Advanced Quantitative Research Methodology, Lecture Notes: Text Analysis II: Unsupervised Learning via Cluster Analysis[1]

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Reading

Justin Grimmer and Gary King. 2010. "Quantitative Discovery of Qualitative Information: A General Purpose Document Clustering Methodology"
`http://gking.harvard.edu/files/abs/discov-abs.shtml`.

The Problem: Discovery from Unstructured Text

- Examples: scholarly literature, news stories, medical information, blog posts, comments, product reviews, emails, social media updates, audio-to-text summaries, speeches, press releases, legal decisions, etc.
- 10 minutes of worldwide email = 1 LOC equivalent
- An essential part of discovery is classification: "one of the most central and generic of all our conceptual exercises. . . . the foundation not only for conceptualization, language, and speech, but also for mathematics, statistics, and data analysis. . . . Without classification, there could be no advanced conceptualization, reasoning, language, data analysis or, for that matter, social science research." (Bailey, 1994).
- We focus on cluster analysis: discovery through (1) classification and (2) simultaneously inventing a classification scheme
- (We analyze text; our methods apply more generally)

Why Johnny Can't Classify (Optimally)

- Bell(n) = number of ways of partitioning n objects
- Bell(2) = 2 (AB, A B)
- Bell(3) = 5 (ABC, AB C, A BC, AC B, A B C)
- Bell(5) = 52
- Bell(100) $\approx 10^{28} \times$ Number of elementary particles in the universe
- Now imagine choosing the *optimal* classification scheme by hand!
- That we think of all this as astonishing . . . is astonishing

Why HAL Can't Classify Either

- The Goal — an optimal application-independent cluster analysis method — is mathematically impossible:
  - No free lunch theorem: every possible clustering method performs equally well on average over all possible substantive applications
- Existing methods:
  - Many choices: model-based, subspace, spectral, grid-based, graph-based, fuzzy *k*-modes, affinity propogation, self-organizing maps,...
  - Well-defined statistical, data analytic, or machine learning foundations
  - How to add substantive knowledge: With few exceptions, who knows?!
  - The literature: little guidance on when methods apply
  - Deep problem in cluster analysis literature: no way to know which method will work ex ante

If Ex Ante doesn't work, try Ex Post

- Methods and substance must be connected (no free lunch theorem)
- The usual approach fails: hard to do it by understanding the model
- We do it ex post (by qualitative choice). For example:
  - Create long list of clusterings; choose the best
  - Too hard for mere humans!
  - An organized list will make the search possible
  - E.g.,: consider two clusterings that differ only because one document (of many) moves from category 5 to 6

Our Idea: Meaning Through Geography



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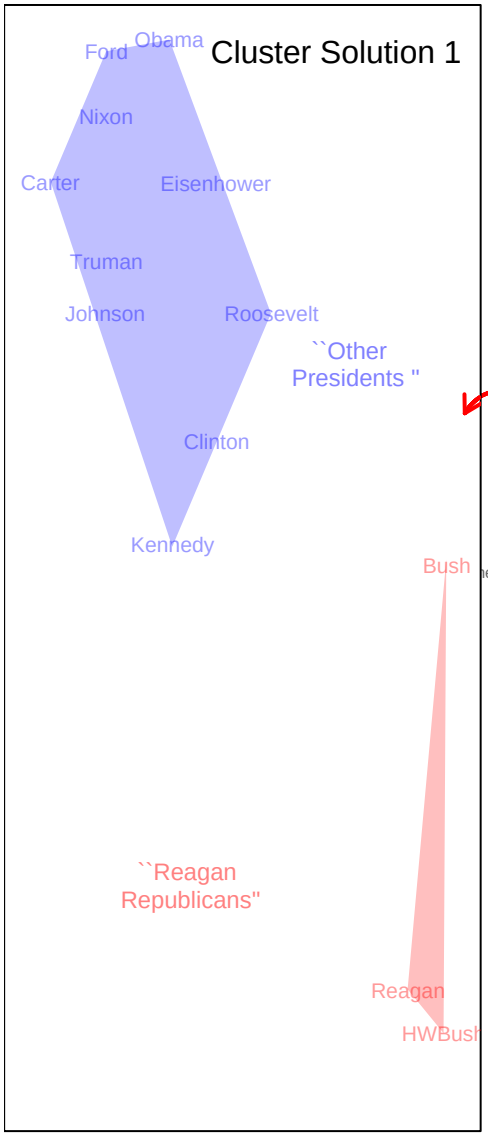
⇝ We develop a (conceptual) geography of clusterings

