Gaël VAROQUAUX

Physics – Applied math

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Research interests: computational and statistical modeling of complex systems.

- My current research is on building quantitative statistical and descriptive models of brain activity through computational analysis of functional imaging.
- My original training is in quantum physics. My PhD research has been focused on developing quantum-based atom-optic metrology.
- In addition, I have a keen interest in developing scientific-computing tools and software-engineering best practices.

EDUCATION

PhD *2005–2007*
Université Paris Sud Orsay, FRANCE, direction: Pr. Alain Aspect, defense January 18, 2008.
Thesis: Atomic sources for long-time-of-flight interferometric inertial sensors

Masters *2004*
Masters in quantum physics (DEA de physique quantique, ENS)

ENS *2001–2004*
Undergraduate studies at École Normale Supérieure Paris (ENS). I ranked 17$^{\text{th}}$ at the selection exam (also accepted at École Polytechnique, 13$^{\text{th}}$, and École des Mines de Paris, 4$^{\text{th}}$)

NEUROIMAGING 2008—Present

Positions

INRIA *Oct. 2008–Present*
Post-doctoral fellow, Parietal team, NeuroSpin, supervision: B. Thirion, J.P. Poline.
Development of statistical methods to study brain resting-state activity.

Research

My main research interest is the development of algorithms and models for multivariate data analysis and statistical inference from the correlation structure of functional MRI images without using a paradigm, such as in resting-state studies. I focus on group models, opening the door to between-subject comparisons.

Spatial models of on-going activity
Spatial Independent Component Analysis (**ICA**) is a widely-used technique in neuroimaging to extract brain networks. I have extended it with a multivariate group model [1, 8] to conduct multi-subject analysis with good reproducibility [2]. In addition, I have used a statistical model of the signal to segment regions from ICA with control on sensitivity and specificity [4].

Graphical models for functional connectivity
I have developed statistical and machine learning tools in the framework of Gaussian graphical models to the study of the correlation structure of the brain-activity signal. With new task-specific comparison methods we have isolated memory-refresh tasks modifications of functional connectivity in schizophrenia [9]. For statistically-principled inter-subject comparison of functional connectivity, we have introduced a new matrix-variate distribution describing group variability of covariance matrices [5]. With A. Kleinschmidt, we have applied this methodology to stroke patients and have for the first time extracted modifications of resting-state networks due to pathologies on single subjects.

Machine learning for inter-subject brain mapping
I work on multivariate analysis to map the neuronal coding of cognitive processes across subjects. Subject-to-subject anatomo-functional variability is a fundamental limitation to population studies in brain functional imaging. We adapt state-of-the-art machine learning and computer vision algorithms to model it explicitly in the data analysis. In the standard analysis framework (GLM), we use functional landmarks to map subject specificities [6]. In the context of inverse inference, we learn regions that predict behavior across subjects [2, 7].

Publications

Peer-reviewed journals

[1] G. Varoquaux, S. Sadaghiani, *et al.* *A group model for stable multi-subject ICA on fMRI datasets*, NeuroImage **51**, p. 288 (2010)

[2] V. Michel, A. Gramfort, *et al.* *Total variation regularization for fMRI-based prediction of behavior*, Submitted to IEEE Transactions on Medical Imaging

Peer-reviewed proceedings

[3] G. Varoquaux, S. Sadaghiani, *et al. Model-based extraction of reproducible group-level ICA patterns from fMRI time series*, MICCAI 2009: fMRI data analysis workshop (2009)

[4] G. Varoquaux, M. Keller, *et al. ICA-based sparse features recovery from fMRI datasets*, IEEE ISBI 2010.

[5] G. Varoquaux, F. Baronnet, *et al. Detection of brain functional-connectivity difference in post-stroke patients using group-level covariance modeling*, MICCAI 2010 (oral presentation).

[6] B. Thirion, G. Varoquaux, J.B. Poline, *Accurate definition of brain regions position through the functional landmark approach*, MICCAI 2010.

[7] V. Michel, A. Gramfort, *et al. Total Variation regularization enhances regression-based brain activity prediction*, ICPR 2010 Workshop on Brain Decoding

International conferences

[8] G. Varoquaux, S. Sadaghiani, *et al.*, *Model-based extraction of resting-state networks across subjects*, NeuroImage, **47**, p. 82, (2009), presented at the annual Organization for Human Brain Mapping meeting (2009).

