

permute: A Python Package for Randomization Inference

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ISNPS, Avignon



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Outline

1 Introduction

2 Examples

- Gender bias in teaching evaluations
- Inter-rater reliability

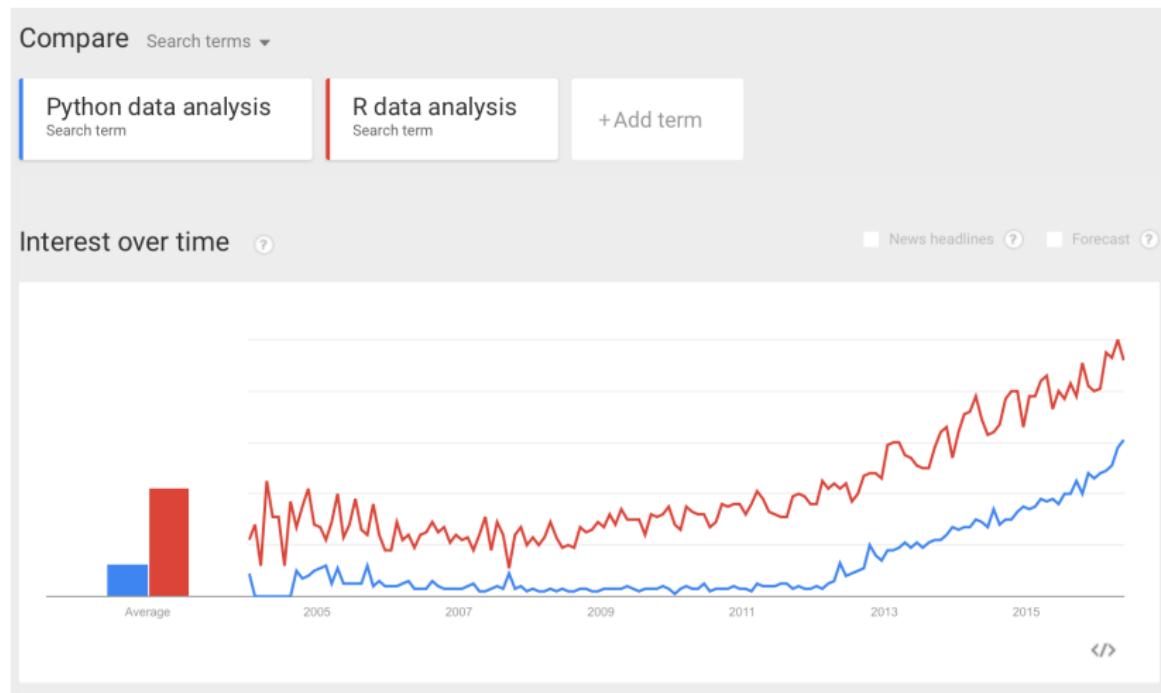
3 The role of software development in Statistics

Python is gaining popularity for doing data analysis

- TO DO: LOOK AT JARROD'S SLIDES - WHY PYTHON?