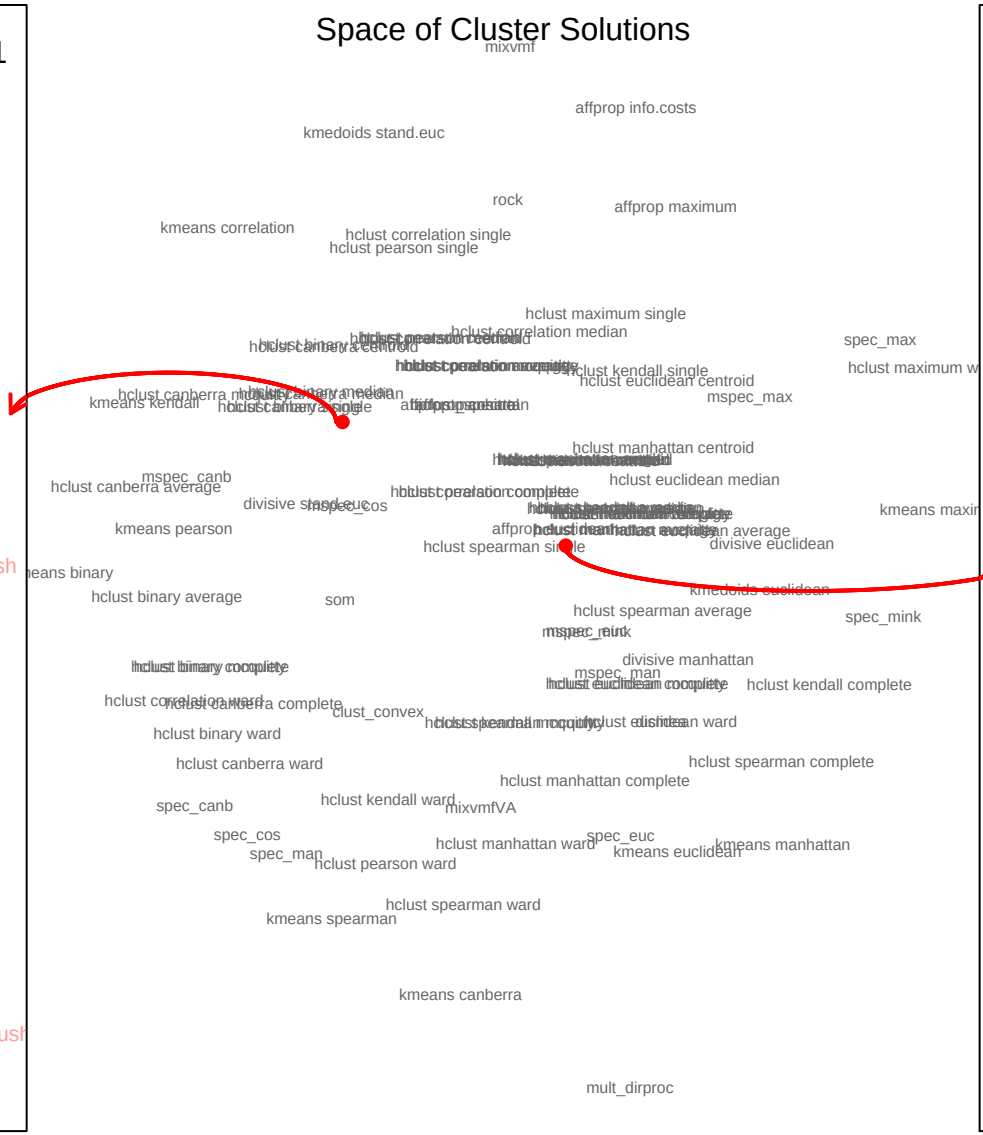
A New Strategy

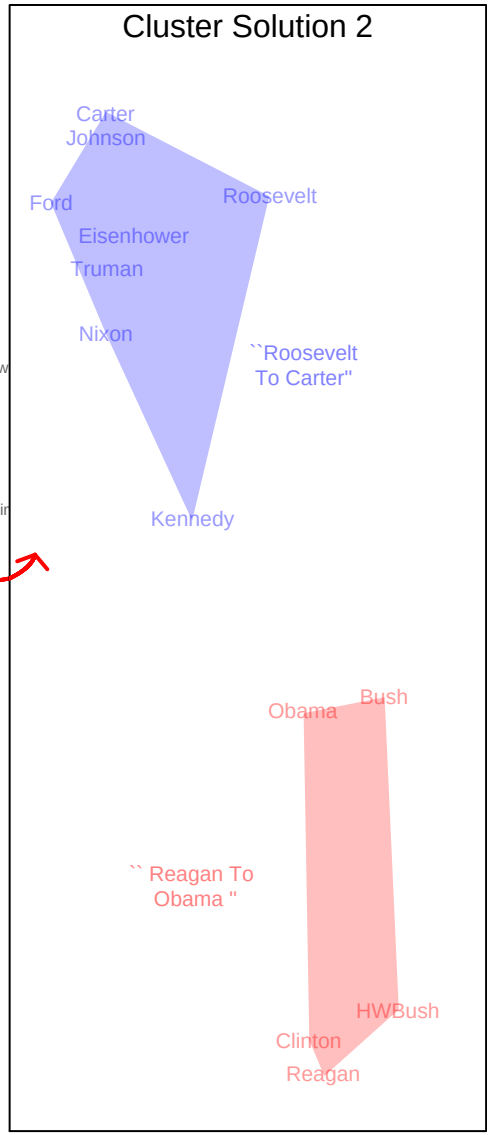
Make it easy to choose best clustering from millions of choices

Many Thousands of Clusterings, Sorted & Organized

You choose one (or more), based on insight, discovery, useful information,. . .

