Statistical uncertainty in NLP

CS 485, Fall 2023
Applications of Natural Language Processing
https://people.cs.umass.edu/~brenocon/cs485_f23/

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- Good luck finishing your progress reports - due today!

Statistical variability in NLP

- How to trust experiment results, given many ***sources of variability***?
  - How variable are the computational algorithms?
  - How were the annotations sampled?
  - How was the text data sampled?
  - How representative is the text sample, compared to the greater population of possible texts?

Text data variability

- Do results generalize to ....
  - new domains?
  - new authors?
  - new documents?
  - new sentences?

- (Typically things get worse if anything changes)

- Also of interest: even if only care about text similar to our current one, did we “get lucky” in our selection of sentences/documents/etc?

Text data variability

- A simpler setting: variability due to a **small sample size**
  - What if we resampled the tokens/sentences/documents from a similar population as our current data sample?
- Rest of today: focus on **classifier accuracy evaluation**.
  - Is the result you see real, or due to chance?

Null hypothesis tests

- Core idea: compare your observed result to what you'd observe, to what you'd expect if results were "random" in some way
- formally, the null hypothesis

- Example #1: are your predictions better than chance?

- Example #2: is the diff. in two classifiers' accuracies better than chance?

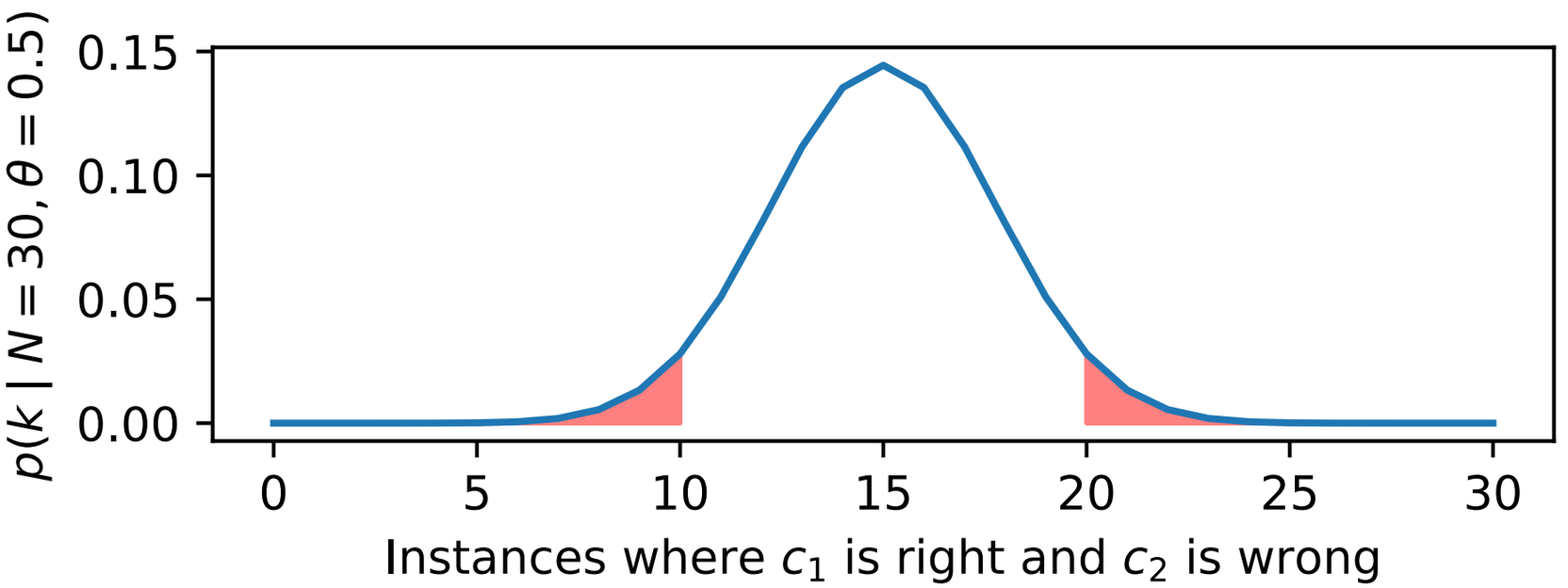
Null hypothesis tests

- Must define a null hypothesis you wish to disprove
  - H0 = the "null hypothesis". Observations were generated in an uninteresting way, "due to chance"
- p-value: probability you could see a result at least as extreme as what you have, if H0 was true
  - pval = P(T(obs) > T(gendata) | gendata ~ H0)

- If you can't beat the null hypothesis, take your results with a grain of salt!

