Neuroimaging Analysis Kit - Overview

Pierre Bellec
pierre.bellec@criugm.qc.ca

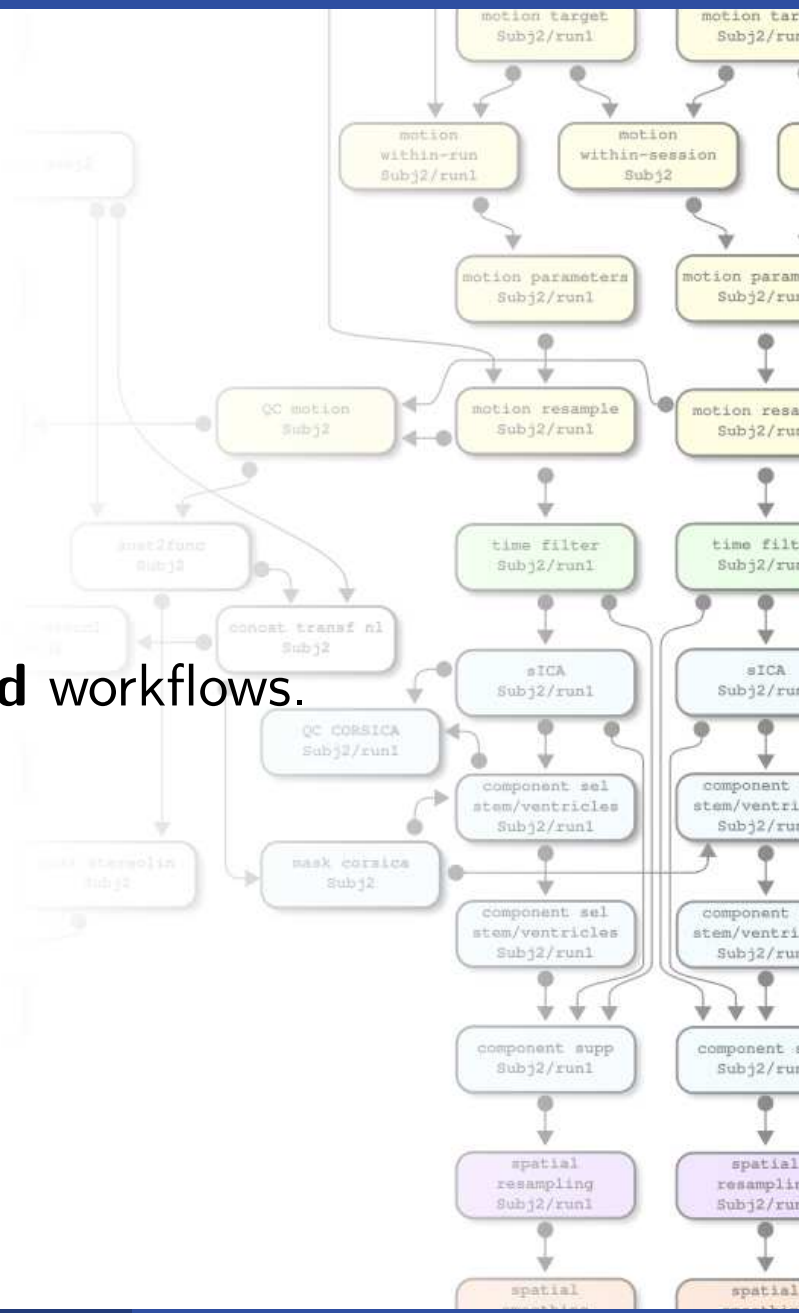
Feindel Brain Imaging Lecture - BIC/MNI/McGill 2016/10

Département d'informatique et de recherche opérationnelle, Université de Montréal

What's NIAK

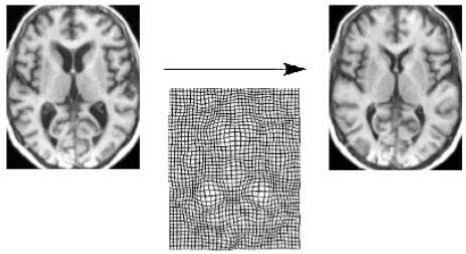
The Neuroimaging Analysis Kit (NIAK):
a software package for connectivity analysis
in large fMRI datasets.