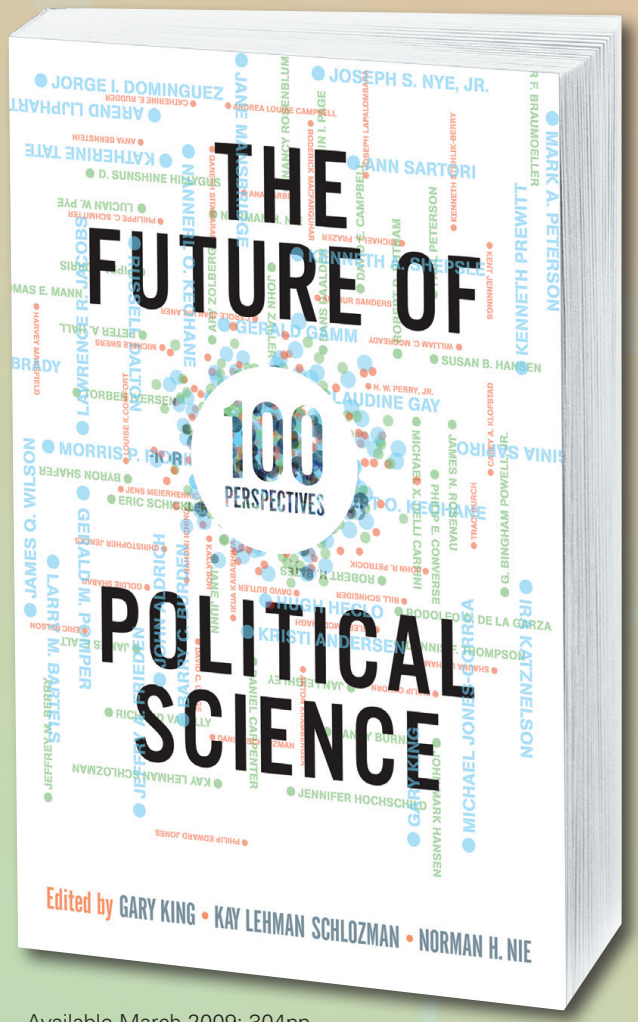






Application-Independent Distance Metric: Axioms

- Metric based on 3 assumptions
  1. Distance between clusterings: a function of the pairwise document agreements (pairwise agreements $\Rightarrow$ triples, quadruples, etc.)
  2. Invariance: Distance is invariant to the number of documents (for any fixed number of clusters)
  3. Scale: the maximum distance is set to log(num clusters)
- $\rightsquigarrow$ Only one measure satisfies all three (the "variation of information")
