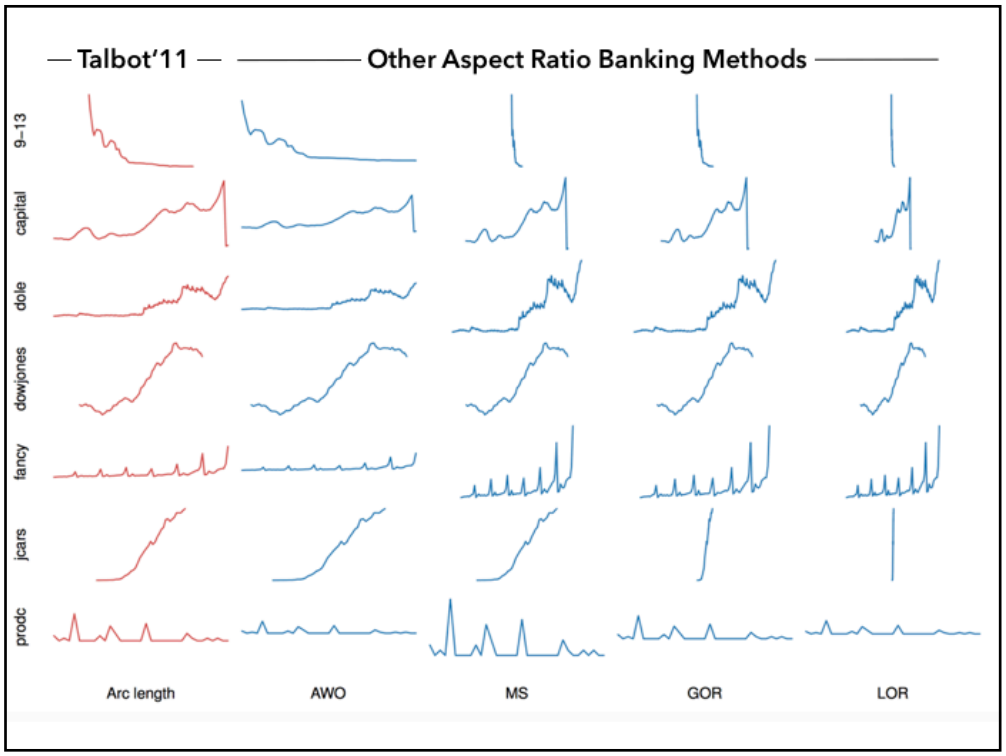

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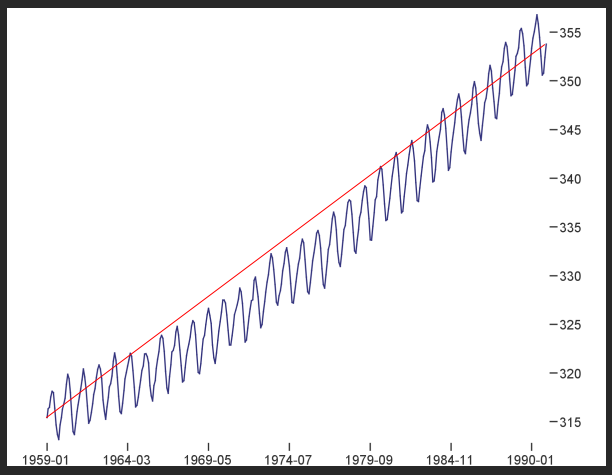
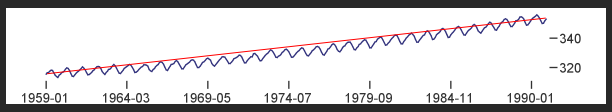


