CS208: Applied Privacy for Data Science
Membership Attacks

School of Engineering & Applied Sciences
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Public Access to Genome-Wide Data: Five Views…

Perusall Comments:

- What is a DNA mixture?
- Paywall?/exclusion to access
- Privacy of means vs. medians and other aggregates
- Researchers are human (“sloppy”) and human factors are real vulnerability
- “I would hope the next 12 months would produce greater clarity and time to produce a proportionate long-term response.” **12 months?**
- Fear of scientific abuse, particularly with genetics

Hypothesis Tests

A null hypothesis is a conjectured model of the world with observable implications.

Often it is a simplified model, for which there is some informational value if it can be refuted.

Null Distributions

If t is a function of the data, it has a sampling distribution. The distribution that t would obtain if the null hypothesis were true is called the *null distribution*.

- If we use the value of t to draw an inference about the null hypothesis, we call t a **test statistic**.
- We observe t^* in some observed dataset $\mathbf{X}^*$ and reason whether it could have been a draw from the null distribution.
- If t^* is unlikely to have come from the null distribution, we **reject the null** hypothesis.
- If t^* could have been obtained from the null distribution, we **fail to reject the null**.
- Failing to reject the null, does not prove the null to be true.

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Fail to Reject Null		
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Fail to Reject Null	Correct Specificity	Error (Type II) Sensitivity
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We parameterize our hypothesis test by choice of δ which results in a **critical value**, c, which divides the null distribution into the rejection regions.

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Fail to Reject Null	Correct Specificity $1 - \delta$	Error (Type II) Sensitivity
Reject Null	Error (Type I) Specificity δ	Correct Sensitivity

Example

H_0 : K-dimensional random variables $\mathbf{x}$ and $\mathbf{z}$ are both drawn from a standard Normal distribution with the same mean, $\mathcal{N}(\vec{\mu}, 1)$.

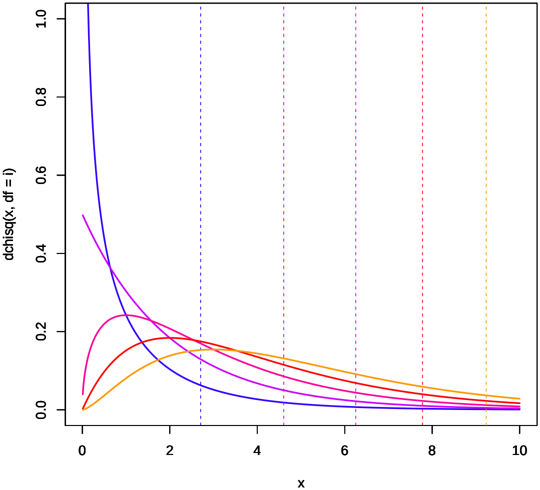
Then one test statistic is:

$$t(\mathbf{x}, \mathbf{z}) = ||\mathbf{x} - \mathbf{z}||_2 = \sqrt{\sum_{i=1}^{K} (x_i - z_i)^2}$$

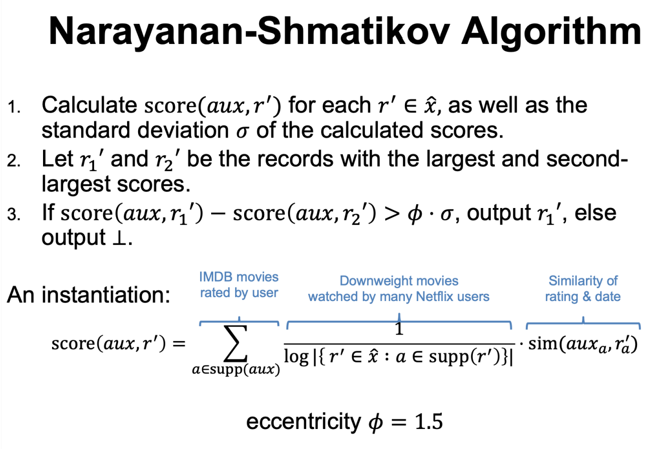
Which has null distribution $\chi^2(K)$.

