IA Cluster ENACT AAP contrats doctoraux IA 2025

PhD thesis proposal 2025-2028
Université de Lorraine - LEMTA laboratory – APREX

TITLE

Optimizing MRI for Energy Systems: Integrating Artificial Intelligence into Imaging Methods and Data Processing.

SUPERVISION

Pr. Jean-Christophe Perrin, LEMTA
Ing. Dr. Mikael Desécures, APREX head of R&D team

CONTEXT

The "MRI for Engineering" team at LEMTA[1] is developing research into mass transfer and fluid flows in the fields of energy and energy processes. The methods used are based on nuclear magnetic resonance (NMR), in the time domain (TD-NMR) and imaging (MRI). The subjects studied are highly interdisciplinary, often involving several laboratories and industrial players, with applications such as nuclear safety, membrane processes, mixing phenomena, water transfer in fuel cells, heat storage, etc... Although efforts to develop robust and reliable methods in healthcare have been intense and fruitful, their optimization for energy and processes applications still requires further development: in such systems the samples are of variable size and composition which makes the NMR signal weak and the images noisy. Furthermore, the fluids flow in complex geometries, often at high velocity.

The proposed thesis topic is part of a new initiative to implement artificial intelligence (AI) tools at various stages of the experimental workflow, for more efficient data and image processing, and to improve acquisition methods, particularly in magnetic resonance velocimetry (MRV).

The work will be carried out between the LEMTA laboratory and the startup APREX[2], which develops AI tools and software suites with the aim of contributing to the digital transition of industry, and which will be co-funding the thesis.

The new tools and methods will be implemented on the software used to control the new MRI platform at LEMTA.

DETAILED PROPOSAL

The Ph.D. thesis will address the following points:

1. Develop an MRI image processing methodology specific to the study of energy systems and industrial processes using tools developed by APREX
   - Correction of geometric artefacts and aberrations due to magnetic field inhomogeneities
   - Correction of aliasing phenomena on velocity maps
   - Noise reduction

2. Training AI models to improve image quality and reduce acquisition time
   - Training of supervised and unsupervised models based on MRI images recorded on samples with controlled geometries produced by additive manufacturing
   - Use of physics-informed AI models to study flow dynamics on these controlled systems, by correlating MRI data with predictive models
   - Correction of measurement errors by correlation with computational fluid dynamics simulations
   - Develop tools for faster, more robust quantitative analysis

[1] https://lemta.univ-lorraine.fr/irm-ingenierie/
[2] https://aprex-solutions.com/en/

- Development of a procedure for reconstructing images from incomplete or compressed data with AI approaches, including generative AI

3. Implementation of AI tools in the MRI acquisition software of the Metro'NRJ platform
   - Assistance during acquisition by defining optimal parameters
   - Improved acquisition frequency, thanks to on-the-fly image processing with AI

OUTCOMES OF THE THESIS PROJECT

By improving image acquisition and processing techniques, we will be able to take full advantage of the remarkable capabilities of MRI and MRV in the field of energy and energy processes. The aim is to disseminate the new methods within the research community and, ultimately, to offer more effective metrological solutions in order to optimize the industrial processes involved in the energy transition.

REFERENCES

See selected documents and publications from the "MRI for Engineering" team:
3D magnetic resonance velocimetry for the characterization of hydrodynamics in microdevices
Low-cost MRI devices and methods for real-time monitoring of flow and transfer phenomena in milli-channels
Dispositifs et méthodes RMN adaptés à la caractérisation d'écoulements et transferts en milli-canaux.
Mesures par imagerie de résonance magnétique en sciences pour l'ingénieur
MRI as a tool for nuclear safety
MRI temperature and velocity measurements in a fluid layer with heat transfer
Magnetic Resonance Imaging of Convection in Phase Change Materials
Characterizing water transfer in compacted soils in the context of energy storage, contribution of magnetic resonance imaging (MRI)
NMR characterization of proton exchange membranes in controlled hygrometry conditions
NMR contributions to the study of water transfer in proton exchange membranes for fuel cells.
Real time monitoring of the through thickness moisture profile of thin sheets using NMR

All publications of the LEMTA laboratory: https://hal.univ-lorraine.fr/LEMTA-UL/browse/latest-publications

WORKING CONDITIONS

The thesis work will take place at the LEMTA laboratory in Vandoeuvre-lès-Nancy, within the "MRI for Engineering" team currently comprising 6 researchers, 2 engineers, 3 PhD student, 1 Postdoctoral fellow and 3 Master students (https://lemta.univ-lorraine.fr/irm-ingenierie/).

The LEMTA laboratory has access to a new 3T MRI installed on its exprimental platform (https://lemta.univ-lorraine.fr/en/metronrj-platform/) and two other equipments (2.34T and 14.1T) on the NMR platform of the University of Lorraine (https://crm2.univ-lorraine.fr/plateformes/plateforme-rmn/).

OPEN SCIENCE COMMITMENT

The results will be disseminated in reference journals and conferences. The project team is committed to maintaining an ongoing dialogue to facilitate data sharing to the greatest extent possible while respecting industrial constraints.
This project follows the FAIR principles (Findability, Accessibility, Interoperability, and Reusability) to ensure that research data are properly managed and shared. Particular attention will be given to the findability of data, ensuring accurate metadata and proper indexing on open-access platforms such as OpenAlex. This will enhance data discoverability and usability for the broader scientific community.

CANDIDATE PROFILES

Candidates should hold a Master's degree or equivalent in one or more of the following disciplines: physics, computer science, engineering, medical sciences. They should also have a strong desire to learn and develop new AI-based physical and software tools. Initial experience in AI, gained through an academic course or internship, is considered a plus.

APPLICATION PROCEDURE

Candidates should contact the thesis supervisors directly by e-mail (jean-christophe.perrin@univ-lorraine.fr) and provide a detailed CV, a cover letter and a list of at least two references who can be contacted by telephone or e-mail. *The deadline for applications is April 22, 2024. The strating date should be between september and december 2025.*

This PhD offer is provided by the ENACT AI Cluster and its partners. Find all ENACT PhD offers and actions on https://cluster-ia-enact.ai/.