Aspect Ratio = 1.17



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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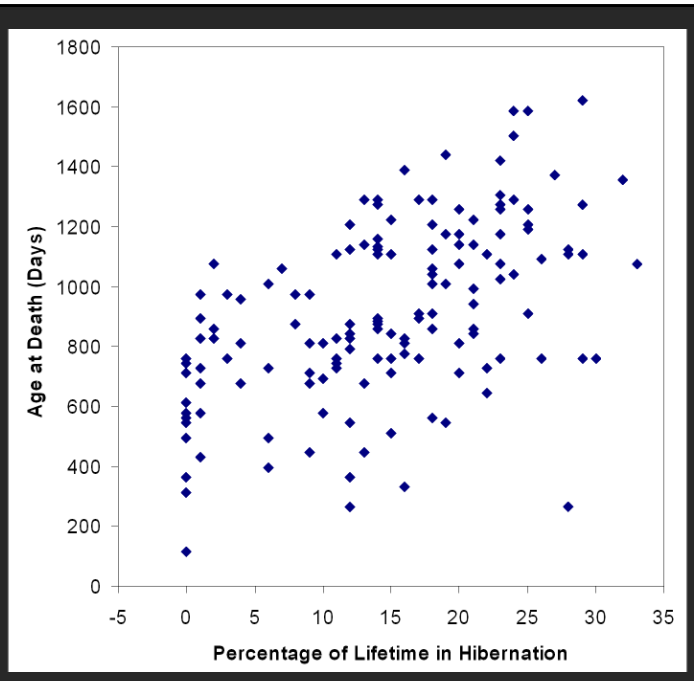

[The Elements of Graphing Data. Cleveland 94]

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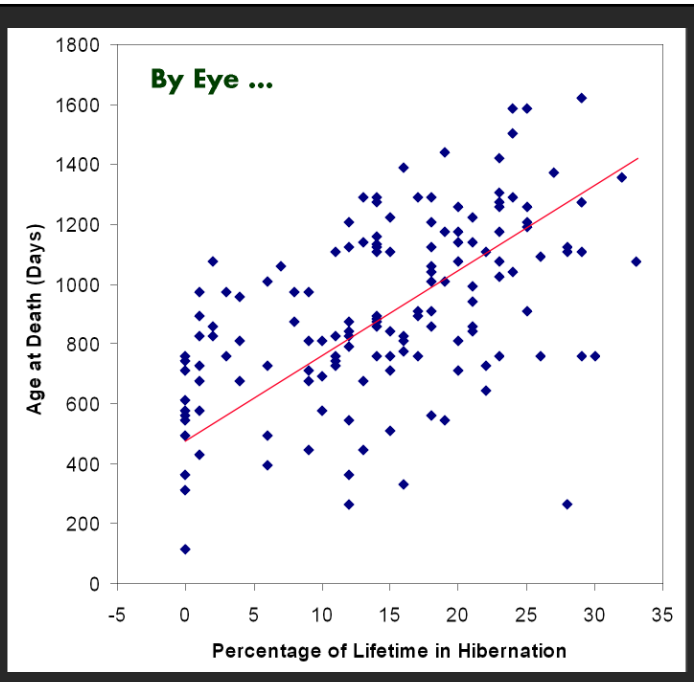

[The Elements of Graphing Data. Cleveland 94]

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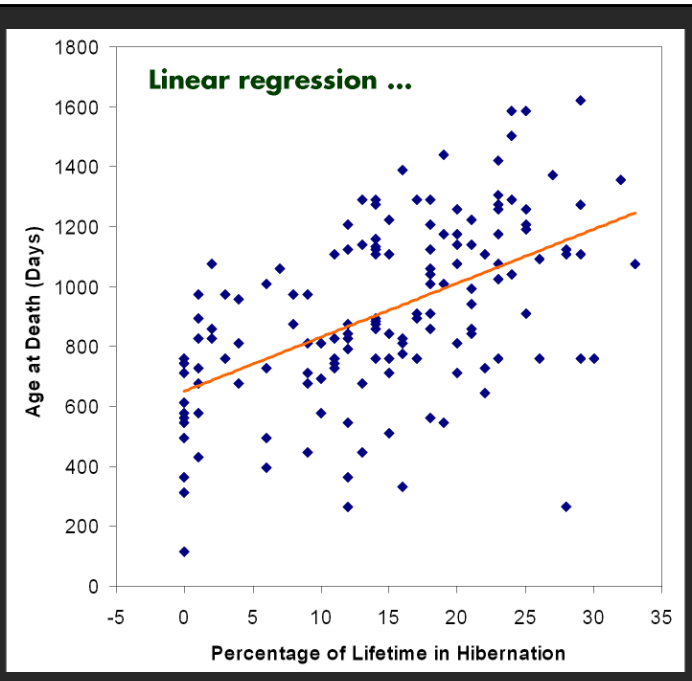

