Data Analysis, Statistics, Machine Learning

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Exploring

- Exploratory Data Analysis (John W. Tukey , *EDA*)
  - Summaries
  - Transformations
  - Smoothing
  - Robustness
  - Interactivity
  - What EDA is not …
    - Letting the data speak for itself
    - Fishing expeditions
    - Null hypothesis testing

- Qualitative Data Analysis
  - Mixed methods
  - Old wine in new bottles

Exploring

"Probability modelers seem to want to believe that their models are entirely correct.
Data analysts regard their models as a basis from which to measure deviation,
as a convenient benchmark in the wilderness, expecting little truth and relying on less."

Tukey (1979)

Exploring

Summaries

Letter values

M (median) sort and split batch

H (hinges) split each half as if it were a new batch

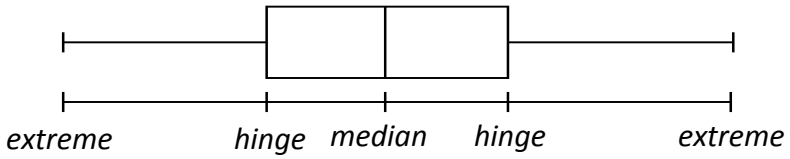
E (eighths) split again, and so on …

Medians and hinges yield a 5-number summary

1. lower extreme
2. lower hinge
3. median
4. upper hinge
5. upper extreme

H-spread is (upper hinge – lower hinge)

Range is (upper extreme – lower extreme)



Exploring

Summaries

What letter values reveal

Symmetry

Outliers

A **Step** is 1.5 times H-spread

Inner fences are 1 step outside hinges

Outer fences are 2 steps outside hinges

Adjacent values are those at each end closest to, but still inside inner fences

Outside values are between inner fence and neighboring outer fence

Far out values are beyond outer fences toward extremes

Exploring

Transformations

Tukey Ladder of Powers (re-expressions)

Assume data are positive, or use $X + 1$ if non-negative

Tukey formula

$X \longmapsto X^p$

Box & Cox formula (derived from Tukey's idea)

$X \longmapsto (X^p - 1) / p$

Values of p

$p = 2$ yields X^2

$p = 1$ yields X

$p = .5$ yields sqrt(X)

$p = 0$ yields log(X)

$p = -1$ yields $1 / X$

For Box & Cox formula

$p = 0$ yields log(X) because $\lim_{p \to 0} (X^p - 1) / p = \log(X)$

Also, dividing by p in Box & Cox formula preserves polarity of X

Ascending the ladder ($p > 1$) spreads out large values and compresses small values.
Descending the ladder ($p < 1$) compresses large values and spreads out small values.