- A catalogue of **complete workflows**.
- **Scales** for large datasets / analyses.
- **Reproducible** deployment of **well tested** workflows.
- Web-based **notebook** interface.
- Interactive **dashboard** reports.
- Free and **open-source** (MIT).

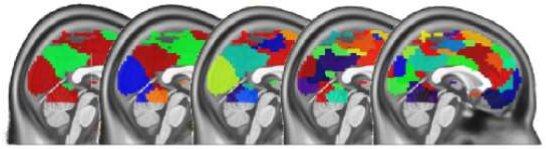


Available pipelines

fMRI preprocessing



Functional brain parcellation



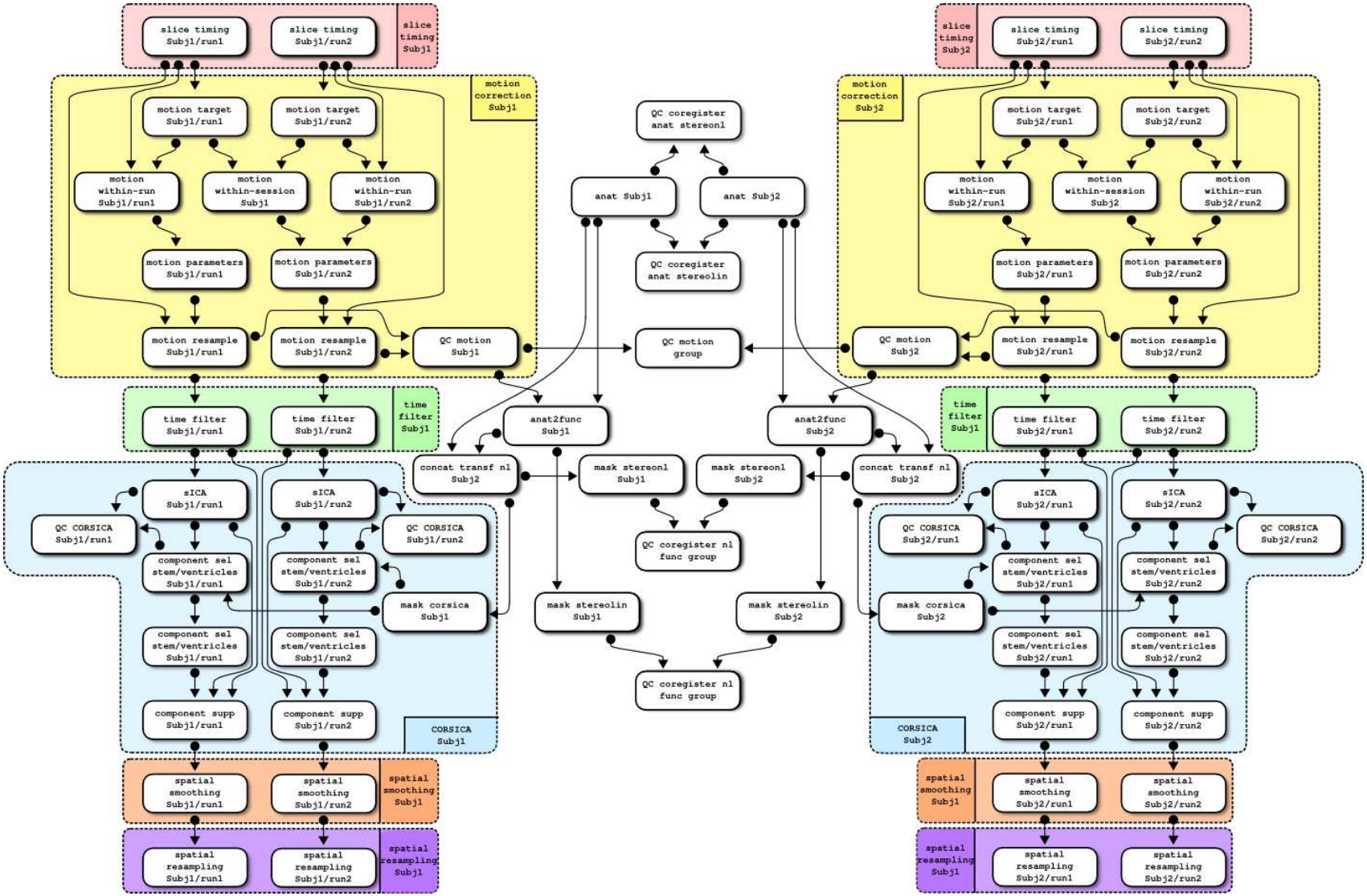
Generation of connectomes and connectivity maps

Check `http://niak.simexp-lab.org` for more info.