[The Elements of Graphing Data. Cleveland 94]

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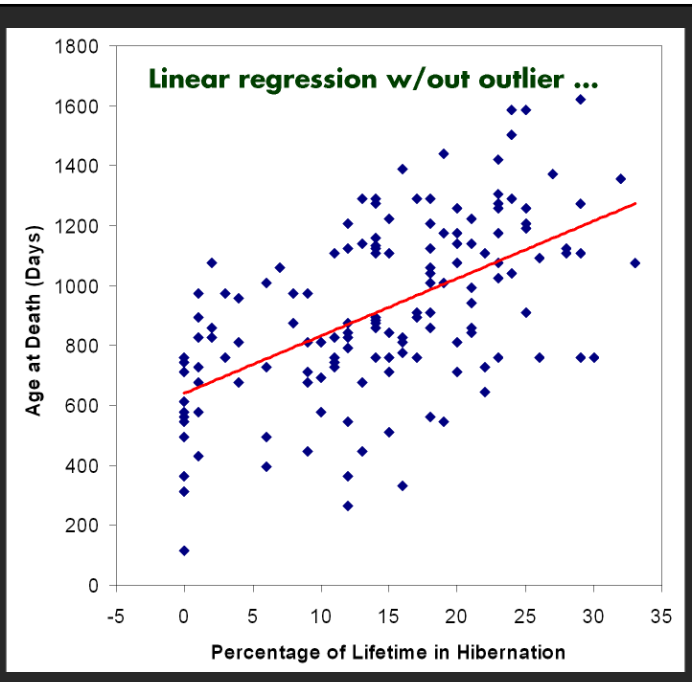

[The Elements of Graphing Data. Cleveland 94]

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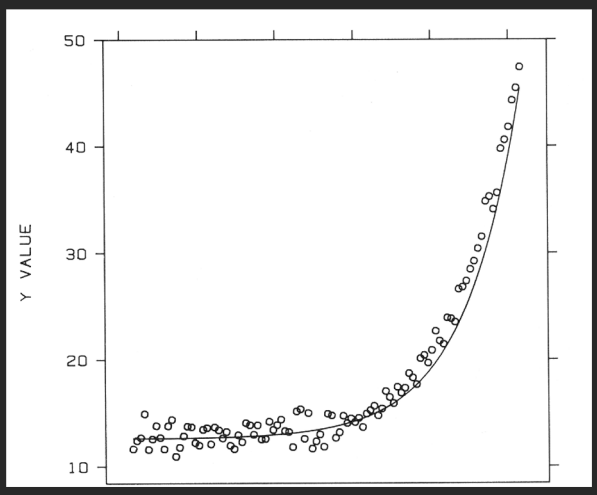
Transforming data

How well does curve fit data?



[Cleveland 85]

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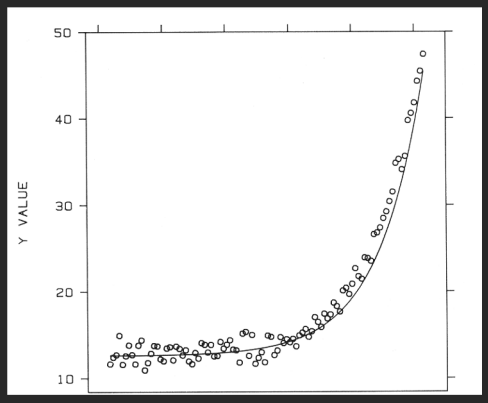
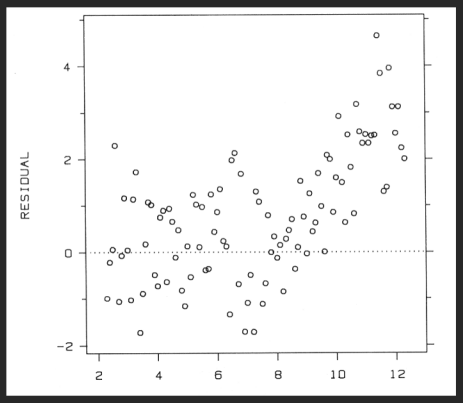
Transforming data