- Meila (2007): derives same metric using different axioms (lattice theory)



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Evaluators' Rate Machine Choices Better Than Their Own

- Scale: (1) unrelated, (2) loosely related, or (3) closely related
- Table reports: mean(scale)

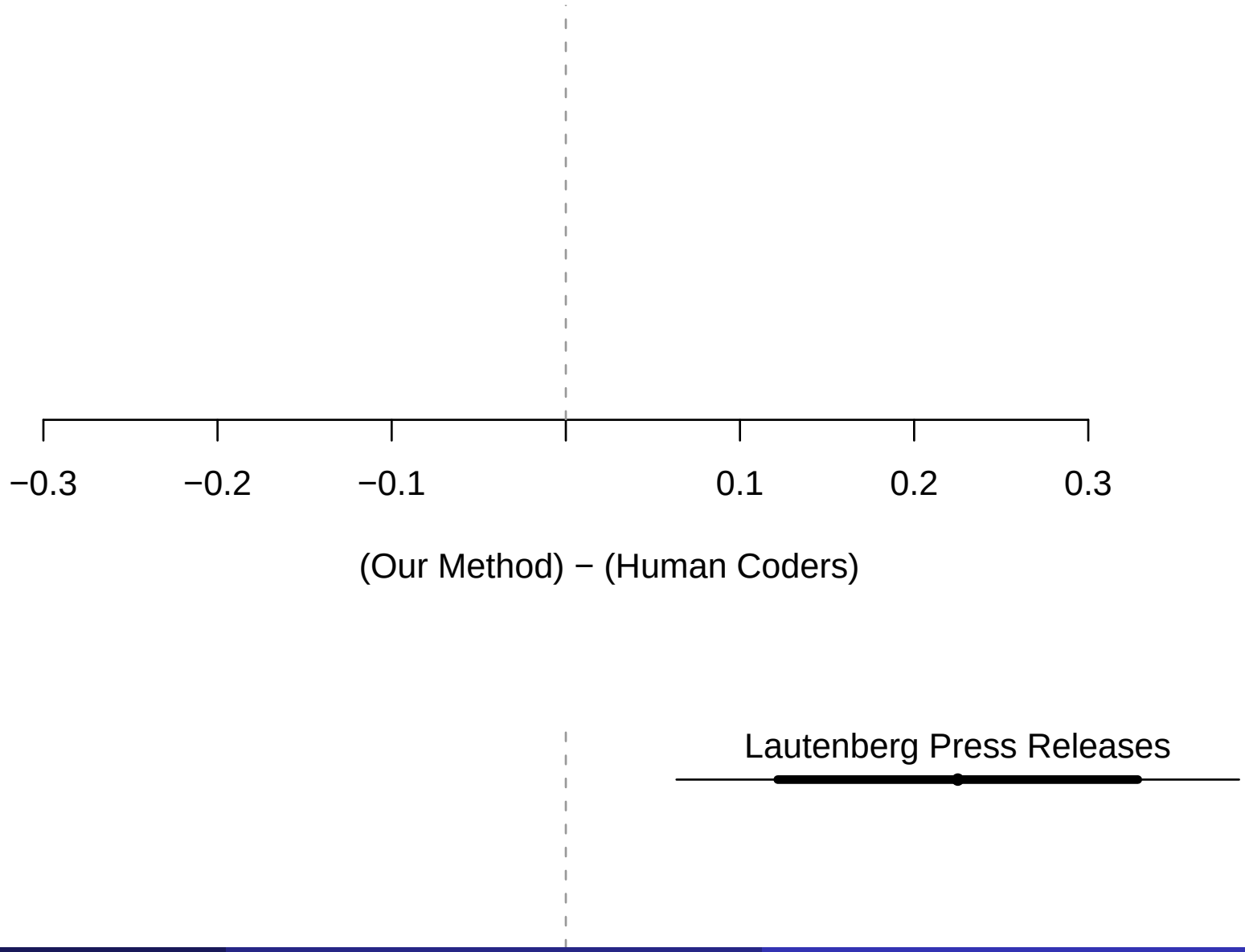
Pairs from	Overall Mean	Evaluator 1	Evaluator 2
Random Selection	1.38	1.16	1.60
Hand-Coded Clusters	1.58	1.48	1.68
Hand-Coding	2.06	1.88	2.24
Machine	2.24	2.08	2.40