Null hypothesis test

- pvalue = Probability of a result as least as extreme, if the null hypothesis was active
- Example: paired testing of classifiers. Two equivalent methods:
  - 1. Randomized simulation
  - 2. Exact binomial test (R: *binom.test*)



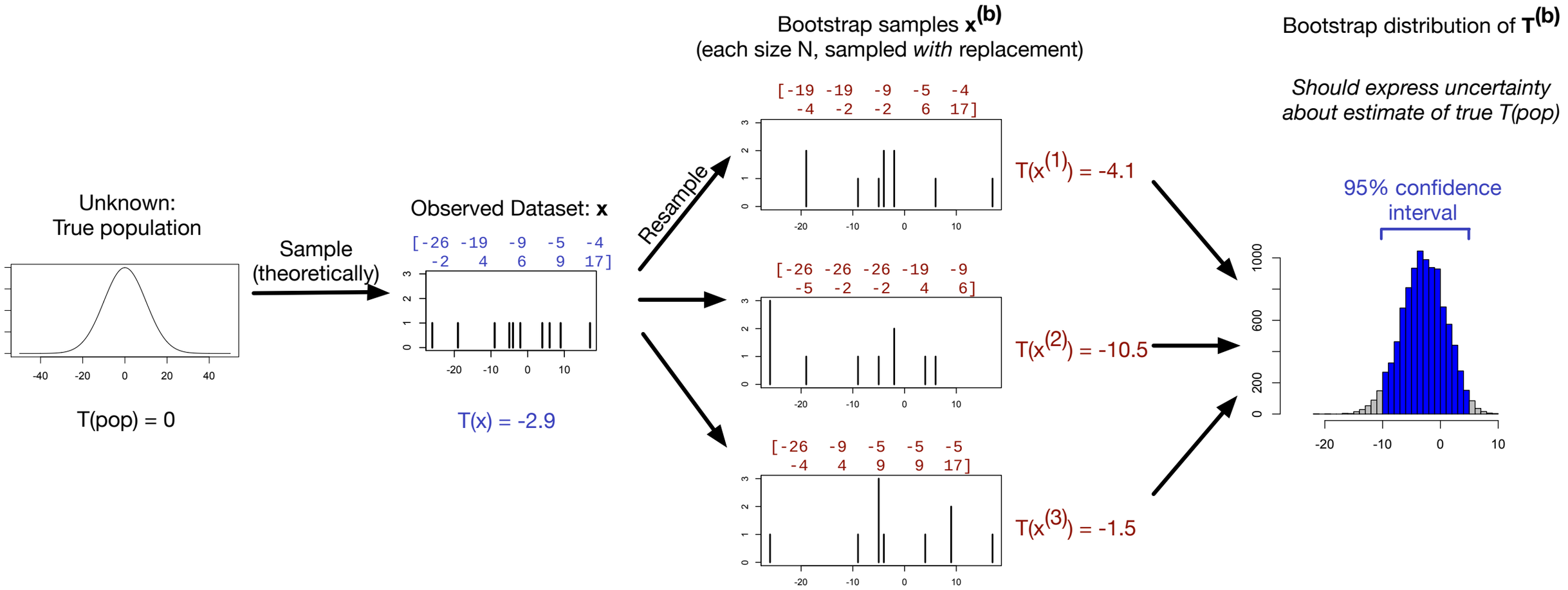
$$\mathrm{p}_{\mathrm{Binom}}(k; N, \theta) = \binom{N}{k} \theta^k (1-\theta)^{N-k}$$

Statistical tests

- Two types of information
  - p-values <=> null hypothesis test
  - confidence intervals
- Simulation-based testing
  - 1. Randomized null hypothesis simulation
  - 2. Bootstrapped confidence intervals
- Closed-form tests
  - t-tests, exact binomial test, chi-square tests....

Bootstrapping

- Excellent, flexible method to infer **confidence intervals**



Paired testing

- Bootstrap sampling implicitly does a "paired test"

- Statistical significance testing may be necessary, but never sufficient, for a meaningful result!
  - Statistical significance *vs.*
  - Substantive significance