Residual graph

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





[Cleveland 85]

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Sorting

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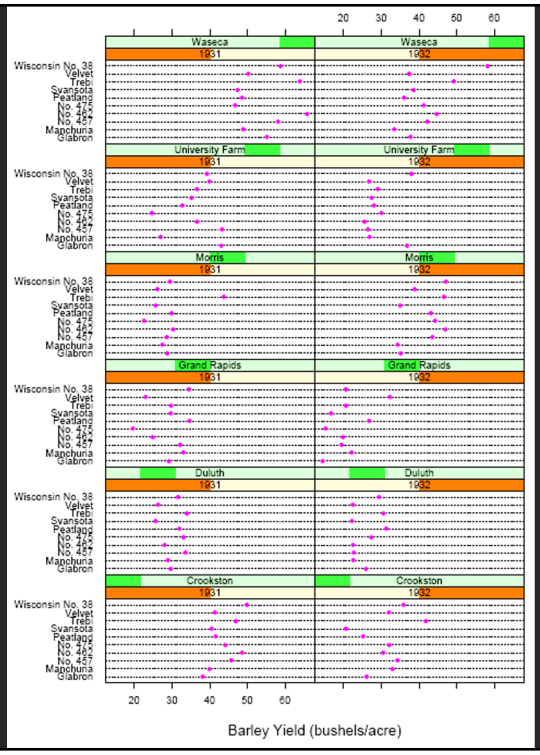
Trellis

[Becker, Cleveland, and Shyu 96]