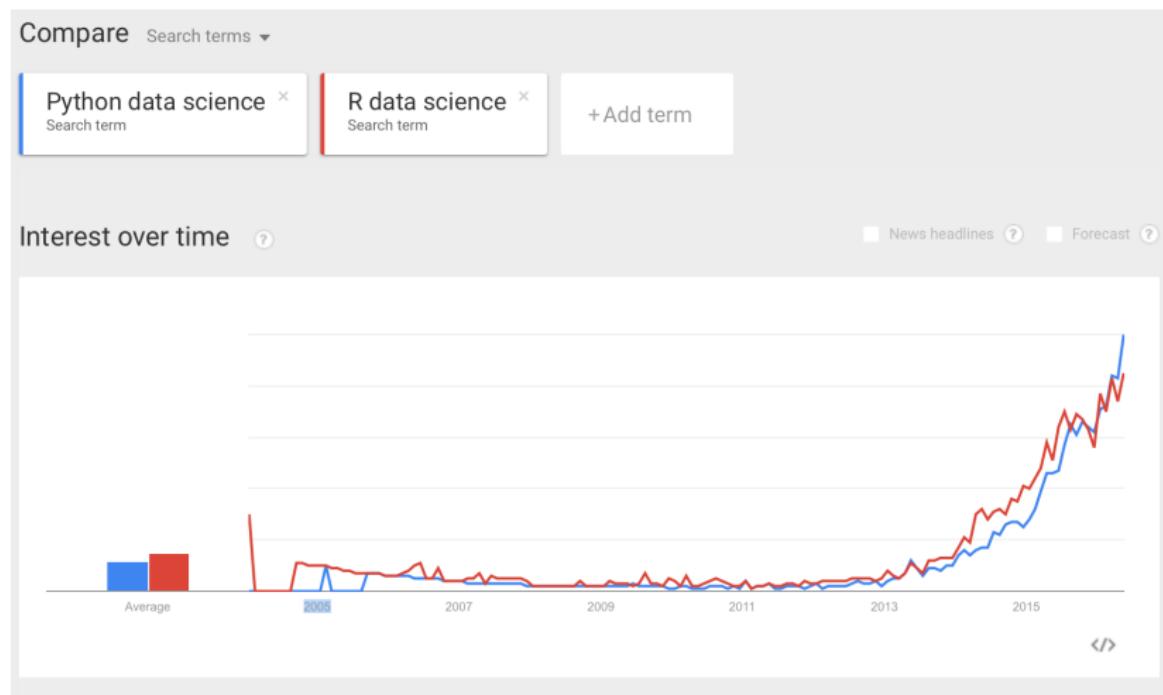
Python is gaining popularity for doing data analysis

Google trends on May 22, 2016



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Google trends on May 22, 2016



Keyword: data science

Python for teaching Statistics



Data Science 8, Spring 2016 at UC Berkeley

Permutation tests

- Fisher [1935] introduced permutation tests for randomized experiments
- TO DO: ADD MORE REFS!
- Rely on assumptions about randomization or exchangeability, rather than parametric assumptions, IID sampling, etc.

James Bradley [1968]

“[a] corresponding parametric test is valid only to the extent that it results in the same statistical decision [as the randomization test].”

Permutation tests

R has several packages for randomization inference.

- `ri`
- `RIttools`
- `coin`
- `perm`

In Python, statistics packages are limited.

- `numpy.random`
- `scipy.stats`
- `StatsModels`
- `scikit-learn`

Download permute!

Permutation tests and confidence sets

[build](#) passing [coverage](#) 99%

Permutation tests and confidence sets for a variety of nonparametric testing and estimation problems, for a variety of randomization designs.

- **Website (including documentation):** <http://statlab.github.io/permute>
- **Mailing list:** <http://groups.google.com/group/permute>
- **Source:** <https://github.com/statlab/permute>
- **Bug reports:** <https://github.com/statlab/permute/issues>

Installation from binaries

```
$ pip install permute
```

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Teaching Evaluations

Student evaluations of teachers (SET) are used to

- Quantify teaching effectiveness
- Compare instructors across courses
- Make hiring, firing, and promotion decisions

Are SET a valid measure of teaching effectiveness?

Teaching evaluations

No!

We reanalyzed data from MacNell et al. [2014].

- Students were randomized to 4 online sections of a course.
- In two sections, the TAs swapped identities.
- Was the TA who identified as female rated lower on average?

Neyman-Rubin model, generalized

Student i is represented by a ticket with 4 numbers, their response to each “treatment.”

$$r_{ijk} = \begin{aligned} &\text{SET given by student } i \text{ to instructor } j \\ &\text{when they appear to have gender } k \\ i = 1, \dots, N; \quad j = 1, 2; \quad k \in \{\text{male, female}\} \end{aligned}$$

Numbers are fixed; randomization reveals one of the numbers.

Assume non-interference: each student's response depends only on that student's treatment.

If gender doesn't matter,

$$r_{ij\text{male}} = r_{ij\text{female}}.$$

Randomization

Conceptually, there are two levels of randomization:

- ① N_m students are randomly assigned to the male instructor, and the remaining N_f get the female instructor.
- ② Of the N_j assigned to instructor j , N_{jm} are told that the instructor is male, for $j = 1, 2$.

