NIDM-Results: Standardized reporting of mass univariate neuroimaging results in SPM, FSL and AFNI

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1. Camille Maumet, Warwick Manufacturing Group, University of Warwick, Coventry, United Kingdom.
2. B Nolan Nichols, Center for Health Sciences, SRI International, Menlo Park, CA, USA.
3. Guillaume Flandin, Wellcome Trust Centre for Neuroimaging, UCL Institute of Neurology, London, United Kingdom.
4. Karl Helmer, Martinos Center for Biomedical Imaging, Massachusetts General Hospital; Dept. of Radiology, Boston, MA, USA.
5. Tibor Auer, MRC Cognition and Brain Sciences Unit, Cambridge, United Kingdom
6. Alexander Bowring, Warwick Manufacturing Group, University of Warwick, Coventry, United Kingdom.
7. Vanessa Sochat, Department of Psychology, Stanford University, Stanford, CA, USA
8. Samir Das, McGill Centre for Integrative Neuroscience, Ludmer Centre, Montreal Neurological Institute, Montreal, Quebec, Canada.
9. Tristan Glatard, McGill Centre for Integrative Neuroscience, Ludmer Centre, Montreal Neurological Institute, Montreal, Quebec, Canada & Université de Lyon, CREATIS ; CNRS UMR5220 ; Inserm U1044 ; INSA-Lyon ; Université Claude Bernard Lyon 1, France.
10. Richard Reynolds, Scientific and Statistical Computing Core, National Institute of Mental Health, National Institutes of Health, USA
11. Robert W. Cox, Scientific and Statistical Computing Core, National Institute of Mental Health, National Institutes of Health, USA
12. Gang Chen, Scientific and Statistical Computing Core, National Institute of Mental Health, National Institutes of Health, USA
13. Mark Jenkinson, University of Oxford, UK.
14. Matthew A. Webster, University of Oxford, UK.
15. Jason Steffener, Department of Neurology, Columbia University, New York, USA.
16. Krzysztof J. Gorgolewski, Department of Psychology, Stanford University, Stanford, CA, USA
17. Jessica Turner, Psychology and Neuroscience, Georgia State University, Atlanta, GA, USA
18. Thomas Nichols, Dept. of Statistics and Warwick Manufacturing Group, University of Warwick, Coventry, United Kingdom.
19. Satrajit Ghosh, McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA, USA.
20. Jean-Baptiste Poline, Helen Wills Neuroscience Institute, H. Wheeler Jr. Brain Imaging Center, University of California at Berkeley, CA, USA.
21. David Keator, Dept. of Psychiatry and Human Behavior, Dept. of Computer Science, Dept. of Neurology, University of California, Irvine, CA, USA.

Introduction

Results of a neuroimaging study are usually shared through the publication of a scientific paper describing the experiment and analysis outcome. While hundreds of gigabytes of data are usually generated as part of an fMRI experiment, in the literature the authors typically report their results as a list of significant local maxima, i.e. locations in the brain defined in a standard space (e.g. MNI) that pass rigorous statistical testing. This practice is unsatisfactory in terms of data re-use as it does not allow for the automatic extraction of acquisition or processing information and it provides only sparse information about the location of the brain activity. While databases have been built to provide manually curated (such as BrainMap [1]) or automatically-extracted (e.g. NeuroSynth [2]) meta-data associated with published papers, ideally, these meta-data should be made available by the authors themselves at the time of the publication.

Full representation of neuroimaging results in a machine-readable form would provide unambiguous description and hence support more reproducible and robust science [3,4]. Another important use-case would be meta-analysis that would allow for quantitative syntheses of the literature.

NIDM-Results is a machine-readable representation of “mass univariate” neuroimaging results, standardised for the 3 major software analysis packages: SPM, FSL, and soon AFNI. It relies on semantic web technologies and integrates with previous efforts to provide standardized vocabularies including PROV [5], Neurolex [6] and STATO [7].

Methods

Since August 2013, we have organised weekly conference calls and 7 focused workshops (under the auspices of the INCF Neuroimaging data sharing Task Force) with a core group of experts representing more than 10 labs involved in various facets of neuroimaging (informatics, software development, statistical analysis, ontologies…). A separate meeting was also organised with each of the development teams of the 3 major neuroimaging software to discuss the model and its implementation. Minutes of the meetings and online discussions are publicly available, links to those resources are provided on GitHub under the incf-nidash organization (https://github.com/incf-nidash/nidm).

Results

NIDM-Results 1.2.0 was released on December 14th, 2015. The specification is available at: http://nidm.nidash.org/specs/nidm-results.html and also formally described in an ontology file. An overview of the proposed model is provided in Fig. 1. NIDM-Results provides not only cluster and peak listing but it also links to the full 3D images of interest for meta-analysis (statistic, standard error, contrast estimate maps).