Main dependencies

- **Ubuntu**: An operating system based on mostly GNU tools as well as the linux kernel. Free software (mixed licenses). `https://www.ubuntu.com/`
- **Octave**: A high-level scientific programming language, largely identical to Matlab. Octave is Free Software (GNU license). `https://www.gnu.org/software/octave/`
- **The MINC toolkit**: A set of command line tools for brain registration, segmentation and basic image processing operation. Underlying code is mostly C and PERL. Free sotware (MIT like custom license). `http://bic-mni.github.io/`
- **The brain connectivity toolbox**: A toolbox to generate properties of brain networks. `https://sites.google.com/site/bctnet/`.

One pipeline, many jobs...



Jobs and dependencies for fMRI preprocessing of two subjects with two functional runs each.

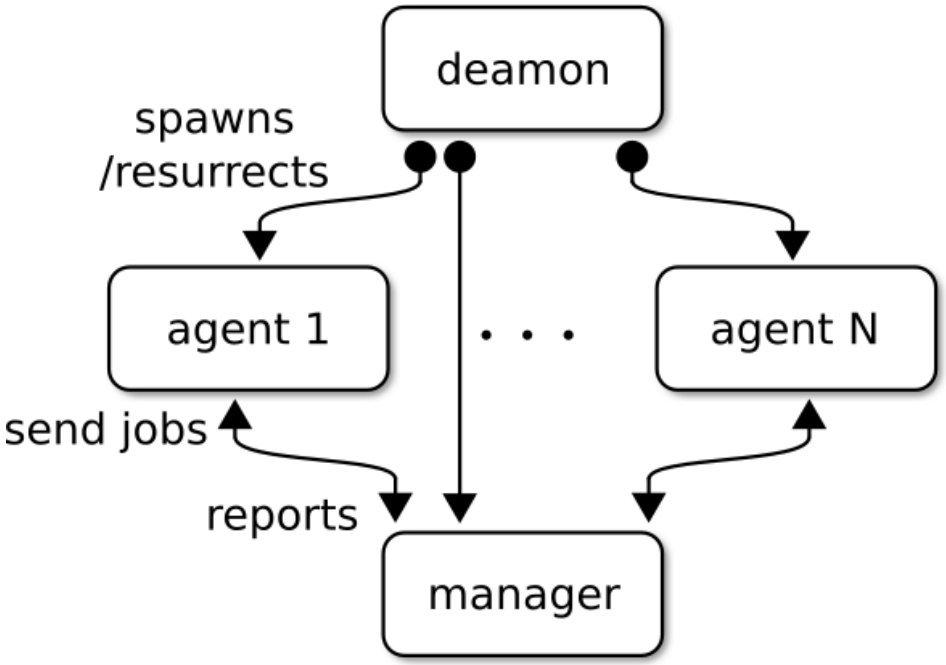
The pipeline system for Octave and Matlab

NIAK is powered by PSOM, an open-source library for scripting pipelines using Octave or Matlab (Bellec et al., Frontiers in Neuroinformatics, 2012).

- **Parallel computing**: Detection and execution of parallel components in the pipeline. The same code can run in a variety of execution environments (local, multi-core, cluster).
- **Provenance tracking**: Generation of a comprehensive record of the pipeline stages and the history of execution.
- **Fault tolerance**: Multiple attempts will be made to run each job before it is considered as failed. Failed jobs can be automatically re-started.
- **Smart updates**: When an analysis is started multiple times, only the parts of the pipeline that need to be reprocessed are executed.

`http://psom.simexp-lab.org`

PSOM architecture

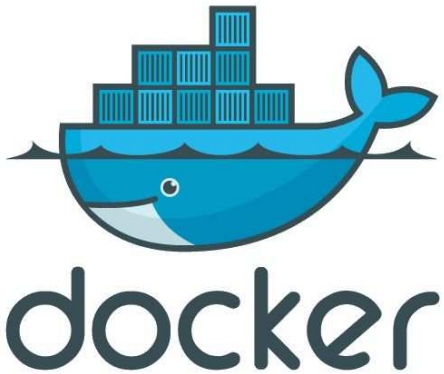


PSOM features an agent-based execution model.