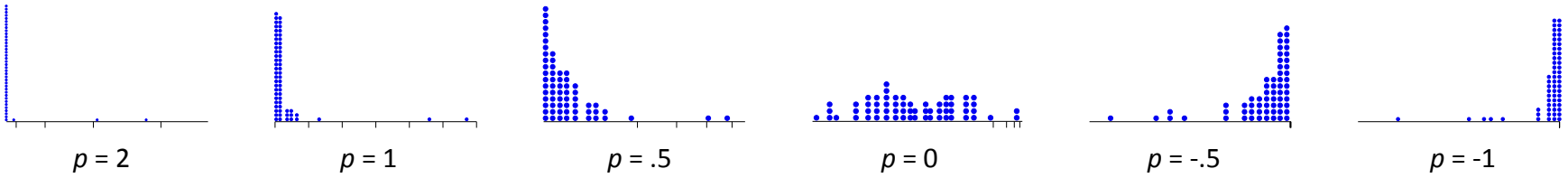
Exploring

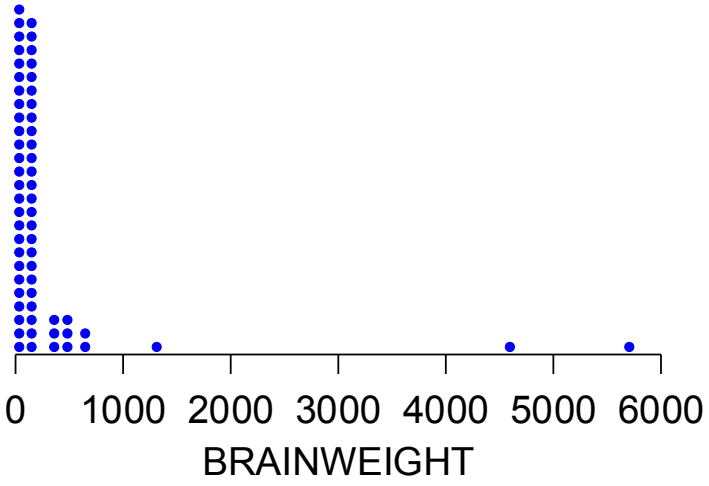
Transformations

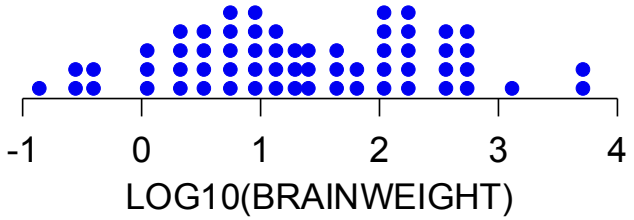
Dealing with skewness

Positive skew: descend the ladder ($p < 1$)

Negative skew: ascend the ladder ($p > 1$)

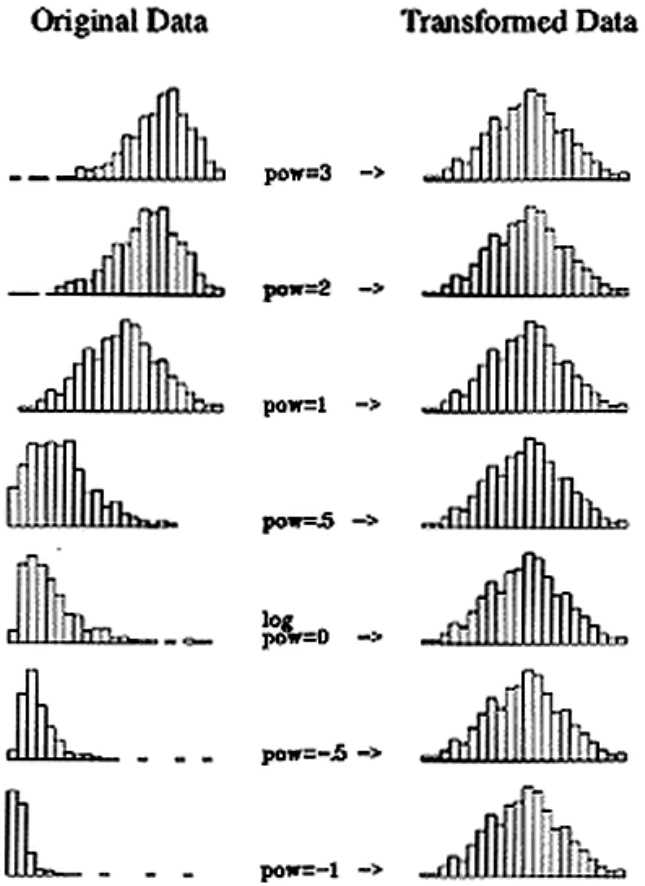






Exploring

Transformations



Wilkinson, Blank, & Gruber (1996)

