
POSTDOC POSITION OFFER AT CEA/NEUROSPIN:
ACCELERATED MULTI-CONTRAST NON-CARTESIAN IMAGING AT 7 TESLA USING
SPARKLING



Supervision:

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Duration: 15 months, with a possible 12-month extension. Salary commensurate upon background and experience

Location: The candidate will be hired by NeuroSpin at CEA Saclay.

Application: The position is to-be-filled as soon as possible (deadline for application: May, 15th 2023). Please send an application with a CV, a motivation letter, a list of publications and 2 letters of recommendation to: philippe.ciuciu@cea.fr.

Context. Understanding brain structure and function is one of the largest scientific challenges of the 21st century that embodies various domains from fundamental research up to medical treatment assisted by and promoted by technological breakthroughs. In the quest to understand the brain, neuroimaging has become a chosen approach to yield brain maps, both in healthy volunteers and patients. In particular, MRI has become the reference neuroimaging technique for the last 20 years to study functional neuroanatomy both in vivo and non-invasively. In the vast majority of investigations, MRI has been used as contrast weighted-imaging technique (e.g., T_1 , T_2 , T_2^*) as such acquisitions are fast and compatible with clinical routine. However, such scans are usually collected at millimetric resolution. Since 2017 7T MR systems have entered the clinical realm and they offer improved signal-to-noise ratio (SNR), hence enabling the possibility to perform high resolution imaging (500 μ isotropic) at the cost of increased acquisition time, which prevents their use in the clinical setting.

The challenge. This project aims to extend the current SPARKLING (Spreading Projection Algorithm for Rapid K-space samPLING) technology [1, 2], which has been initially developed for T_2^* imaging, to other imaging contrasts such as T_1 and T_2 -weighted imaging with potential applications hereafter to multiple imaging sequences such as MPRAGE and MP2RAGE in regards to T_1 -w imaging, and FLAIR, DIR and diffusion-weighted imaging concerning T_2 -w imaging. The difficulty is that the SPARKLING sampling patterns generated for T_2^* -w imaging, which are associated with long echo times and readouts, cannot directly be translated to other imaging contrasts. Moreover moving from T_2^* to T_2 induces changing the pulse sequence and considering a turbo spin echo sequence (TSE) in lieu of a gradient echo sequence (GRE). This significantly changes the way the contrast must be preserved over time and requests some adaptation on the sampling trajectories. For instance, in T_1 -w short or ultra-short echo times must be used. Hence, this impacts the design of sampling trajectories which have to start from the center of k-space (center-out patterns) instead of traversing the whole k-space volume from edge to edge. T_1 -w can be implemented within a GRE sequence, however the contrast is improved using additional inversion pulses as done in the MPRAGE and MP2RAGE sequences. Another challenge will be to incorporate the newly generated sampling patterns in the 3D SPACE sequence from Siemens in order to implement the T_2 -w, FLAIR and DIR accelerated imaging contrasts. SPACE actually implements a 3D TSE.

Second, to be fully efficient accelerated imaging based on compressed sensing requires iterative image reconstruction which, at high resolution becomes costly numerically notably for 3D imaging (e.g. cf [2] 15min for a single volume). This typically hinders the widespread dissemination of CS based approaches in the clinical setting. This issue can be

addressed either using online CS based image reconstruction (see [3] for details) or by deploying specific deep learning architectures like the versatile Primal Dual Neural Network (XPDNet) [4, 5] or its non-Cartesian extension (NC-PDNet) [6] that have been trained beforehand on massive brain datasets (fastMRI [7], Calgary [8]).

Work plan. The goal of the proposed work is first to accelerate data acquisition in k-space by developing a multi-contrast (T_1 -w, T_2 -w, FLAIR and DIR) version of the most recent full 3D SPARKLING technology based on the recently proposed Minimized Off Resonance (MORE) extension of SPARKLING [9]. Second, we will address the computational issue related to CS based image reconstruction first by implementing the **Gadgetron** solution to allow the physician fast visualization of reconstructed images on the MR scanner console. From a technical viewpoint, the first approach will consist in performing offline reconstruction once all the data has been collected and then for the sake of efficiency an on-line version will be proposed. However as image quality in CS based reconstruction can be impaired by undersampling artifacts in highly accelerated regimes, our NC-PDNet deep learning approaches will be also tested and compared to their CS counterpart on the different imaging contrasts. Finally, the methods will be validated on the 7T MR system at NeuroSpin prior to being deployed in our clinical partners, notably the University Hospital in Poitiers and later at the Paris Brain institute (La Salpêtrière hospital). The sequences will be tested in the first place on neurodegenerative indications.

Environment. This postdoc will take place at NeuroSpin, in the **MIND team**. This is a large team focused on mathematical methods for statistical modeling of brain function using neuroimaging data (MRI, fMRI, MEG, EEG) as well as advanced computational imaging methods for applications to cognitive and clinical neuroscience.

Skills. We seek candidates who are strongly motivated by challenging research topics in neuroscience and MRI. Applicants should have a PhD in one of the following domains: Biomedical engineering, signal processing, neuroimaging or neuroscience. Solid background in the MRI field is expected, ideally with preliminary experience in the clinical setting. Proficiency in software programming, notably in scientific Python is necessary. Preliminary knowledge of the IDEA environment is a plus but not mandatory.

References

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- [4] Ramzi, Z., Ciuciu, P. & Starck, J.-L. Benchmarking MRI reconstruction neural networks on large public datasets. *Applied Sciences* **10**, 1816 (2020).
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- [6] Ramzi, Z., Chaithya, G., Starck, J.-L. & Ciuciu, P. NC-PDNet: A density-compensated unrolled network for 2D and 3D non-Cartesian MRI reconstruction. *IEEE Transactions on Medical Imaging* **41**, 1625–1638 (2022).
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- [9] Radhakrishna, C. G. *et al.* MORE-SPARKLING: non-cartesian trajectories with minimized off-resonance effects. In *Joint Annual Meeting ISMRM-ESMRMB & ISMRT 31st Annual Meeting* (2022).