[9] M.-L. Grillon, F. Charbonneau, *et al.*, *fMRI study of the Refreshing Process in Schizophrenia*, NeuroImage,**159**, proceedings of the 50th Annual Meeting of the Psychonomic Society (2009).

Other

Reviewer for *Human Brain Mapping* (Wiley InterScience), *NeuroImage* (Elsevier) and *Journal of Machine Learning Research* (MIT Press).

PHYSICS 2002—2008

Positions

LENS Fellow *Nov. 2007–March 2008*
EST Marie Curie European Fellow: LENS (European laboratory for non-linear spectroscopy, Florence, ITALY), quantum degenerate gases group, supervision: prof. M. Inguscio.

PhD candidate *2005–2007*
Atom optics group, Institut d'Optique Graduate School, Palaiseau, FRANCE

University of Toronto *Sept.–Oct. 2006*
Guest researcher. Degenerate quantum gases group, prof. J. Thywissen. I implemented a new camera on the world's first Fermi degenerate gas experiment on chip [18].

Internships *Jan.–Aug. 2003*
University of Otago, ultra-cold atom group, supervision A. Wilson. Design and construction of a rubidium magneto-optical trap for a new atomic quantum gases experiment.

Sept.–Oct. 2002
University of Lancaster, liquid-^{4}He group, supervision: prof. P. Mc Clintock. Cryogenic work.

Research

Atoms are promising candidates to replace photons in interferometric measurements of inertial forces, due to their strong gravitational coupling. In my research, I have addressed two fundamental limits to the scale of atom interferometers: divergence and fall of the atomic source.

Quantum atomic sources
I have contributed to experimental techniques for well-controlled production of quantum gases to create *atom lasers*, that is maximally coherent and focused atomic sources. New developments include development of light-weight noise-controlled tunable lasers [10], design of a new atom cooling and trapping apparatus [11], and a new atom probing and imaging method [14].

Free-fall atom interferometry
The ICE project is a collaboration between Institut d'Optique, ONERA, and Observatoire de Paris for atom interferometry in microgravity using a freely-falling plane as a platform for longer interrogation times of falling atoms. I developed the mobile laboratory and atom interferometer for the first test flight (March 2007). I was coordinator of the flight campaign, including designing, planning, and supervising the assembly of the interferometer and the in-flight operations [12]. Our experiment was the second to ever achieve cold atoms in flight and the apparatus is now used in bi-annual measurement campaigns [15].

Matter-wave interferometry measure and estimation
The phase measured by atom interferometry is directly linked to the inertial fields [17], but in a freely-falling plane these fields are confounded by acceleration noise. I have introduced Bayesian statistical modeling to atom-interferometric inertial sensing and shown that tests of general relativity are possible using a noisy platform [16].

Other

YAO conference *2006*
Member of the scientific and organizing committees of the European Young Atom Opticians conference "YAO2006" (J.B. Trebbia, G. Varoquaux and F. Arcara, *Nature Physics* **8**, p. 287, 2007).

Teaching *2005–2007*
Monitorat: teaching students labs and tutorials in optics and electronics, at the "*Institut d'Optique Graduate School*" (SupOptique).

Student supervision
I supervised the work of several students: 3 undergraduates, and 2 masters students, on experimental and numerical work.

Publications

Peer-reviewed journals

[10] R. A. Nyman, G. Varoquaux, *et al.*, *Tapered-amplified AR-coated laser diodes for Potassium and Rubidium atomic-physics experiments*, Review of Scientific Instruments **77**, p. 033105 (2006)

[11] R. A. Nyman, G. Varoquaux, *et al.*, *I.C.E.: a Transportable Atomic Inertial Sensor for Test in Microgravity*, Journal of Applied Physics B, **84** pp. 673-681 (2006)

[12] G. Varoquaux, N. Zahzam, *et al.*, *ICE: an ultra-cold atom source for long-baseline interferometric inertial sensors in reduced gravity*, Proceedings of the international Moriond meetings on gravitational waves and experimental gravity (2007)

[13] E. Varoquaux and G. Varoquaux, *The Sagnac effect in superfluids*, Uspekhi Fizicheskikh Nauk, **2** p. 217 (2008)

[14] J. P. Brantut, J. F. Clément, *et al.*, *Light-shift tomography in an optical-dipole trap for neutral atoms*, Physical Review A, **78**, 031401 (2008)

[15] G. Stern, B. Battelier, *et al.*, *Light-pulse atom interferometry in microgravity* European Physical Journal D **53**, 3 pp. 353-357 (2009)