Exploring

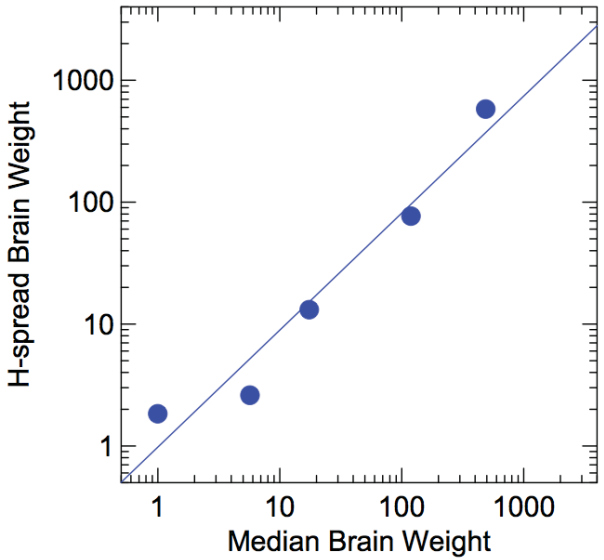
Transformations

Spread-level plot

Divide batch into quintiles and plot H-spread against median

1 – slope of line is estimate of *p*

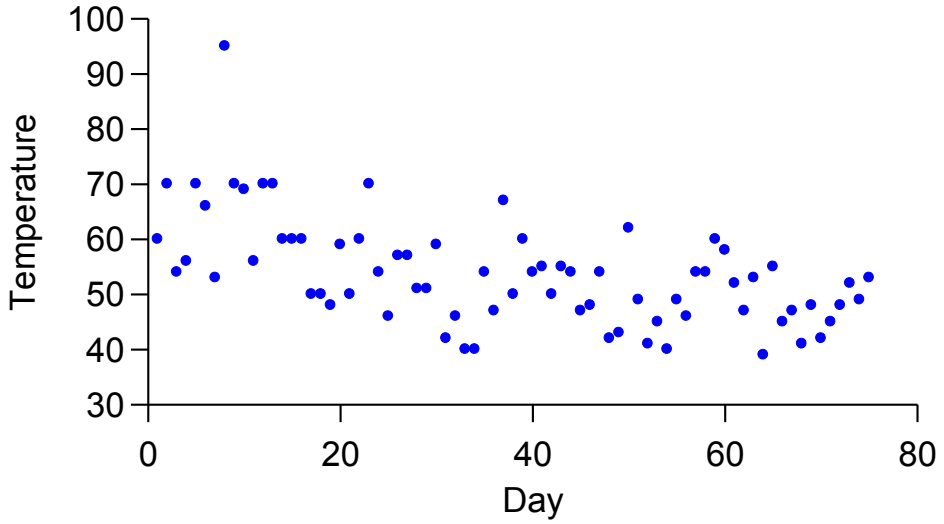
In this case, *p* = 0 is best choice



Exploring

Smoothing

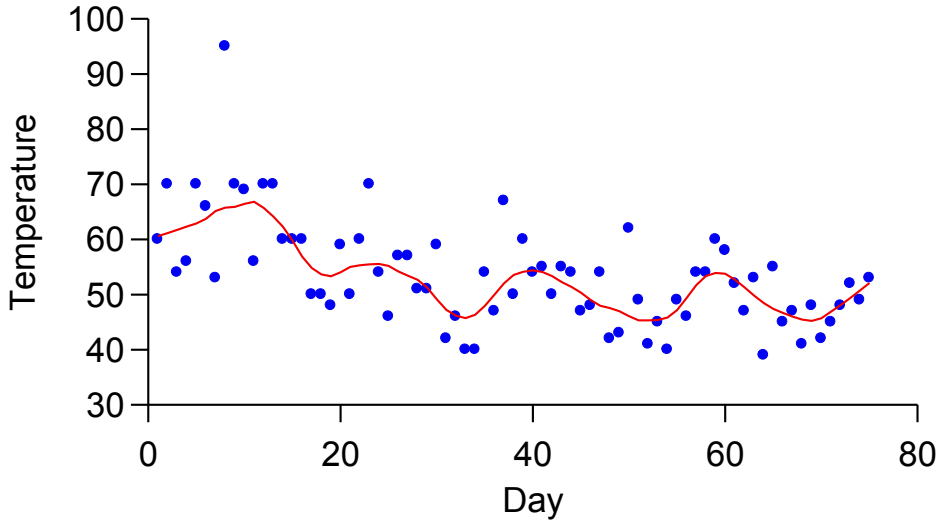
See any pattern here?



Exploring

Smoothing

Give yourself a medal if you saw this



Velleman & Hoaglin (1981)

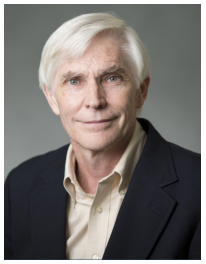
Exploring

- Smoothing
  - Data = smooth + rough
  - Data = fit + residuals
    - Fit a model
    - Compute residuals
    - Examine residuals for systematic variation
    - If residuals look nonrandom, fit a model to the residuals
    - Iterate

Exploring

Robustness

- Tukey was skeptical regarding Gaussian assumption
- Inspired a search for statistical estimators that are robust against outliers and other forms of contamination
- Simple location estimators involved trimming outliers
  - Median
  - Winsorizing
  - Trimmed mean
- Others (Tukey, Hampel, …) involved weighting functions
- Peter Huber developed maximum-likelihood-like methods



