CEA NeuroSpin Parietal Team CosmoStat Lab

CEA PhD Scholarship:
"Compressed sensing 3D and 3D+t MR image reconstruction from highly under-sampled data in high resolution anatomical and functional imaging at 7 and 11.7 Tesla"

Applications are invited for a PhD position funded by a CEA grant in the context of the interdisciplinary COSMIC (Compressed Sensing for Magnetic resonance Imaging & Cosmology[1] project, in collaboration between Philippe Ciuciu (CEA/NeuroSpin[2] & INRIA-CEA Parietal team[3]) and Jean-Luc Starck (CEA/DAp, CosmoStat lab[4]).

The position is for **3 years**, gross salary will be about 2000 € per month including social insurance. The starting date will be on October, 1st 2018 by the earliest.

Research field: Signal & image processing. MRI. Neuroimaging. Machine learning.

Profile: The successful candidate will have demonstrated proficiency with data processing and/or data analysis in neuroimaging or in astrophysics. Eligible qualifications for this position include:

- Msc in Image/Signal Processing, Data science or in biomedical engineering; the candidate will have to show a strong interest in magnetic resonance imaging (MRI) and in functional neuroimaging;
- Solid background in convex optimization and inverse problem solving (e.g., compressed sensing, deconvolution, image restoration or reconstruction);
- Strong coding aptitudes, proficiency in Python and C or C++ Preliminary experience in GPU and/or multi-CPU parallel programming (e.g. using CUDA);
- Excellent written and verbal communication skills in English;
- Strong interpersonal skills, assertive and proactive.

Research Topic: Magnetic Resonance Imaging (MRI) is the gold-standard medical imaging technique to probe the brain in vivo in a non-invasive manner. MR image resolution improvement in a standard scanning time (e.g., 200 μm isotropic in 15 min) is a major challenge to allow neuroscientists and medical doctors to push the limits of their current knowledge and to significantly improve both their diagnosis and patients' follow-up. The raise of the new sampling theories like Compressed Sensing (CS) has revolutionized the way of collecting data in numerous scientific fields (e.g., ultrasound imaging, MRI, radio-astronomy) by drastically reducing acquisition times. In this context, NeuroSpin's efforts have been focused on the development of new sampling schemes as well as new MR pulse sequences for 2D and 3D high resolution anatomical imaging, the 3D imaging schenario allowing us to achieve isotropic high resolution imaging.

Since 2016, the DRF impulsion COSMIC project between the NeuroSpin and IRFU/CosmoStat teams has provided us with the opportunity to improve 2D MR image quality using multi-resolution analysis based on geometrically-informed sparse dictionaries (e.g., curvelets). The main goal of this PhD thesis will consist of extending this work to 3D and 3D+t settings for

[1] https://cosmic.cosmostat.org/
[2] http://joliot.cea.fr/drf/joliot/Pages/Entites_de_recherche/NeuroSpin.aspx
[3] https://team.inria.fr/parietal/
[4] http://www.cosmostat.org/

respectively high resolution anatomical and functional brain imaging at ultra-high magnetic fields (on the 7 Tesla and the future 11.7T system). The first challenge will be to identify optimal sparse dictionaries in space and time, and their combination, for optimal 3D and 3D+t MR images recovery. Fixed and data-adaptive dictionaries will be tested in particular the possibility offered by machine learning techniques to uncover data-driven decompositions. Efficient off-line and on-line 3D and 3D+t parallel imaging (i.e. multi-channel) reconstruction algorithms will be developed using the PySAP software[5] in the context of sparse + low-rank regularization for functional MRI data. On-line implementation will be implemented using the Gadgetron solution installed on NeuroSpin's scanners. In vivo validation will be performed on healthy volunteers first at 7 Tesla and then at 11.7 Tesla to reach isotropic anatomical (200 μm) and functional (500 μm) high resolution imaging. Using GPU-based implementation, the objective will be to achieve a reconstruction time less than 20 sec/volume for each $512 \times 512 \times 512$ fMRI scan (2GB in memory/volume) and less than 5 min for a single high resolution anatomical image ($1024 \times 1024 \times 1024$).

Keywords: convex optimization; MRI reconstruction; compressed sensing; ultra-high fields; parallel imaging; sparsity; dictionary learning; GPU parallelization; high resolution; anatomical MRI; functional MRI.

Location & Resources: The successful participant will be located at NeuroSpin and will work under the joint supervision of Philippe Ciuciu and Jean-Luc Starck; he/she will benefit from all the MRI and power computing facilities installed at NeuroSpin, a neuroimaging center located in CEA-Saclay dedicated to the understanding of the human brain. Five laboratories currently share their expertise on site and provide a stimulating research environment. The hosting team would be Parietal team lead by Bertrand Thirion.

Applications deadline: April, 30th 2018. Please, submit a motivation letter detailing your current research interests, a curriculum vitae, and the contact information of up to three individuals who can provide a letter of recommendation to Philippe Ciuciu (philippe.ciuciu@cea.fr) and Jean-Luc Starck (jlstarck@gmail.com).

[5] `https://github.com/CEA-COSMIC/pysap`