p.s. The hand-coders did the evaluation!

Evaluating Performance

Evaluation 1: Cluster Quality

Evaluation 1: Cluster Quality



Evaluation 2: More Informative Discoveries

- Found 2 scholars analyzing lots of textual data for their work
- Created 6 clusterings:
  - 2 clusterings selected with our method (biased against us)
  - 2 clusterings from each of 2 other methods (varying tuning parameters)
- Created info packet on each clustering (for each cluster: exemplar document, automated content summary)
- Asked for $\binom{6}{2}$=15 pairwise comparisons
- User chooses $\Rightarrow$ only care about the one clustering that wins
- Both cases a Condorcet winner:

"Immigration":

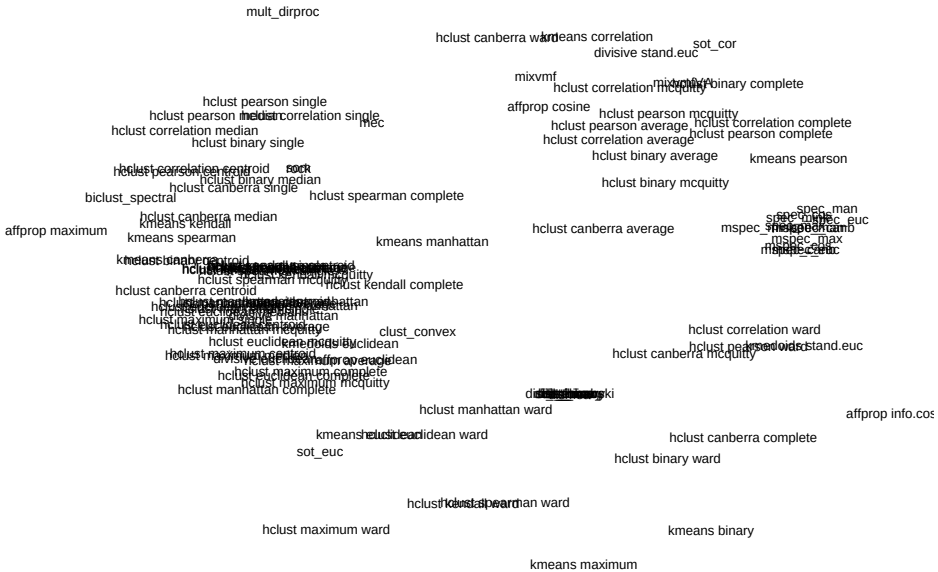
Our Method 1 $\rightarrow$ vMF 1 $\rightarrow$ vMF 2 $\rightarrow$ Our Method 2 $\rightarrow$ K-Means 1 $\rightarrow$ K-Means 2

"Genetic testing":

Our Method 1 $\rightarrow$ {Our Method 2, K-Means 1, K-means 2} $\rightarrow$ Dir Proc. 1 $\rightarrow$ Dir Proc. 2

Evaluation 3: What Do Members of Congress Do?