Benchmark PSOM 2.0

- Dataset Human Connectome Project, 875 subjects with T1 + 7 mutliband fMRI task runs.
- 123k jobs / 3.4 T raw input / 3.8 T output / 173k unique input/output files.
- `guillimin`: supercomputer (Xeon, 20k+ cores on 2016), infiniband parallel file system.
- Up to 300 concurrent processes allowed.
- Serial time: 17.9k hours / 746.87 days. Parallel time: 70 hrs. Parallelization efficiency: 85%
- deviation from 100% efficiency mostly attributable to queuing delays in order to access resources.

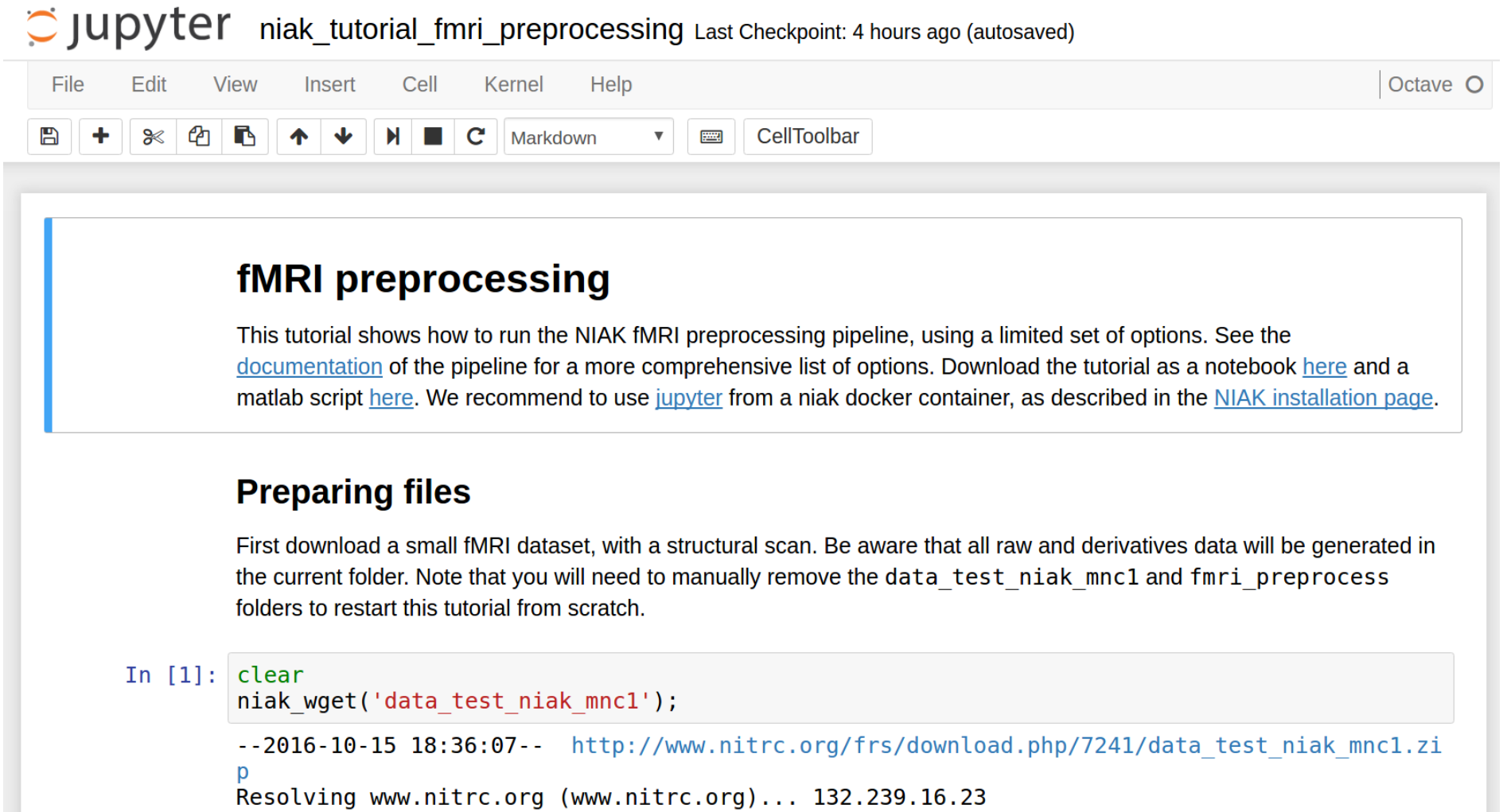
NIAK deployment using Docker