All $\binom{N_m}{N_{mm}} \times \binom{N_f}{N_{fm}}$ assignments of students to sections are equally likely.

Stratified two-sample test

- For each instructor, permute perceived gender assignments
- Use difference in mean ratings for female-identified minus male-identified

Stratified two-sample test

Results

In all categories, the male-identified instructor was rated higher.

| Characteristic | M-F | perm P | t-test P |
|-----------------------|------------|---------------|-----------------|
| Overall | 0.47 | 0.12 | 0.128 |
| Caring | 0.52 | 0.10 | 0.071 |
| Consistent | 0.47 | 0.21 | 0.045 |
| Enthusiastic | 0.57 | 0.06 | 0.112 |
| Fair | 0.76 | 0.01 | 0.188 |
| Feedback | 0.47 | 0.16 | 0.054 |
| Helpful | 0.46 | 0.17 | 0.049 |
| Knowledgeable | 0.35 | 0.29 | 0.038 |
| Praise | 0.67 | 0.01 | 0.153 |
| Professional | 0.61 | 0.07 | 0.124 |
| Prompt | 0.80 | 0.01 | 0.191 |
| Respectful | 0.61 | 0.06 | 0.124 |
| Responsive | 0.22 | 0.48 | 0.013 |

Omnibus Test

Nonparametric combination of tests (NPC): combine individual p-values into a single omnibus test when there are many responses

Test whether **all null** hypotheses are true or **at least one alternative** is true

Fisher's combining function

Let $\{P_j\}_{j=1}^J$ be p-values for J hypotheses. Define

$$X^2 = -2 \sum_{j=1}^J \ln(P_j)$$

If $\{P_j\}_{j=1}^J$ are independent and all nulls are true, then $X^2 \sim \chi_{2J}^2$.

Omnibus Test

Ratings by the same student for different categories are **dependent**.

⇒ Treat all ratings from a student as a vector and calibrate the distribution of X^2 using the this permutation distribution.

TO DO: CHECK THAT THIS IS LEGIBLE

NPC Permutation Procedure

- ① Calculate the vector of observed values of test statistics (use the **same permutation** of section memberships to compute all statistics)
- ② Apply the combining function to get a single combined statistic for the permutation.
- ③ Repeat a large number B times to find the permutation distribution of the combined statistic.

Omnibus Test

```
# Initialize placeholders
ind = 0
test_distr = np.zeros( (10**5, len(categories)) )
pvalues = np.zeros( len(categories) )

# Loop over rating categories
for col in categories:
    (p, t, distr) = stratified_two_sample(
                    group=ratings.tagender,
                    response=ratings[col],
                    condition=ratings.taidgender,
                    alternative="two-sided",
                    stat="mean", seed = seed,
                    reps = 10**5, keep_dist = True)
    ind += 1
    test_distr[:,ind] = distr; pvalues[ind] = p

# NPC
omnibus_pvalue = npc(pvalues, test_distr, combine="fisher",
                      alternatives="two-sided")
```

Conclusions

Omnibus test: $P = 0$

- Reject the null hypothesis that there is no difference in ratings for any category
- The male-identified instructor was rated significantly higher than the female-identified instructor on several dimensions, **even on objective measures** such as how promptly assignments were returned
- SET measure something other than teaching effectiveness

NSGK Data

- Naomi Stark and Gilbert Kliman (NSGK) collected videos of therapy sessions with children on the autism spectrum
- A team of trained raters watched and tagged each 30-second interval of video from a collection of 183 clinically relevant tags
- Is tagging of therapist-patient interactions reliable (Millman et al. [2016])? Which tags do raters agree on?

Inter-rater reliability test

There are four dimensions. Can we simplify?