Example Discovery



In Sample Illustration of Partisan Taunting

Taunting ruins deliberation



Sen. Lautenberg
on Senate Floor
4/29/04

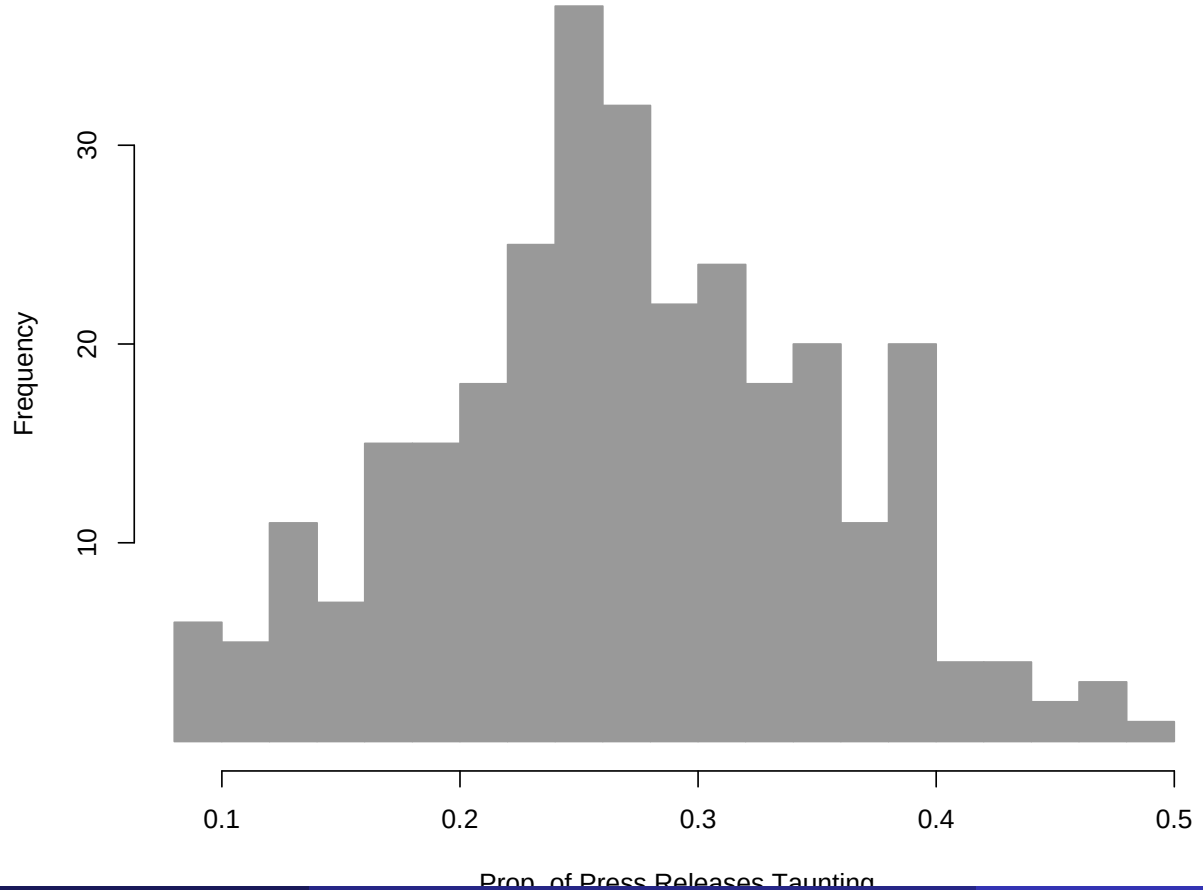
- "Senator Lautenberg Blasts Republicans as 'Chicken Hawks' " [Government Oversight]

