3-year postdoc fellow position at NeuroSpin (France), immediately available

TOPIC: Cutting edge image reconstruction algorithms for high-spatiotemporal resolution SPARKLING fMRI imaging on humans at 11.7T

Supervision:
Dr Philippe Ciuciu, Head of Inria-CEA MIND team
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Key points:

- Duration: 3 years starting as soon as possible.
- Salary: commensurate upon background and experience
- Location: The candidate will be hired by NeuroSpin at CEA Saclay.
- Application: Please send an application with a CV, a motivation letter, a list of publications and 2 letters of recommendation to: philippe.ciuciu@cea.fr

Description:

The **CEA Paris-Saclay** complex is a leading research and innovation center at the national and European level. It is part of the Community of Universities and Establishments "Université Paris-Saclay" which represents approximately 15% of French research. **NeuroSpin** is Europe's main platform for innovation in brain imaging technologies and neuroscience. It was opened on January 1, 2007 and is embedded within the Fundamental Research Division of the CEA. NeuroSpin is headed by Prof. Stanislas Dehaene, (professor at the Collège de France, Paris) and affiliated with **the Paris-Saclay University**. The overarching goal at NeuroSpin is to understand the singularity of human brain using unprecedented tools, such as the unique 11.7T clinical MR system in addition to 7T/3T clinical scanners, which will be soon upgraded for full pTx Terra.X and Cima.X, respectively.

NeuroSpin's organization includes four research units of which the **Inria-CEA MIND and the CEA-CNRS BAOBAB labs** play pivotal roles in the use of AI, signal processing and MR physics for developing new accelerated MR imaging techniques, notably for functional imaging (fMRI).

"**EXPLORE +**" BlueSky project is a large scale CEA-funded project (1.5M€ over 4 years since 2023) awarded to **Dr Philippe Ciuciu**. The project aims to understand learning and decision making processes in the healthy brain at the mesoscale using fMRI imaging at high spatiotemporal resolution (e.g. up to 500µm and < 1s). This cognitive neuroscience study is supervised by **Dr Florent Meyniel'**s team at NeuroSpin.

The postdoc fellow will contribute in collaboration to a recently hired PhD candidate to making this extremely challenging fMRI acquisition scenario realistic both on the **fMRI data acquisition and image reconstruction** sides. The PhD candidate will use and extend 3D SPARKLING, a non-Cartesian readout (1-4), which embodies strong acceleration potential to enable high spatial and temporal resolution fMRI without impeding whole brain coverage. Additionally, SPARKLING acquisitions currently require a computationally-demanding image reconstruction process prior to conducting statistical analysis for the detection of evoked brain activity during the EXPLORE+ experimental paradigm.

Consequently, the postdoc fellow that will be recruited will work on improving the existing fMRI image reconstruction pipeline to make it easier and faster for end-users, i.e. cognitive neuroscientists. For doing so, he/she will rely first on in-house developments notably the PySAP software package and its plugin for fMRI. Second, he/she will investigate deep learning solutions based on unrolled deep neural networks (5) and/or Plug&Play algorithms (6). When addressing deep learning solution for image reconstruction in fMRI, as ground truth, i.e. fully sampled data cannot be collected first due to the short scan time constraint and second because brain activity is never completely reproducible, two competing solutions can be envisaged: either training DL architectures on realistic synthetic data, such as those yielded by our recent SNAKE-fMRI simulator (7), and then proceeding to transfer learning or domain adaptation, or using self-supervised approaches (8). Both methods will be investigated.

A very important deliverable will be to implement a complete reconstruction solution directly connected at the console using “Gadgetron” (9) or “Open Recon” Siemens Healthineers platform (10). Automating the correction of off-resonance artifacts within the pipeline is also a key aspect.

Importantly, implementation and demonstrations of SPARKLING fMRI have been done at 7T but **EXPLORE+ aims to collect fMRI data at 11.7T** in order to benefit from the larger BOLD contrast to noise ratio. The candidate will also need to adapt the SPARKLING fMRI pulse to 11.7T by adding parallel transmission capabilities with the so-called Universal Pulses (11) to maintain its user-friendly characteristic while delivering homogeneous $B1^+$ RF field. This upgrade should allow us to access layer-specific (500µm) spatial resolution in the cortex. Last, the candidate will participate in fMRI acquisitions and data processing in collaboration with the neuroscientists involved in EXPLORE+.