- The NIAK now as a docker container, available in docker hub `https://hub.docker.com/`, as well as singularity `http://singularity.lbl.gov/`, designed for high-performance computing infrastructures.
- The container includes all dependencies (MINC-toolkit, Octave, PSOM, NIAK, Brain Connectivity Toolbox, Jupyter).
- This facilitates installation and increases reproducibility on all platforms, Linux, Mac, Windows `http://niak.simexp-lab.org/niak_installation.html`

How does it work?

Octave (similar to matlab) runs in a jupyter notebook.



Testing pipelines...

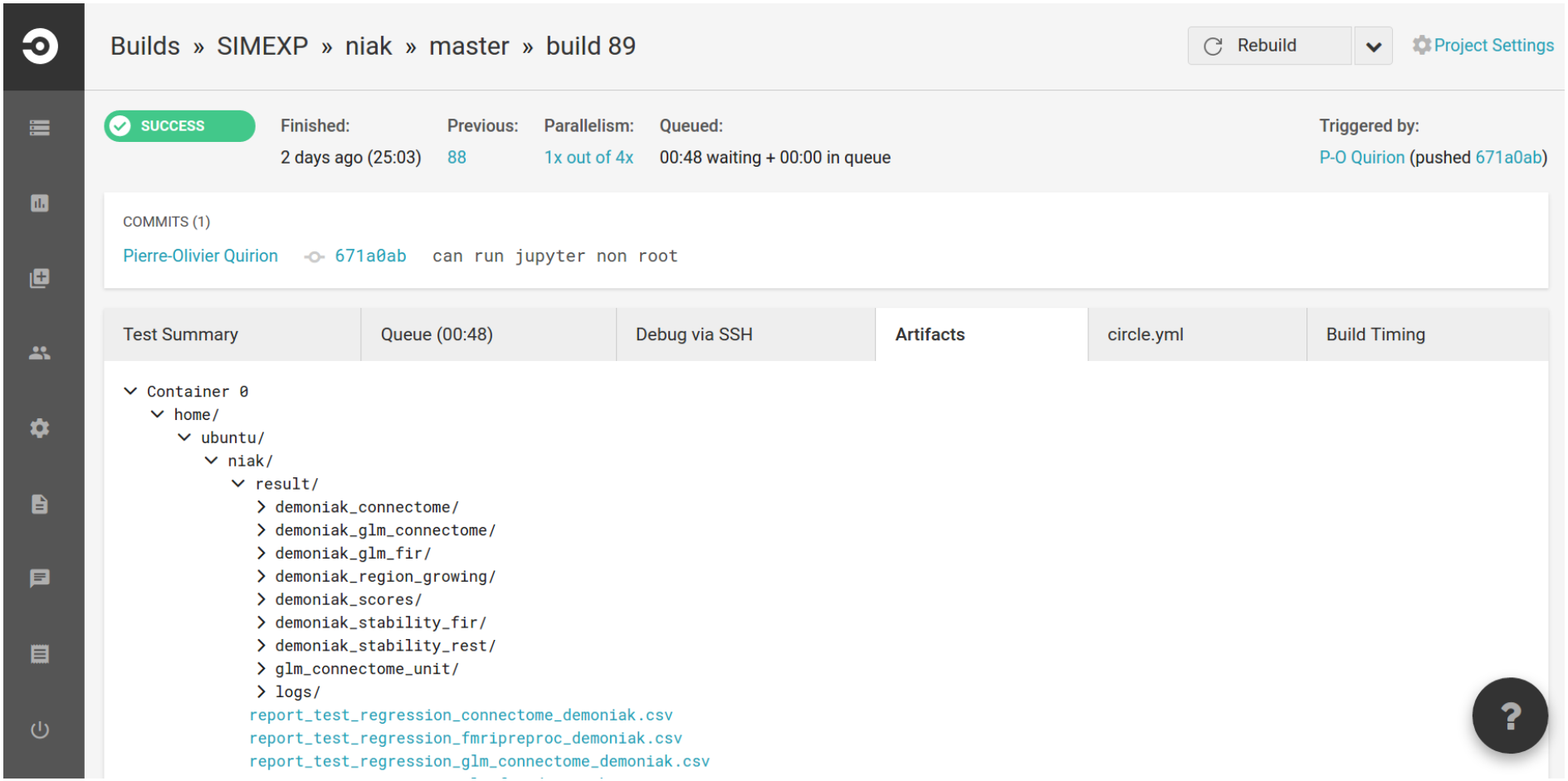
Numerical instabilities creep up in a complex pipeline.