Out of Sample Confirmation of Partisan Taunting

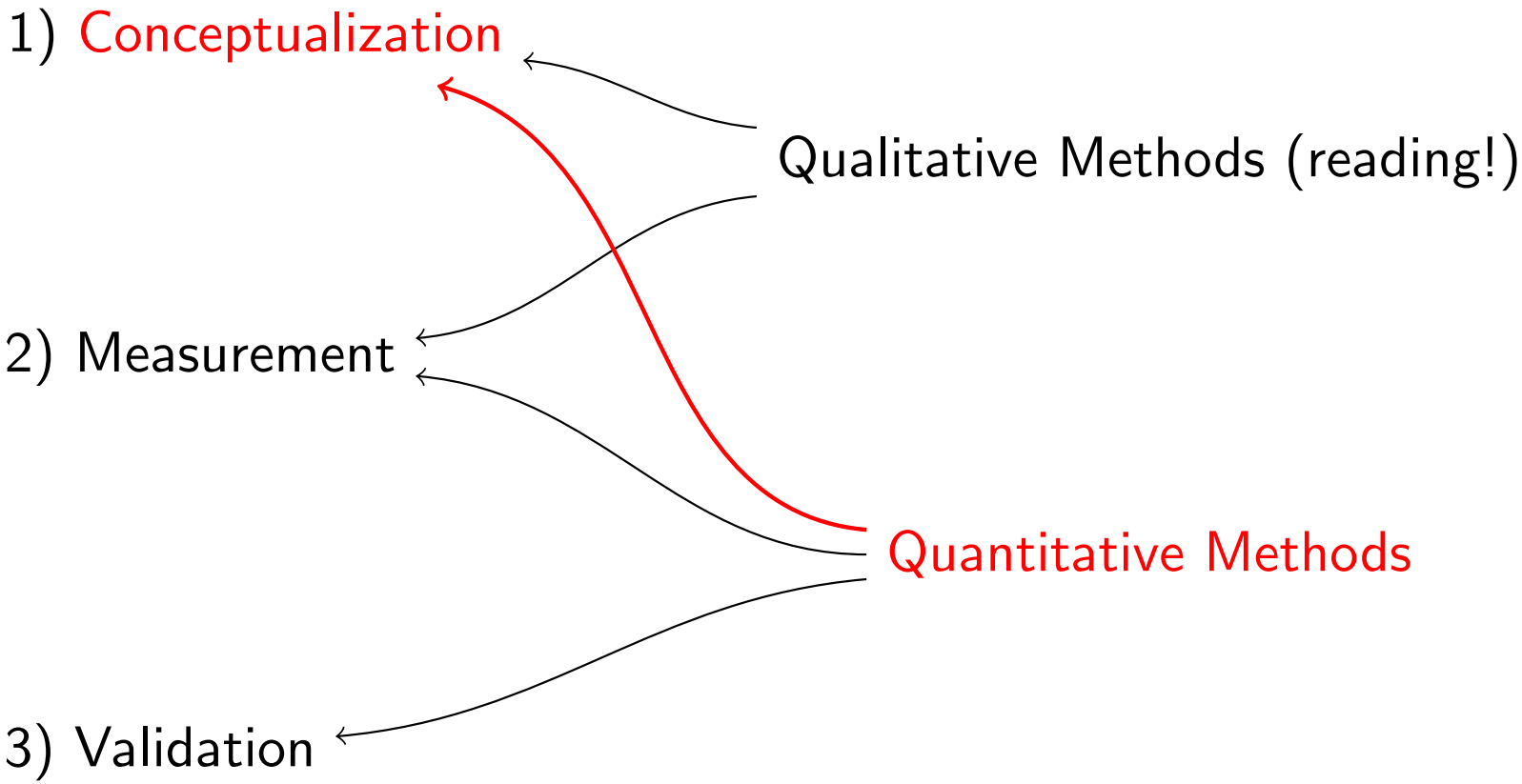
- Discovered using 200 press releases; 1 senator.

Out of Sample Confirmation of Partisan Taunting

- Discovered using 200 press releases; 1 senator.
- Confirmed using 64,033 press releases; 301 senator-years.
- Apply supervised learning method: measure proportion of press releases a senator taunts other party



Advancing the Objective of Discovery



Quantitative methods for conceptualization: aiding discovery

For more information:

http://GKing.Harvard.edu