- Consider each clinical tag individually
- Do a partial hypothesis test for each video, then combine using NPC

| NSGK | IRR |
|--------------------------|---------------------|
| 183 types of activity | T tags |
| 8 videos | S strata |
| ~ 35 segments/video | N_s items/stratum |
| 10 raters | R raters |

Inter-rater reliability test

Is agreement within columns better than expected by chance?

| | | Video segment | | | |
|-------|---|---------------|-------|-------|-------|
| | | 1 | 2 | ... | N_s |
| Rater | 1 | White | Dark | White | Dark |
| | 2 | Dark | White | White | Dark |
| | 3 | Dark | White | White | White |
| | 4 | White | White | White | White |
| | 5 | Dark | Dark | White | White |
| | 6 | White | Dark | White | White |
| | 7 | Dark | White | White | White |
| | 8 | White | Dark | White | White |
| | R | White | Dark | White | Dark |

Inter-rater reliability test

Define

- $\{L_{s,i,r}\}$ = indicator for whether rater r tagged item i in stratum s
- $y_{si} = \sum_{r=1}^R L_{s,i,r}$ = number of raters who tagged item i in stratum s

The test statistic within stratum s is

$$\begin{aligned}\rho_s &\equiv \frac{1}{N_s \binom{R}{2}} \sum_{i=1}^{N_s} \sum_{r=1}^{R-1} \sum_{v=r+1}^R \mathbf{1}(L_{s,i,r} = L_{s,i,v}) \\ &= \frac{1}{N_s R(R-1)} \sum_{i=1}^{N_s} (y_{si}(y_{si} - 1) + (R - y_{si})(R - y_{si} - 1)).\end{aligned}$$

Inter-rater reliability test

Now we have a measure of concordance. What is the chance model?

| | | Video segment | | | |
|-------|---|---------------|------|-------|-------|
| | | 1 | 2 | ... | N_s |
| Rater | 1 | White | Dark | White | Dark |
| | 2 | Dark | Dark | White | Dark |
| . | | | | | |
| . | | | | | |
| . | | | | | |
| R | | White | Dark | White | Dark |

Permutation test

If tags are assigned completely at random, then

- any of 2^{N_s} assignments of tags are equally likely for each rater.
- raters assign tags independently of each other
- Each rater may have different “propensity” to assign a tag
 \Rightarrow condition on the number of items that a rater tagged.

IRR Permutation Test

- Permute tags within rows, independently across rows and across strata.
- Compute ρ_s and the corresponding p-value P_s , for $s = 1, \dots, S$.
- For overall test of tag, the NPC test statistic is

$$T = - \sum_{s=1}^S \frac{P_s}{\sqrt{N_s}}$$

Inter-rater reliability test

Observed tags for stratum s

| | | Video segment | | | |
|-------|---|---------------|-------|-------|-------|
| | | 1 | 2 | ... | N_s |
| Rater | 1 | White | Dark | White | Dark |
| | 2 | Dark | White | White | Dark |
| | 3 | Dark | White | White | White |
| | 4 | White | White | White | White |
| | 5 | Dark | Dark | White | White |
| | 6 | White | Dark | White | Dark |
| | 7 | Dark | White | White | White |
| | 8 | White | Dark | White | Dark |
| | R | White | Dark | White | Dark |

Inter-rater reliability test

Equally likely tags for stratum s , under the null

| | | Video segment | | | |
|-------|---|---------------|---|-----|-------|
| | | 1 | 2 | ... | N_s |
| Rater | 1 | ■ | | | ■ |
| | 2 | ■ | | ■ | ■ |
| | . | | ■ | | |
| | . | | | | |
| | . | | | | |
| | . | | ■ | | ■ |
| | R | ■ | | ■ | |
| | | | | | |

Inter-rater reliability test

Equally likely tags for stratum s , under the null

| | | Video segment | | | |
|-------|---|---------------|-------|-------|-------|
| | | 1 | 2 | ... | N_s |
| Rater | 1 | White | Dark | Dark | White |
| | 2 | Dark | White | White | White |
| | . | White | White | White | Dark |
| | . | White | White | White | White |
| | . | Dark | White | Dark | White |
| | . | White | White | Dark | Dark |
| | R | White | White | Dark | Dark |