[16] G. Varoquaux, R. A. Nyman, *et al.*, *How to estimate the differential acceleration in a two-species atom interferometer to test the equivalence principle*, New Journal of Physics **11**, 113010 (2009)

Conference proceedings

[17] P. Bouyer, G. Varoquaux, *et al.*, *Testing the universality of free fall in a freely-falling two-species atom interferometer: the I.C.E project*, Proceedings of the International Conference on Space Optics, Toulouse, France, October 2008

SCIENTIFIC COMPUTING

2005—Present

I have been contributing to the elaboration of a general-purpose tool stack for scientific computing, using the Python language. My effort is shared between software development and improving communication and cooperation between scientific software projects and users.
The various projects are driven by an emphasis on communication, readability, and quality of the code for more reproducible science and sharing of efforts and idea across scientific fields.

Positions

Enthought, consultant *2008*
Consultant on scientific computing solutions in Python for Enthought Inc. (Austin).
I contributed to customer-specific data processing and visualization code and general-purpose scientific computing frameworks.

UC Berkeley *June–Sept. 2008*
Junior specialist, scientific computing: development of NeuroImaging computing in Python (Nipy project), supervision: F. Perez.

Computing skills

- Proficient developer, with a specialization in scientific computing and data visualization.
- Very good knowledge of the Python language. Knowledge of C and Matlab.
- Experience in software project management and software architecture design.
- Experienced Linux system administrator on servers and desktops since 2001.
- Very good knowledge of LaTeX and publishing technologies.

Software

Mayavi *2007–Present*
One of the two developers of Mayavi, the lead 3D scientific data visualization library and application for Python [19,21]. This project won the FOSS India awards in 2008, and the second price at the MICCAI 2009 visualization awards. It is packaged in all the major Linux distributions and scientific Python environments and comes with a 300-pages long manual.

Pyreport *2005–Present*
Author of pyreport, a tool for literate programming of scientific Python code, widely used in teaching and tutorials.

Nipy *2008–Present*
Contributing to and maintaining Nipy, a cross-institute project to share neuroimaging algorithms in Python via a consistent library (actors: CEA, INRIA, UC Berkeley, MIT, Stanford).

joblib *2009–Present*
Author of joblib, metaprograming for light-weight and high-performance pipelining of scientific Python code.

scikit-learn *2010–Present*
Project manager and core developer for scikit-learn, machine learning in Python.

SciPy community

EuroScipy conference *2010*
Co-chair of the 3rd European Python in science conference (EuroScipy), ENS, Paris, (France), July 8-11 2010.

SciPy conference *2008–2009*
Chair of the scientific committee for the Python in science conference (SciPy), Caltech, Pasadena (USA), 2008 and 2009. Also organizer and editor of the proceedings.

Code contributions *2007–Present*
Contributions to various key projects (IPython, Matplotlib, scipy, numpy [20]). In particular, development of a graphical frontend to IPython.

Server administration *2008–Present*
Administration of the SciPy web servers and documentation and conference applications: www.scipy.org, planet.scipy.org, conference.scipy.org, docs.scipy.org.

Publications

Peer-reviewed journals

[18] G. Varoquaux, *Agile computer control of a complex experiment*, Computing in Science and Engineering, **10**(2) p. 55 (2008).

[19] P. Ramachandran, G. Varoquaux, *Mayavi: a package for 3D visualization of scientific data*, Computing in Science and Engineering, In press.

[20] S. van der Walt, S. Colbert, G. Varoquaux, *The numpy array: a structure for efficient numerical computation*, Computing in Science and Engineering, In press.

Peer-reviewed proceedings

[21] P. Ramachandran, G. Varoquaux, *Mayavi: Making 3D Data Visualization Reusable*, Proceedings of the 7th Python in Science conference, G. Varoquaux, T. Vaught, J. Millman (Eds.), pp. 51-56 (2008).

[22] G. Varoquaux, T. Vaught, J. Millman (Eds), *Proceedings of the 7th Annual Python in Science Conference* – Pasadena, CA, August 19-24, (2008)

[23] G. Varoquaux, S. van der Walt, J. Millman (Eds), *Proceedings of the 8th Annual Python in Science Conference* – Pasadena, CA, August 18-23, (2009)

Other

Reviewer
Reviewer for *Computing in Science and Engineering* (AIP/IEEE).

Teaching and training
I teach various aspects scientific computing in Python on a regular basis, both introduction courses, and advanced courses, in conferences (SciPy, EuroSciPy, PyConFr), or in research labs.

Contact

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