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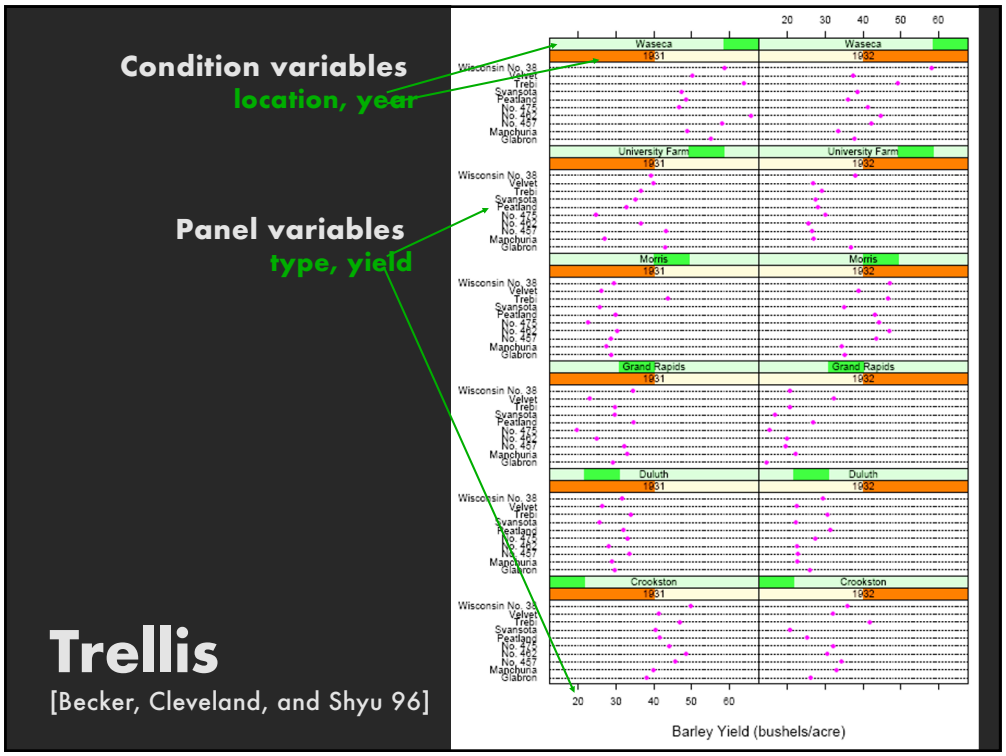
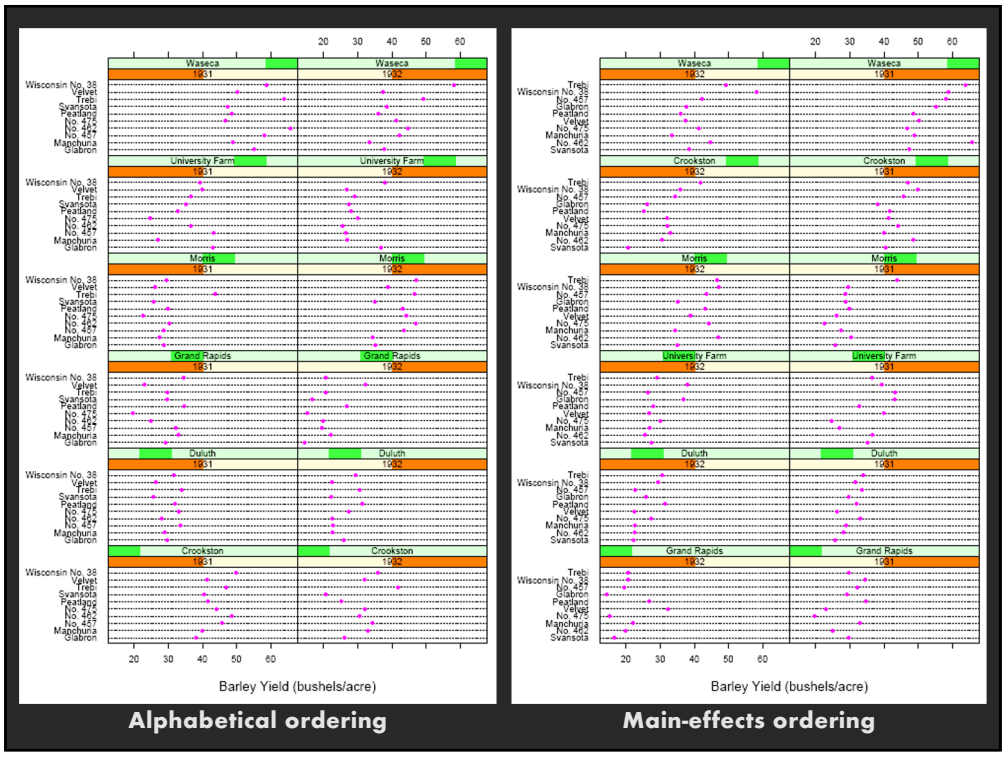
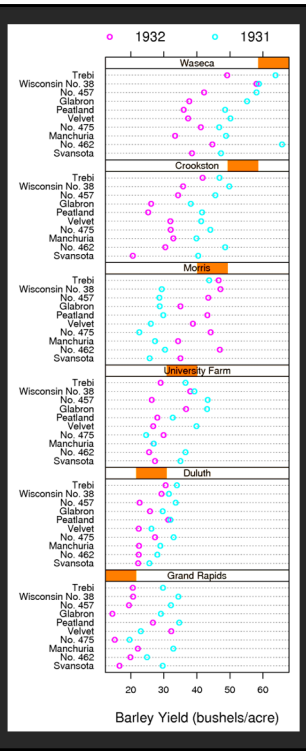

Condition variables
location, year
Panel variables
type, yield
Trellis
[Becker, Cleveland, and Shyu 96]
Waseca
1931
1932
University Farm
Morris
Grand Rapids
Duluth
Crookston
Wisconsin No. 38
Velvet
Trebi
Svansota
Peatland
No. 475
No. 462
No. 457
Manchuria
Glabron
20
30
40
50
60
Barley Yield (bushels/acre)

