NiPreps: enabling the division of labor in neuroimaging beyond fMRIPrep

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Introduction

The current neuroimaging workflow has matured into a large chain of processing and analysis steps involving a large number of experts, across imaging modalities and applications. The development and fast adoption of *fMRIPrep* [1] have revealed that neuroscientists need tools that simplify their research workflow, provide visual reports and checkpoints, and engender trust in the tool itself. Here we present the *NiPreps* (NeuroImaging Preprocessing tools) framework, which extends *fMRIPrep*'s approach and principles to new imaging modalities. The vision for *NiPreps* is to provide end-users (i.e., researchers) with applications that allow them to perform quality control smoothly and to prepare their data for modeling and statistical analysis.

Methods

The *NiPreps* framework (Figure 1) encompasses a wide array of software projects organized into three layers of scientific software:

- Software infrastructure: including quite mature projects such as *NiPype* [2] and *NiBabel*; the standard specifications of the Brain Imaging Data Structure (*BIDS* [3], and *BIDS-Derivatives*); and some other tools such as *NiTransforms* or *TemplateFlow*, under development. These tools deliver low-level interfaces (e.g., data access to images and spatial transforms) and utilities (see Figure 1).
- Middleware: these are utilities that generalize their functionalities across the end-user tools. These utilities cover foundational processing methodologies (e.g., *NiWorkflows* and *SDCFlows*), the crowdsourcing of metadata (e.g., *MRIQC Web-API* [4]), and the support for deep learning models (*MRIQC-nets*).
- End-user tools such as *fMRIPrep*: Some existing end-user tools include *sMRIPrep* (Structural MRI Preprocessing), which lies in between an end-user tool and middleware, as it is involved in higher-level tools such as *fMRIPrep*. Finally, quality control tools (e.g., *MRIQC* [5]) to be executed before any preprocessing happens.

End-user *NiPreps* abide by the following principles:

1. *NiPreps* only and fully support *BIDS* and *BIDS-Derivatives* for the input and output data.
2. *NiPreps* are packaged as a fully-compliant *BIDS-Apps* [6], not just in its user interface, but also in the continuous integration, testing, and delivery.
3. The scope of *NiPreps* is strictly limited to preprocessing tasks.
4. *NiPreps* are agnostic to subsequent analysis, i.e., any software supporting *BIDS-Derivatives* for its inputs should be amenable to analyze data preprocessed with them.
5. *NiPreps* are thoroughly and transparently documented (including the generation of individual, visual reports with a consistent format that serve as scaffolds for understanding the underpinnings and design decisions).
6. *NiPreps* are community-driven, and contributors (in any sense) always get credited with authorship within relevant publications.
7. *NiPreps* are modular, reliant on widely-used tools such as *AFNI*, *ANTs*, *FreeSurfer*, *FSL*, *NiLearn*, or *DIPY* [7-12] and extensible via plug-ins.

Results

fMRIPrep is the first *NiPrep* application and has served to pilot the approach. The tool has successfully helped many researchers to preprocess their data while minimizing friction and time-cost, and maximizing the transparency of their research. The tool has demonstrated an appropriate performance on an extense domain of diverse data, as shown by the number of successful runs around the world (see Figure 2). *fMRIPrep* has engaged a substantial number of researchers, as evidenced in our latest documentation sprint.

Discussion and conclusion

fMRIPrep has demonstrated that it is possible to alleviate the comprehensive computing knowledge required for functional MRI studies. Leveraging *BIDS* and *Derivatives*, it is possible to view preprocessing as an extension to the scanning device. In other words, standardizing preprocessing is a way of creating smart imaging devices that produce data ready for analysis.

References

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Figure 1. The NiPreps software stack. To ensure the best software engineering practices, and to separately continuously test software, the framework comprehends several strates of tools.

Figure 2. fMRIPrep is continuously expanding over time. (top) The documentation website has an average of 2,100 monthly visitors, which has steadily increased over time. (bottom) The number of weekly runs is in the order of 3,000~4,000 successful executions.