Independencies in Causal Graphs with Text Variables: Embeddings vs. Frequencies

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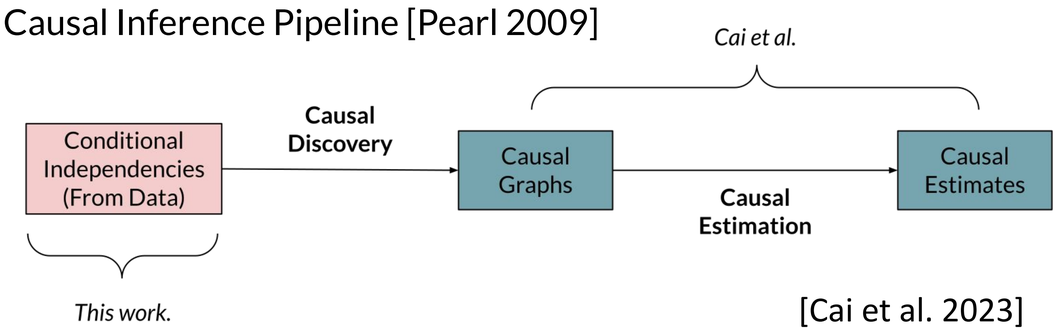
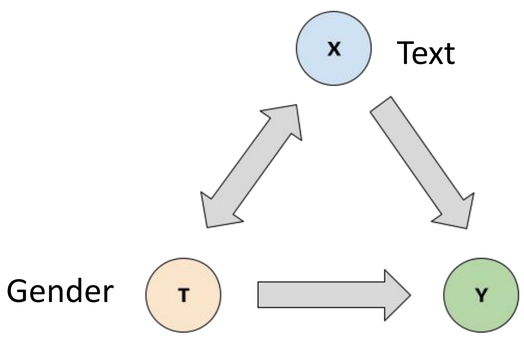
Motivation

Causal Inference Pipeline [Pearl 2009]



[Cai et al. 2023]

Case Study

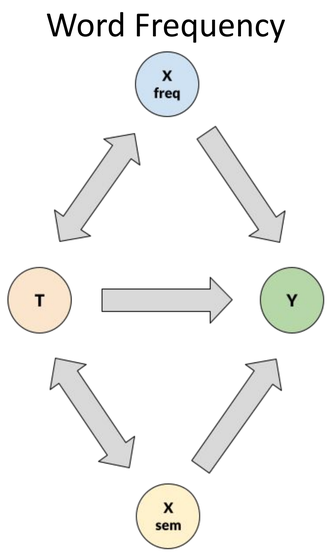


U.S. Supreme Court Transcripts:
- 256 conversations
- 16225 tokens
- 4 years (2016-2019)

[Data: Chang et al. 2023]

How do we operationalize text?

Content Warning: this section contains a reference to abuse.



*"Justice Kagan, what we think is that if you want to give a definition for sexual **abuse** of a minor, at least in the context of the allegation of abuse being due to age,"*
`jeffrey_l_fisher,male`

*"So I do take your point that there could be the potential for **abuse**, even under our interpretation,"*
`matthew_s_hellman,male`

*I agree with Ms. Ratner on this. I -- I -- I think there is some daylight between plain error and **abuse** of discretion, probably not much."*
`k_winn_allen,male`

*"The court should limit this crime to its core…and that core is the insider's **abuse** of confidential corporate information for personal profit."*
`alexandra_a_e_shapiro,female`

RQ: *Can a causal edge exist between X_freq and T but not between X_sem and T (or vice versa)?*

Preprocessing Steps: simple rule-based method used to determine advocate gender signal; text lower-cased and stripped of line breaks; tokens lemmatized to noun forms referencing WordNet, utterances with <10 tokens filtered out; tokens with no corresponding GloVe embedding filtered out.