Export of statistical results using NIDM is natively available in SPM12. External scripts have been developed for FSL 5.0 and are under developement for AFNI (both available at https://github.com/incf-nidash). As an example of application, we liaised with NeuroVault [8] to propose a one-click upload of NIDM-Results labeled data. Here, users can benefit from all Neurovault features including state-of-the-art visualization and online hosting (public or private).

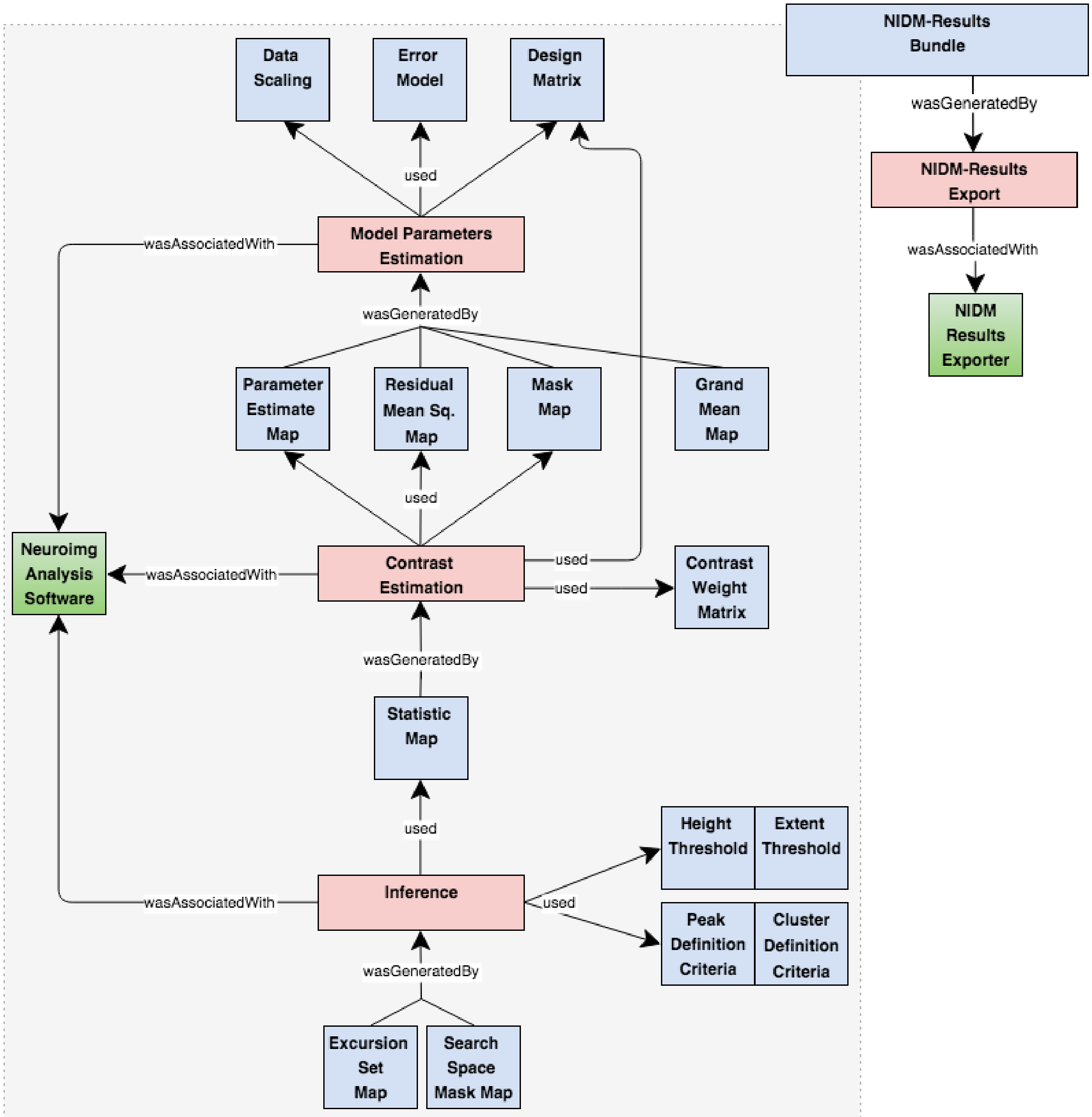

Fig. 1. NIDM-Results core structures. Each box represents an Activity (red), Entity (blue) or Agent (green) as defined in PROV data model.

Conclusions

We have introduced NIDM-Results, a data model to encode the results of GLM-based neuroimaging studies. Export as a NIDM-Result archive is available in SPM12 and in FSL 5.0. Development of the AFNI export is in-progress. NIDM-Results folders can be easily uploaded to Neurovault providing access to a common platform for sharing and visualization. As a machine-readable representation of neuroimaging results, NIDM-Results is a step forward to support transparency of neuroimaging studies.

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