Exploring

- Interactivity
  - Linking
  - Brushing
  - Projecting
    - Tukey, Friedman, Fisherkeller: Prim9
      - https://www.youtube.com/watch?v=B7XoW2qiFUA
    - Tukey and Friedman: Projection pursuit
      - https://www.youtube.com/watch?v=n5i9RLCe1rQ

Exploring

Qualitative Data Analysis (QDA)

The QDA movement is a reaction against…

- Quantitative analysis (mathematics in general, statistics in particular)
- Scientific objectivism, realism, and positivism
- Peer review (controversial within QDA community)
- Educational testing

Subjectivity

- Hermeneutics
  - Translational
- Postmodernist
  - The researcher constructs own reality that others may not share
- Reliance on "trustworthiness" instead of formal measures of validity
  - credibility, dependability, auditability, confirmability, corroboration
- Focus on symbolic interpretations of icons (text, videos, …) leads to "mixed methods"

Fluidity

- No predefined measures or hypotheses
- Progressive data collection and coding leads to "grounded theory"

Politics

- Peculiar QDA journals
- Activism in academic departments

Exploring

- Qualitative Data Analysis
  - Nothing new here
    - Introspection (Wundt, …)
    - Clinical observation (Freud, Piaget, …)
    - Personal knowledge (Polanyi, …)
    - Participant observation (Malinowski, Mead, …)
    - Community psychology interviewing (Sarason, Levine, Kelly, …)
    - Group dynamics (Lewin, Bales, Slater, …)
  - Bottom line:
    - If you can't quantify or qualify something, you don't understand it
      - In science, understanding means being able to communicate to a rational person
      - In religion, understanding is a non-cognitive experience of the transcendent
      - In aesthetics, understanding is a judgment of taste (Kant)
      - But you can't build a science on subjective or non-cognitive foundations
    - Quantification doesn't mean simply assigning a number
      - It can mean "these two things are not comparable"
      - Or, "this is greater than that"
      - Or, "these two things are related"

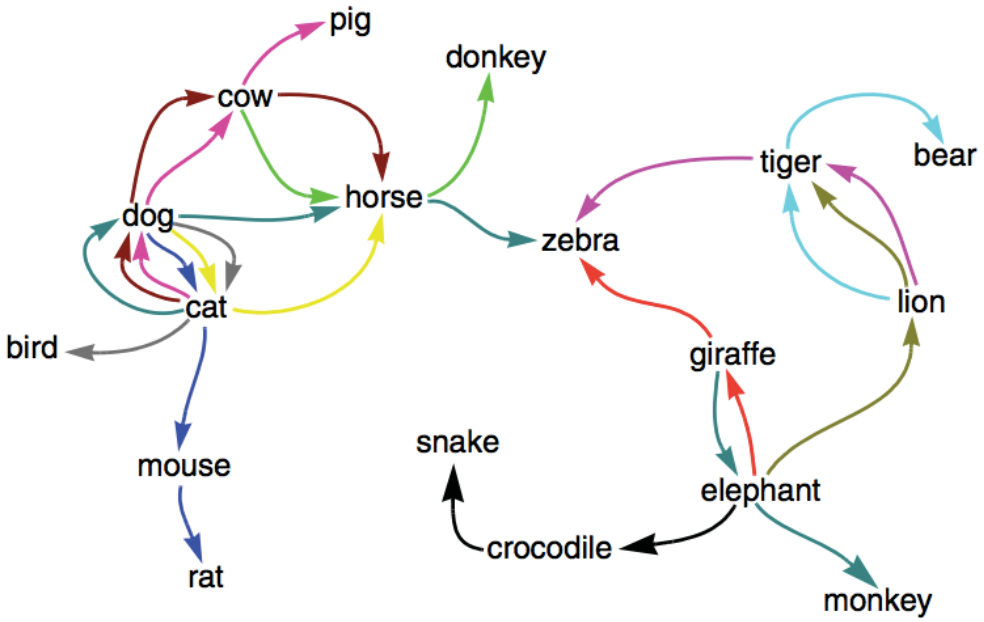
Exploring

Qualitative Data Analysis Alternatives

Text analysis (Shepard, Rosenberg, …)

Collect the data through simple comparisons (no numbers)