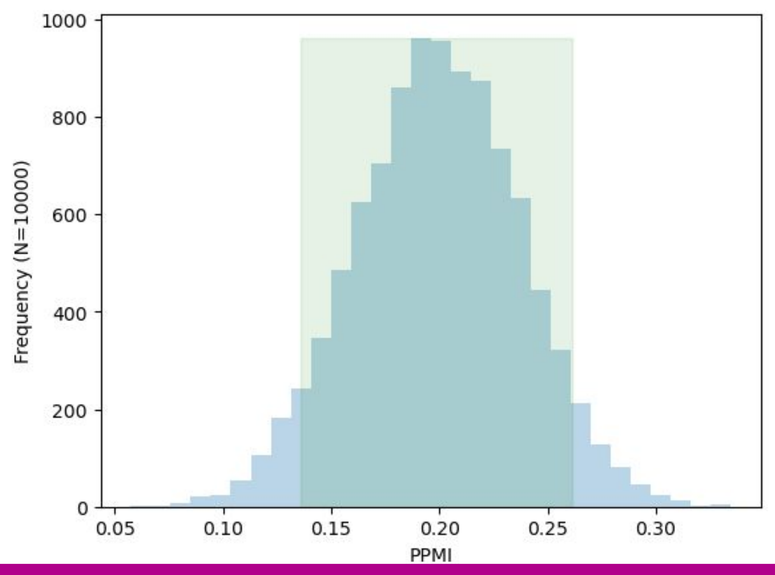
Measuring Word Frequency

We use PPMI with bootstrap resampling as our independence test.

$$a \perp\!\!\!\perp b \iff P(a,b) = P(a)P(b)$$

X_freq and T are independent if PPMI (X, T) > 0 and the 95% bootstrapped confidence interval of PPMI(X, T) does not contain 0.

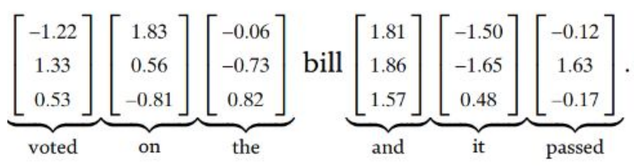
$$\mathbf{PPMI}(X,T) = \max(\log_2 \frac{P(X,T)}{P(X)P(T)}, 0)$$



Measuring Word Semantics

Word embeddings capture semantic meaning (distributional hypothesis)

Recent work has shown how to embed tokens on the utterance level.



[Rodriguez et al.]

We can perform regressions on these à la carte (ALC) embeddings, and measure how a token's meaning changes across each time it is used.

$$\boldsymbol{X_{sem}} = \boldsymbol{T}\beta + \boldsymbol{E}$$

We use a permutation test which shows **correlation, not independence.**

X_sem and T are correlated iff. $||\boldsymbol{\beta}||$, the Euclidean norm of the coefficient vector $\boldsymbol{\beta}$ that results from performing an ALC regression on X, does not equal 0 and the p-value from permutation is less than 0.05.

Dependent-Correlated

130 Total Word Types

Examples:
1. "ha"
2. Claim
3. Whether
4. Yes
5. Defendant

Independent-Correlated

229 Total Word Types

Examples:
1. Number
2. State
3. Rule
4. Government
5. Way

Dependent-Uncorrelated

277 Total Word Types

Examples:
1. Court
2. "wa"
3. Case
4. Honor
5. Know

Independent-Uncorrelated

900 Total Word Types

Examples:
1. Think
2. Would
3. Say
4. Justice
5. One

The answer to our RQ is yes (we think)!

- As far as we know, the existence of the diagonal above is a novel result.
- We are still looking for a test that shows conditional independence between X_sem and T.

Future Work

- Find a conditional independence test for semantic meaning
- Visualize differences in semantic use when they exist
- Investigate other ways of operationalizing text
- Test on other corpora

References

1. Erica Cai, Ankita Gupta, Katherine Keith, Brendan O'Connor, and Douglas R Rice. 2023. "Let Me Just Interrupt You": Estimating Gender Effects in Supreme Court Oral Arguments.
2. Jonathan P. Chang, Caleb Chiam, Liye Fu, Andrew Wang, Justine Zhang, and Cristian Danescu-Niculescu-Mizil. 2020. ConvoKit: A Toolkit for the Analysis of Conversations. In *Proceedings of the 21th Annual Meeting of the Special Interest Group on Discourse and Dialogue*, pages 57–60, 1st virtual meeting. Association for Computational Linguistics.
3. Pedro L. Rodriguez, Arthur Spirling, and Brandon M. Stewart. 2023. Embedding Regression: Models for Context-Specific Description and Inference. American Political Science Review:1–20.
4. Judea Pearl. 2009. Causality. Cambridge University Press.