The ideal candidate holds a PhD in electrical or biomedical engineering, with a solid **background in MRI, signal processing, and Artificial Intelligence (deep learning)** and is proficient in software programming notably in scientific Python. Preliminary experience on supercomputers is a plus.

Since the project requires multiple skills, the candidate will be supported both by Philippe Ciuciu and his team, but also by the BAOBAB (specialized in MRI methodology) and UNICOG (cognitive neuroscience) labs. Therefore he/she must demonstrate team player capabilities. **The position allows partial teleworking and includes social advantages offered to employee working in France** (minimum of 5 weeks of vacations, full healthcare coverage, and free public school for children up to high school).

References:

1. Chaithya GR, Weiss P, Daval-Frérot G, Massire A, Vignaud A, Ciuciu P. Optimizing full 3d sparkling trajectories for high-resolution magnetic resonance imaging. IEEE Transactions on Medical Imaging. 2022 Mar 7;41(8):2105-17.

2. Amor Z, Ciuciu P, GR C, Daval-Frérot G, Mauconduit F, Thirion B, Vignaud A. Non-cartesian 3D-SPARKLING vs cartesian 3D-EPI encoding schemes for functional magnetic resonance Imaging at 7 Tesla. Plos one. 2024 May 13;19(5):e0299925.

3. Amor Z, Le Ster C, Gr C, Daval-Frérot G, Boulant N, Mauconduit F, Thirion B, Ciuciu P, Vignaud A. Impact of ΔB0 field imperfections correction on BOLD sensitivity in 3D-SPARKLING fMRI data. https://onlinelibrary.wiley.com/doi/full/10.1002/mrm.29943;

4. Giliyar Radhakrishna C, Daval-Frérot G, Massire A, Vignaud A, Ciuciu P. Improving spreading projection algorithm for rapid k-space sampling trajectories through minimized off-resonance effects and gridding of low frequencies. Magnetic Resonance in Medicine. 2023 Sep;90(3):1069-85.

5. Ramzi Z, Chaithya GR, Starck JL, Ciuciu P. NC-PDNet: A density-compensated unrolled network for 2D and 3D non-Cartesian MRI reconstruction. IEEE Transactions on Medical Imaging. 2022 Jan 18;41(7):1625-38.

6. Kamilov US, Bouman CA, Buzzard GT, Wohlberg B. Plug-and-play methods for integrating physical and learned models in computational imaging: Theory, algorithms, and applications. IEEE Signal Processing Magazine. 2023 Jan 2;40(1):85-97.

7. Comby PA, Vignaud A, Ciuciu P. SNAKE-fMRI: A modular fMRI data simulator from the space-time domain to k-space and back. arXiv preprint arXiv:2404.08282. 2024 Apr 12.

8. Yaman B, Hosseini SA, Moeller S, Ellermann J, Uğurbil K, Akçakaya M. Self-supervised learning of physics-guided reconstruction neural networks without fully sampled reference data. Magnetic resonance in medicine. 2020 Dec;84(6):3172-91.

8. Dowdle LT, Vizioli L, Moeller S, Akçakaya M, Olman C, Ghose G, Yacoub E, Uğurbil K. Evaluating increases in sensitivity from NORDIC for diverse fMRI acquisition strategies. NeuroImage. 2023 Apr 15;270:119949.

9. Gadgetron: An open source framework for medical image reconstruction - Hansen - 2013 - Magnetic Resonance in Medicine - Wiley Online Library [Internet]. [cité 27 avr 2024]. Disponible sur: https://onlinelibrary.wiley.com/doi/10.1002/mrm.24389

10. Siemens Healthineers presents two revolutionary high-end MRI scanners for clinical and scientific use [Internet]. Disponible sur: https://www.siemens-healthineers.com/press/releases/cimaterrax

11. Gras V, Vignaud A, Amadon A, Le Bihan D, Boulant N. Universal pulses: A new concept for calibration-free parallel transmission. Magnetic Resonance in Medicine. févr 2017;635-43.