Scale them by exploiting distance and ordering constraints



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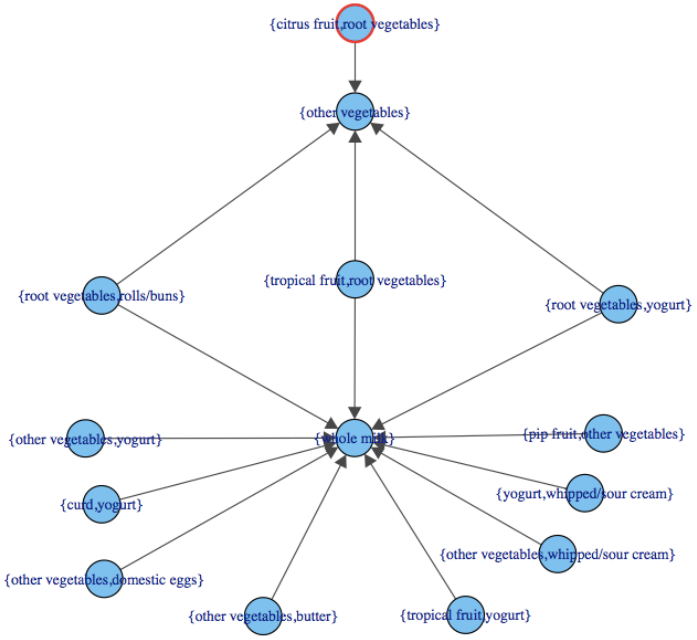
Qualitative Data Analysis Alternatives

- Sequence analysis (Agrawal *A priori* algorithm)
- Association rules



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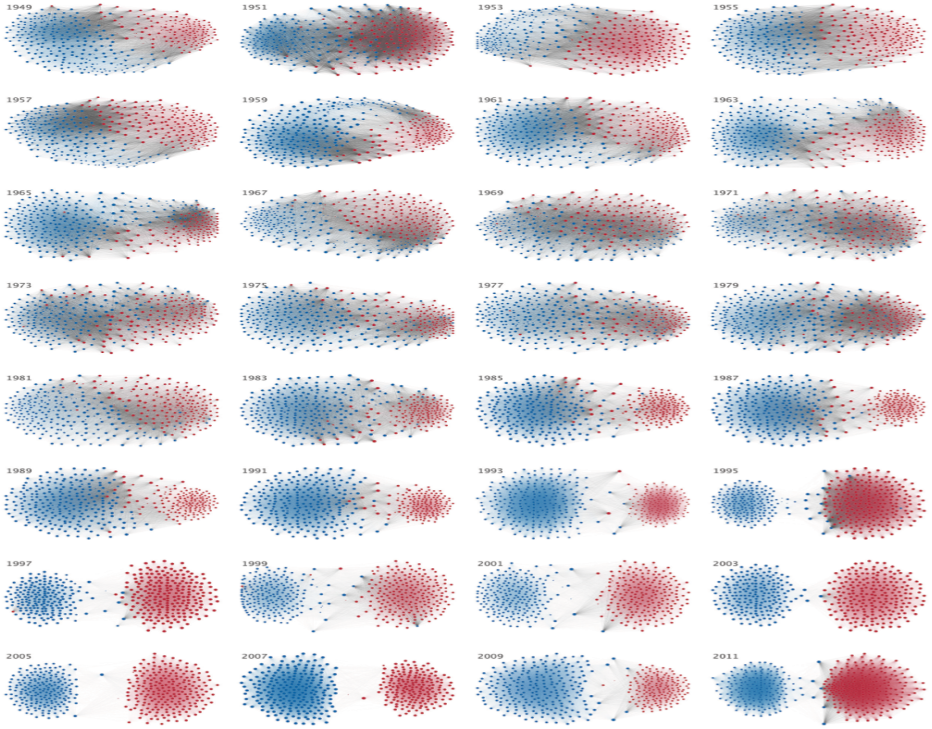
Qualitative Data Analysis Alternatives

Network analysis

No numbers here



Andris C, Lee D, Hamilton MJ, Martino M, Gunning CE, Selden JA (2015) The Rise of Partisanship and Super-Cooperators in the U.S. House of Representatives. PLoS ONE 10 (4): e0123507.

Exploring

Qualitative Data Analysis Alternatives

Innovative experimental paradigms

No numbers used here

Color vision and hue categorization in young human infants.
Bornstein, Marc H.; Kessen, William; Weiskopf, Sally
Journal of Experimental Psychology: Human Perception and Performance, Vol 2(1), Feb 1976, 115-129

"Infant looking at shiny object" by Mehregan Javanmard, Wikipedia

Exploring

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