91


Waseca
1931
1932
University Farm
Morris
Grand Rapids
Duluth
Crookston
Wisconsin No. 38
Velvet
Trebi
Svansota
Peatland
No. 475
No. 462
No. 457
Manchuria
Glabron
20
30
40
50
60
Barley Yield (bushels/acre)
Alphabetical ordering
Waseca
1932
1931
Crookston
Morris
University Farm
Grand Rapids
Duluth
Trebi
Wisconsin No. 38
No. 457
Glabron
Peatland
Velvet
No. 475
Manchuria
No. 462
Svansota
Barley Yield (bushels/acre)
Main-effects ordering

92



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Graphical Calculations

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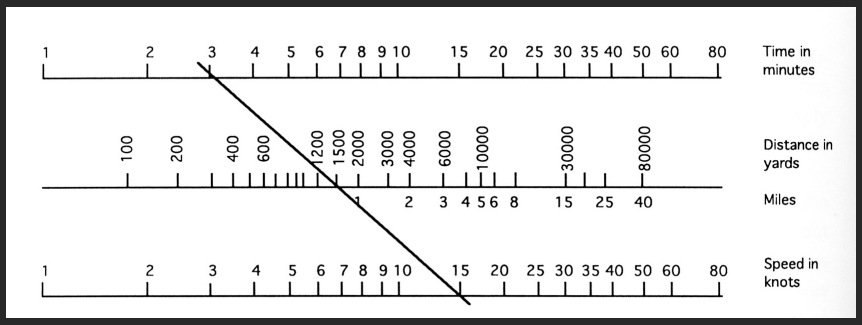
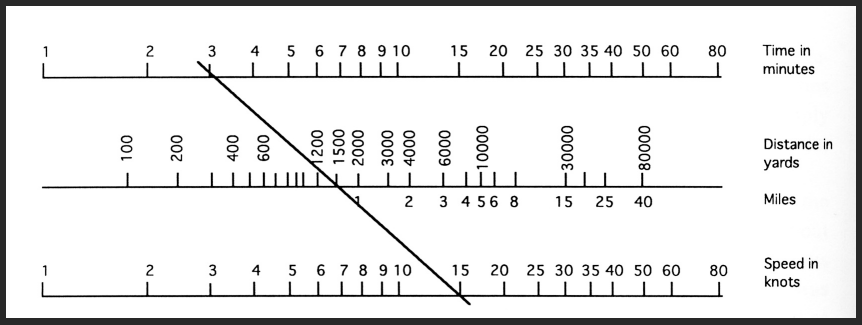
Nomograms



Sailing: The Rule of Three

95

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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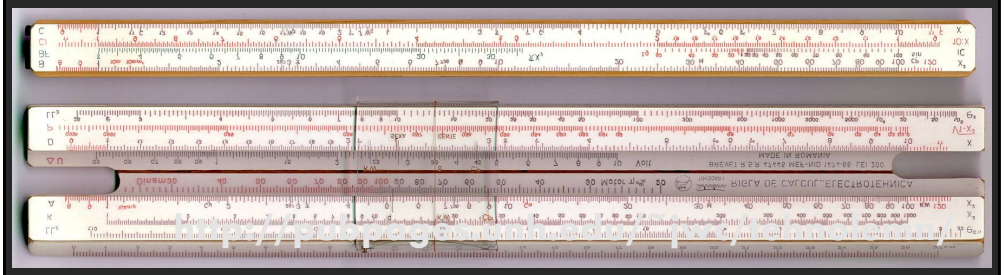
Slide rule



