PARI PACKAGE: VALID DOUBLE-DIPPING VIA PERMUTATION-BASED ALL RESOLUTIONS INFERENCE

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USER! - 6 JULY 2021



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MOTIVATION - FMRI DATA

fMRI measures brain activation as changes in blood flow (BOLD) under a sequence of stimuli.

Cluster-wise method:

- Analyze set of contiguous voxels (S);
- H_S rejected means that S contains at least one active voxel
 → We don't know which ones and how many!!
- Spatial specificity paradox;
- Double-dipping.

ARI AND PARI

Solution: All-resolutions inference (ARI) $^1 \rightarrow$ Inference on the number of truly active voxels.

- pARI is the Permutation-based version of ARI. The permutation structure permits to account for the correlation structure between tests unlike ARI;
- Both methods are based on the closed testing procedure for controlling the familywise error rate.

¹Resenblatt, J. et al. (2018).

NOT ONLY FMRI DATA!

Every time that we want to infer inside a data-driven (and not) cluster (features set), we can use ARI/pARI:

- Cluster fMRI data analysis ²;
- Gene expression cluster analysis ³;
- Cluster EEG data analysis ⁴.

²Woo, C. et al. (2014).

³Berge, K. et al. (2017).

⁴Maris, E. et al. (2007).

MAIN FUNCTIONS OF PARI

```
devtools::install_github(angeella/pARI)
library(pARI)
```

fMRI framework:

```
pARIbrain(copes, thr, mask, alpha, ...)
```

where **copes** is a list of **contrast** parameter estimates involving brain activation differences for each subject in NIfTI format.

General framework:

```
pARI(data, ix, alpha, test.type, ...)
```

where ix is the **features set** of interest. It can be a vector of indices or a vector with length equals the number of features where different values indicate the different sets.

FMRI DATA APPLICATION - CODE

We analyzed the **Auditory data** collected by Pernet et al. (2015), i.e, people listening vocal and non-vocal sounds.

Group analysis on 140 subjects of the Vocal > Non-vocal **contrast** by the one sample t-test flipping the sign of 140 voxel-wise contrasts maps.

First, let download the data from the fMRIdata package:

```
devtools::install_github(angeella/fMRIdata)
library(fMRIdata)
data(Auditory_clusterTH3_2)
data(Auditory_copes)
data(Auditory_mask)
```

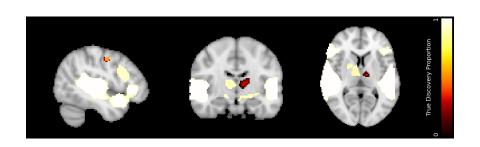
FMRI DATA APPLICATION - CODE

FMRI DATA APPLICATION - RESULTS

Cluster S	Threshold t	Size S	$\%$ active $\bar{\pi}(S)$		P-Values p _{FWER}
			pARI	ARI	
Right STG/PT HG/IFG/T	3.2	11683	92.36%	84.98%	< 0.0001
Right STG/PT HG/IFG/T	4	8875	99.54%	98.5%	_
Right IFG	4	422	91.47%	83.18%	_
Right T	4	292	85.96%	64.04%	=
Right T	4	15	13.33%	ο%	_

FMRI DATA APPLICATION - RESULTS

map_TDP: Create true discovery proportion map in nifti format.



Thanks to the amazing group that worked on the paper Permutation-based true discovery proportions for fMRI cluster analysis! (in arXiv)

- Livio Finos University of Padua;
- Jelle Goeman Leiden University Medical Centre;
- Jesse Hemerik Wageningen University;
- Wouter Weeda Leiden University;

and thanks for your attention!

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