Code

```
from permute.data import nsgk
from permute.irr import simulate_ts_dist, simulate_npc_dist

# load data, set video sizes
x = nsgk()
time_stamps = np.array([36, 32, 35, 37, 31, 35, 40, 32])

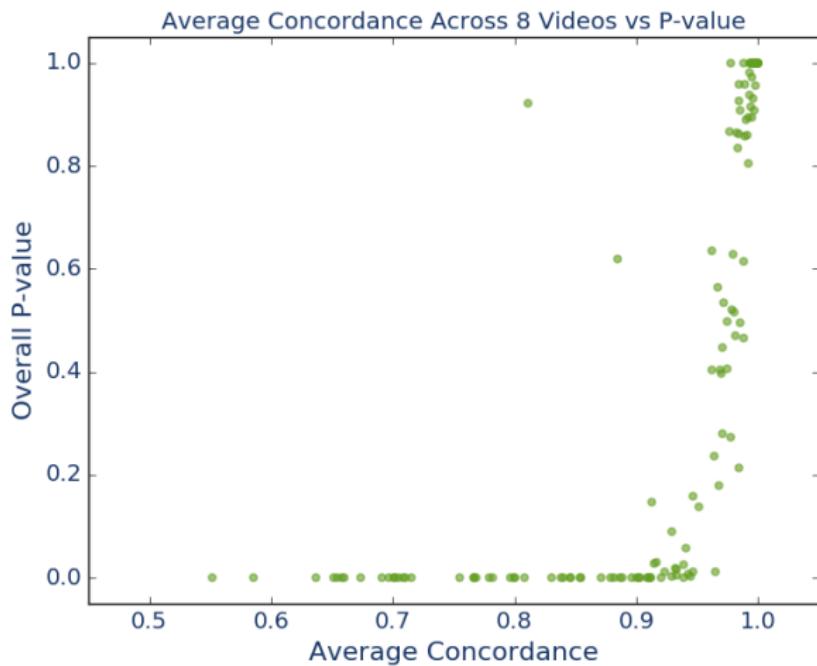
# Empty lists to store distrs and statistics for each video
d = []; tst = [] ; vid_temp = []

# Run analysis for a single category i
for j in range(len(x[i])): # loop over videos
    res = simulate_ts_dist(x[i][j], keep_dist=True)
    d.append(res["dist"])
    tst.append(res["obs_ts"])
    vid_temp.append(res["pvalue"])

# Combine permutation distributions for each video
perm_distr = np.asarray(d).transpose()
simulate_npc_dist(perm_distr, size=time_stamps,
                  obs_ts=tst, keep_dist=False)
```

Results

- 60 tags had $P < 0.05$
- Statistical vs practical significance – consult domain scientists
- Is there a more useful summary statistic than ρ_s ?



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Reproducibility

Why should Statisticians worry about writing software?

- Ethics
- Impact

Monkey Cage

Does social science have a replication crisis?

RESEARCH ARTICLE

Estimating the reproducibility of psychological science

Open Science Collaboration^{*†}



OPEN ACCESS

ESSAY

Why Most Published Research Findings Are False

John P. A. Ioannidis

Published: August 30, 2005 • <http://dx.doi.org/10.1371/journal.pmed.0020124>

SundayReview

There's a replication crisis in biomedicine—and no one even knows how deep it runs.

By Daniel Engber

Why Do So Many Studies Fail to Replicate?

Gray Matter

By JAY VAN BAERL MAY 27, 2016

NATURE | EDITORIAL

Reality check on reproducibility

POLICY & ETHICS

Is There a Reproducibility Crisis in Science?

About 40% of economics experiments fail replication survey

By John Bohannon | Mar. 3, 2016, 2:00 PM

NATURE | NEWS

Over half of psychology studies fail reproducibility test

Largest replication study to date casts doubt on many published positive results.

Monya Baker

27 August 2015

Ethics

Much of the reproducibility crisis can be traced back to bad statistics.

- Publication bias: positive findings are more likely to get published
- P-hacking and the garden of forking paths (Gelman and Loken [2013])
- Inappropriate statistical tests (Randomization inference may help here)

It is our responsibility to make it easy for researchers to do the right statistics.

Impact

Let us own data science (Yu [2014]).

We have to build the tools to

- facilitate reproducible scientific research,
- enable people to use the methods we develop (correctly!), and
- influence the way people do statistics more broadly.

Download `permute`!

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[build](#) passing [coverage](#) 99%

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<https://github.com/statlab/permute>

Collaborators



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**Stefan van der
Walt**
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