Model 1474-66 Electrotechnica 18 Scales

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

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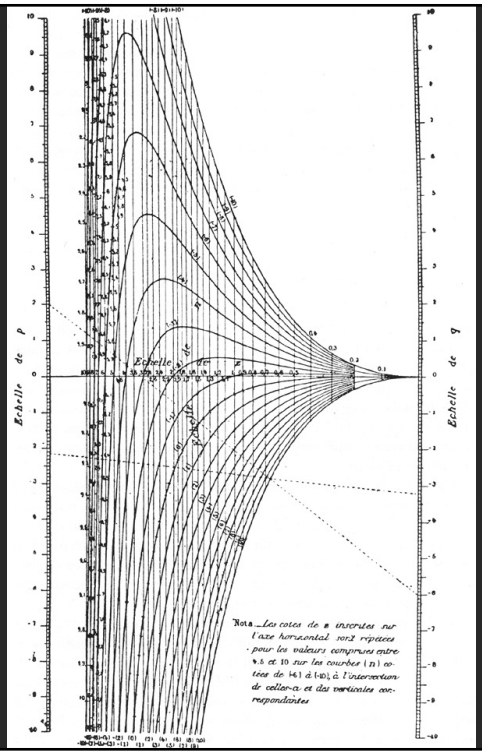

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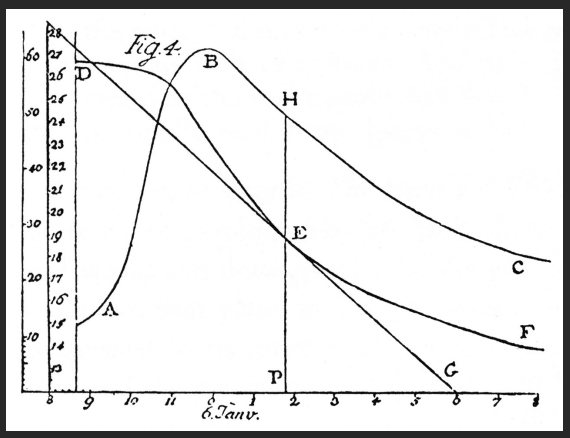
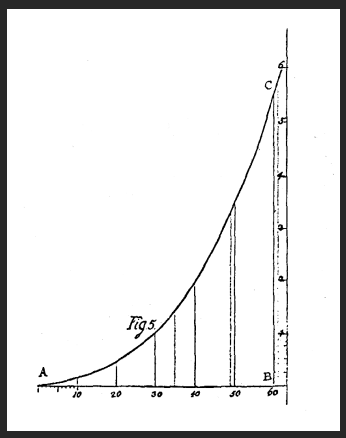
Lambert' s graphical construction





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

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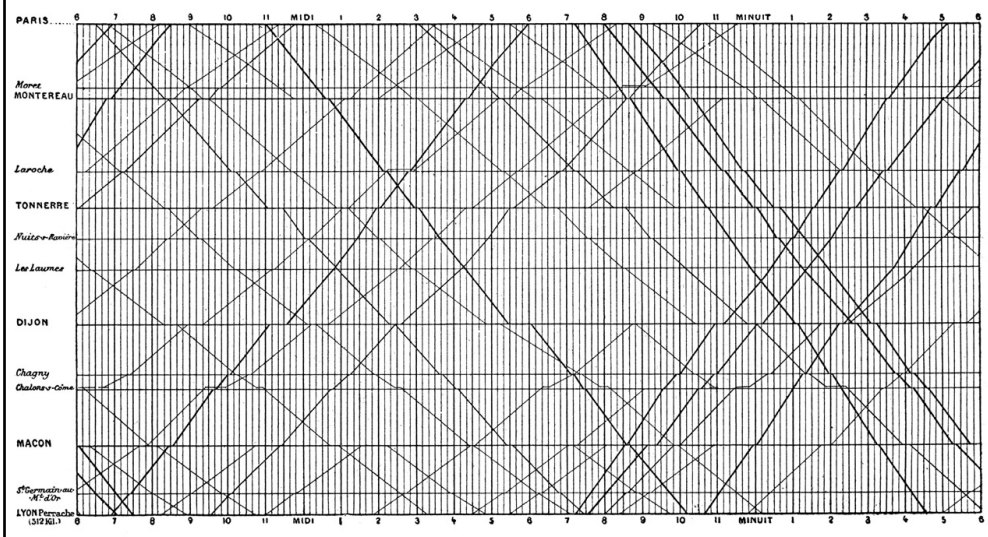

E. J. Marey, *La Méthode Graphique* (Paris, 1885), p. 20. The method is attributed to the French engineer, Ibry.

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Cartographic Distortion

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