Effective numerical stabilization strategies are required to extract reliable measures.

An engineering problem suprisingly little studied in the fMRI field.

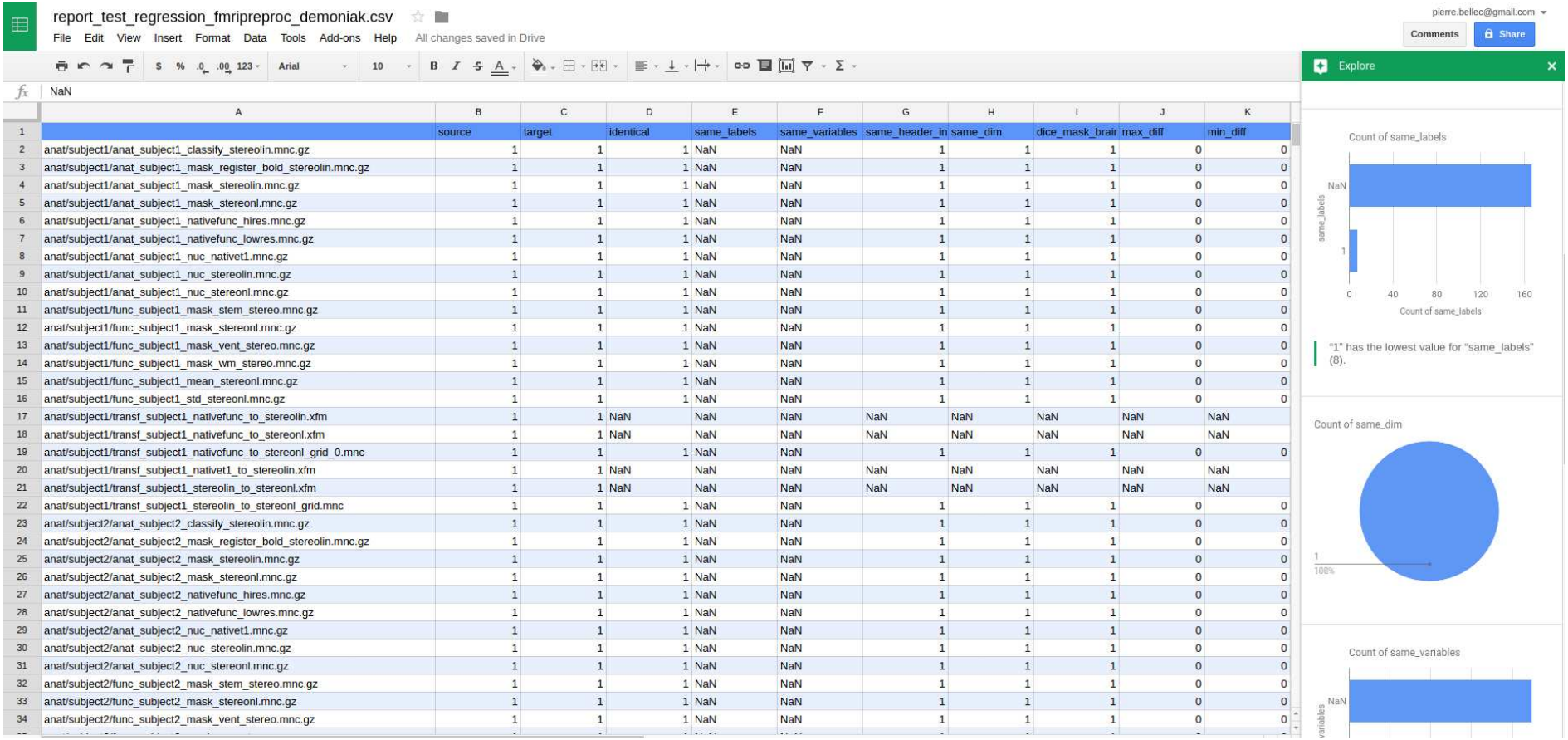
Continuous integration tests

NIAK continuous integration tests running on `https://circleci.com/gh/SIMEXP/niak`



Continuous integration tests

Each change in NIAK triggers a comparison between current results and a fixed, target version, across all available pipelines. Quantitative reports show which stage of the pipeline has changed, and by how much.



report_test_regression_fmripreproc_demoniak.csv

File Edit View Insert Format Data Tools Add-ons Help All changes saved in Drive

pierre.bellec@gmail.com

Comments Share

fx NaN

	A	B	C	D	E	F	G	H	I	J	K
1		source	target	identical	same_labels	same_variables	same_header_in	same_dim	dice_mask_brair	max_diff	min_diff
2	anat/subject1/anat_subject1_classify_stereolin.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
3	anat/subject1/anat_subject1_mask_register_bold_stereolin.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
4	anat/subject1/anat_subject1_mask_stereolin.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
5	anat/subject1/anat_subject1_mask_stereonl.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
6	anat/subject1/anat_subject1_nativefunc_hires.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
7	anat/subject1/anat_subject1_nativefunc_lowres.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
8	anat/subject1/anat_subject1_nuc_nativet1.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
9	anat/subject1/anat_subject1_nuc_stereolin.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
10	anat/subject1/anat_subject1_nuc_stereonl.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
11	anat/subject1/func_subject1_mask_stem_stereo.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
12	anat/subject1/func_subject1_mask_stereonl.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
13	anat/subject1/func_subject1_mask_vent_stereo.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
14	anat/subject1/func_subject1_mask_wm_stereo.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
