Image Reconstruction for Low field MRI

The SEED[1] program (standard track)

www.imt-atlantique.fr/seed

PhD topic open for applications until March 20, 2025

1 Definition

1.1 Domain and scientific/technical context

This project aims to develop computational imaging methods for low-field MRI [Arnold2023, Hennig2023]. Its aim is to develop low-cost, portable neuroimaging systems that integrate artificial intelligence (AI) [Iglesias2022] with low-field MRI technology. Unlike conventional MRI systems that rely on high magnetic fields (1.5-7T), this approach aims to democratise access to MRI by enabling imaging at the patient's bedside.

The project is highly interdisciplinary, combining expertise in medical imaging, image processing, AI and neuroscience. It targets perinatal neuroimaging, in particular for premature newborns, for whom traditional MRI remains complex. By combining hardware development (in collaboration with the company Multiwave) and AI-driven image reconstruction, this project could redefine neuroimaging and improve its accessibility in clinical settings.

1.2 Scientific/technical challenges

The project tackles fundamental challenges in low-field MRI and computational imaging, necessitating a multidisciplinary approach. One of the very first challenges is related to

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signal-to-noise ratio limitations. The weak magnetic fields in low-field MRI produce inherently noisier signals, demanding innovative AI-driven denoising and reconstruction strategies tailored to low SNR conditions. A second challenge is related to the optimization of hardware design: developing a portable, cost-efficient MRI system requires a careful trade-off between coil design, acquisition protocols, and system portability while maintaining sufficient imaging resolution.

Our scientific objective will focus mainly on advanced AI methodologies. Incorporating physics-guided deep learning models that explicitly integrate the underlying MRI signal formation process to enhance reconstruction reliability and interpretability. To this end, part of the project will be dedicated to the development of efficient computational strategies: Achieving real-time image reconstruction necessitates optimized numerical solvers and meta-learning techniques for rapid inference at the point of care.

1.3 Considered methods, targeted results and impacts

The project will leverage physics-informed deep learning for image reconstruction, integrating prior knowledge of MRI signal formation to enhance image quality. Variational optimization techniques [Fablet2021] will be explored to control the balance between acquired data and reconstructed images [Crockett2022], minimizing artifacts and improving clinical reliability. Meta-learning algorithms [Andrychowicz2016] will be implemented to optimize reconstruction efficiency for real-time bedside applications.

The expected results include the development of a fully functional image reconstruction prototype for low-field MRI, achieving millimetric resolution and demonstrating feasibility for neonatal brain imaging. The impact of the project extends beyond neonatal imaging, offering a scalable and accessible MRI solution for broader applications such as stroke detection [Yuen2022] and point-of-care diagnostics, particularly in low-resource settings. By bridging advances in AI and medical imaging, such a project has the potential to transform clinical neuroimaging and improve patient care worldwide.

1.4 Environment (partners, places, specific tools and hardware)

The research will take place at LaTIM UMR 1101, a renowned medical imaging laboratory at IMT Atlantique, Brest, France. The project benefits from a strong partnership with Multiwave, a company specializing in MRI hardware innovations, which will contribute to system development and optimization. Clinically, the study is integrated into CHU de Brest, facilitating direct validation of neonatal imaging applications in a hospital setting. This project will also benefit from collaboration with the academic partner in Lausanne (UNIL, EPFL) to extend the methods developed as part of this thesis to low-field fetal MRI.

The project will employ low-field MRI prototypes to refine and validate novel imaging methodologies. For computational aspects, high-performance computing infrastructure at IMT Atlantique will be utilized for AI-driven image reconstruction and processing. The research environment is enriched by a multidisciplinary team with expertise in MRI physics, computational imaging, deep learning, and neonatal healthcare, fostering a collaborative approach to advancing neuroimaging technologies.

1.5 Interdisciplinarity aspects

The proposed research is inherently highly interdisciplinary, bridging medical imaging, physics, artificial intelligence, and clinical applications. It combines MRI physics for ultra-low-field acquisition, computational imaging and inverse problem-solving for image reconstruction, and deep learning techniques tailored to real-world biomedical constraints. Moreover, its integration into clinical neonatology ensures direct medical applicability, fostering collaboration between engineers, computer scientists, and healthcare professionals.

1.6 References

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2 Partners and study periods

2.1 Supervisors and study periods

- **IMT Atlantique**: Prof. François Rousseau, IMT Atlantique, Brest, France
- **International academic and industrial partner**: The PhD student will stay 3 months each at an international academic and an industrial partners, respectively at University of Lausanne and Multiwave enterprise (to be confirmed).

2.2 Hosting organizations

2.2.1 IMT Atlantique

IMT Atlantique, internationally recognized for the quality of its research, is a leading French technological university under the supervision of the Ministry of Industry and Digital Technology. IMT Atlantique maintains privileged relationships with major national and international industrial partners, as well as with a dense network of SMEs, start-ups, and innovation networks. With 290 permanent staff, 2,200 students, including 300 doctoral students, IMT Atlantique produces 1,000 publications each year and raises 18€ million in research funds.