Example

$\chi^2(K)$ Distribution with critical values for $\delta = 0.1$, for i in 1 to 5:



Netflix Challenge (from last week)



Narayanan-Shmatikov Algorithm

1. Calculate $\mathrm{score}(aux, r')$ for each $r' \in \hat{x}$, as well as the standard deviation σ of the calculated scores.
2. Let $r_1{}'$ and $r_2{}'$ be the records with the largest and second-largest scores.
3. If $\mathrm{score}(aux, r_1{}') - \mathrm{score}(aux, r_2{}') > \phi \cdot \sigma$, output $r_1{}'$, else output $\perp$.

An instantiation:

$$\mathrm{score}(aux, r') = \overbrace{\sum_{a \in \mathrm{supp}(aux)}}^{\text{IMDB movies rated by user}} \overbrace{\frac{1}{\log|\{r' \in \hat{x} : a \in \mathrm{supp}(r')\}|}}^{\text{Downweight movies watched by many Netflix users}} \cdot \overbrace{\mathrm{sim}(aux_a, r'_a)}^{\text{Similarity of rating \& date}}$$

eccentricity $\phi = 1.5$

Homer , Szelinger, Redman, Duggan, Tembe, Muehling, Pearson, Stephan, Nelson, & Craig (2008)

Resolving individuals contributing trace amounts of DNA to highly complex mixtures using high-density SNP genotyping microarrays.

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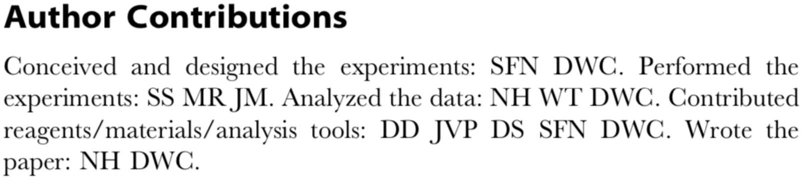


Author Contributions

Conceived and designed the experiments: SFN DWC. Performed the experiments: SS MR JM. Analyzed the data: NH WT DWC. Contributed reagents/materials/analysis tools: DD JVP DS SFN DWC. Wrote the paper: NH DWC.

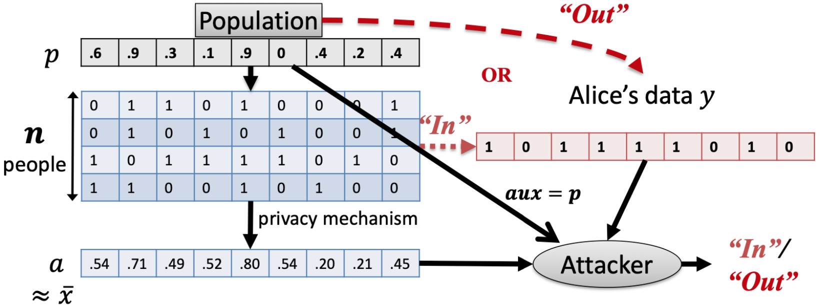
Homer *et al. (2008)*

Resolving individuals contributing trace amounts of DNA to highly complex mixtures using high-density SNP genotyping microarrays.

- Membership attack on individual's inclusion in sample/dataset with published summary statistics (means).
- Membership can violate privacy if membership betrays an implicit variable.
- *"Their [Braun et al.] work showed high specificity for the test statistic of Homer et al., but with possibility of low sensitivity."* Bruce Weir's Viewpoint: Individual Genotyping in Forensics and GWAS Contexts

Dwork, Smith, Steinke, Ullman, Vadhan (2015)

The Attacker



p	.6	.9	.3	.1	.9	0	.4	.2	.4

0	1	1	0	1	0	0	0	1
0	1	0	1	0	1	0	0	1
1	0	1	1	1	1	0	1	0
1	1	0	0	1	0	1	0	0

a	.54	.71	.49	.52	.80	.54	.20	.21	.45

1	0	1	1	1	1	0	1	0

$$A(y,a,p) = \begin{cases} \text{IN} & \text{if } \langle y-p, a-p\rangle > T \\ \text{OUT} & \text{if } \langle y-p, a-p\rangle \le T \end{cases}$$

$$T = T_{p,a} = O\left(\sqrt{d\log(1/\delta)}\right)$$