15	anat/subject1/func_subject1_mean_stereonl.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
16	anat/subject1/func_subject1_std_stereonl.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
17	anat/subject1/transf_subject1_nativefunc_to_stereolin.xfm	1	1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
18	anat/subject1/transf_subject1_nativefunc_to_stereonl.xfm	1	1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
19	anat/subject1/transf_subject1_nativefunc_to_stereonl_grid_0.mnc	1	1	1	NaN	NaN	1	1	1	0	0
20	anat/subject1/transf_subject1_nativet1_to_stereolin.xfm	1	1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
21	anat/subject1/transf_subject1_stereolin_to_stereonl.xfm	1	1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
22	anat/subject1/transf_subject1_stereolin_to_stereonl_grid.mnc	1	1	1	NaN	NaN	1	1	1	0	0
23	anat/subject2/anat_subject2_classify_stereolin.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
24	anat/subject2/anat_subject2_mask_register_bold_stereolin.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
25	anat/subject2/anat_subject2_mask_stereolin.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
26	anat/subject2/anat_subject2_mask_stereonl.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
27	anat/subject2/anat_subject2_nativefunc_hires.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
28	anat/subject2/anat_subject2_nativefunc_lowres.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
29	anat/subject2/anat_subject2_nuc_nativet1.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
30	anat/subject2/anat_subject2_nuc_stereolin.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
31	anat/subject2/anat_subject2_nuc_stereonl.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
32	anat/subject2/func_subject2_mask_stem_stereo.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
33	anat/subject2/func_subject2_mask_stereonl.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0
34	anat/subject2/func_subject2_mask_vent_stereo.mnc.gz	1	1	1	NaN	NaN	1	1	1	0	0

Explore

Count of same_labels

same_labels: NaN, 1

0 40 80 120 160

Count of same_labels

"1" has the lowest value for "same_labels" (8).

Count of same_dim

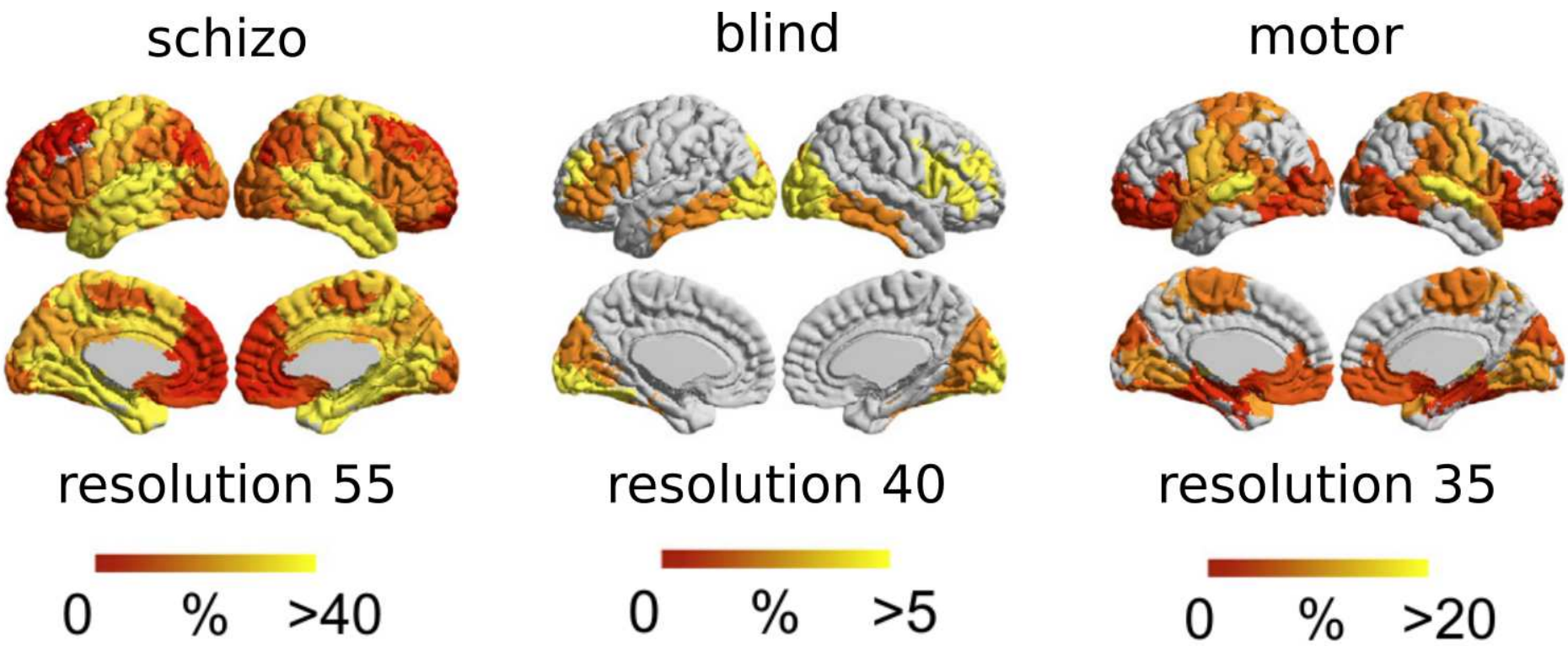
1 100%

Count of same_variables

same_variables: NaN

Large-scale validation at release

Future NIAK releases will systematically replicate a number of key large-scale validation experiments and compare results across versions.



Between-group comparisons in resting-state connectivity across three populations. See Bellec et al., Orban, Neuroimage 2015.

Acknowledgements

- **Funding**: Brain Canada CBRAIN, UdM, UNF/CRIUGM, CCNA (CIHR), Courtois foundation, Lemaire foundation.
- **QC@NIAK**: **Yassine Benhajali**, Sebastian Urchs, AmanPreet Badhwar, Perrine Ferré, Angela Tam, Christian Dansereau.
- **validation@NIAK**: **Pierre Orban**, Yassine Benhajali, Felix Carbonell, Christian Dansereau, Geneviève Albouy, Maxime Pelland, Cameron Craddock, Olivier Collignon, Julien Doyon, Emmanuel Stip.
- **NIAK**: Pierre-Olivier Quirion, Angela Tam, Sebastian Urchs, Yassine Benhajali, Christian Dansereau, Felix Carbonell, Jussi Tohka. Many indirect contributions

License

The NIAK project is under an MIT opensource license