

6-month Master's internship (Stage de fin d'études)

AI-guided Plug-and-Play Electrical Impedance Tomography for Robust Stroke Imaging

Keywords: electrical impedance tomography, microwave imaging, multimodal imaging, deep learning prior, Plug-and-Play

Context and challenges: Stroke imaging helps physicians to quickly tell whether a brain event is due to bleeding or a blocked vessel, and to follow the patient's condition at the bedside. There is still no single radiation-free tool that is at once portable, reliable, and rich in structural detail. Electrical Impedance Tomography (EIT) injects small alternating currents through scalp electrodes and measures boundary voltages to estimate a conductivity map [1]. It is low-cost, safe, and real-time, yet the inverse problem is much ill-posed, results are sensitive to electrode placement and contact, and spatial resolution is limited. Microwave Imaging (MWI) [2] uses microwave signals to probe tissue at high frequencies where dielectric contrast is strong, so it can capture the structure better, but the reconstruction is strongly non-linear, is sensitive to differences between the model and reality, and there are few matched clinical datasets. This project aims at leveraging the strengths of both: one will learn a structural image prior from realistic MWI simulations and insert that prior, via a plug-and-play optimization scheme, into absolute or semi-absolute EIT reconstruction on real patient data to improve robustness in localization and classification.

Research objectives: The project aims to design and test an intermodal reconstruction method based on deep learning, which learns structural priors from MWI simulations in order to regularize EIT tomography in a Plug-and-Play framework.

On the physics side, one keeps the models simple but faithful: for EIT, one models how a small alternating current spreads through the head and how scalp electrodes measure voltages, including the effect of contact impedance at each electrode (the "Complete Electrode Model" [3]). For MWI, one generates forward data with a standard Method-of-Moments solver on head geometries obtained from CT/MR segmentations. The EIT clinical set and the MWI simulations are not naturally paired; to align them, one has to synthesize MWI on the same meshes and tissue labels derived from the EIT cases (when CT/MR is available), so both modalities live within the same coordinate system.

On the algorithmic side, one will train a denoiser (convolutional or diffusion-based type) in image space using MWI outputs to capture brain-relevant structure at the scale that matters for stroke. The trained denoiser will then be plugged into an EIT solver via a plug-and-play scheme [4], so each iteration enforces EIT data consistency while the learned prior removes typical artefacts and restores plausible structure.

This project therefore lies at the interface between physical imaging and deep learning, exploring the integration of deep models in electromagnetic inverse problems, with direct applications to multimodal medical imaging.

Internship plan: 1. Understanding both imaging mechanisms and implementing forward models. The student will familiarize themselves with CEM-based EIT simulation, and with MoM-based MWI forward modeling. In parallel, the data workbench will be assembled: real EIT measurements for stroke (e.g., UCLH Stroke EIT Dataset [5]) and MWI simulations.

2. Reconstructions will be performed using classical iterative solvers (e.g., Gauss–Newton for EIT and Contrast Source Inversion for MWI) to analyze which structures each modality can reliably reconstruct and to define the statistical features that the learned prior should capture.

3. A deep denoising network will be trained on MWI data to learn a structural prior representative of brain tissue. This trained denoiser will then be integrated into an EIT solver within a Plug-and-Play optimization framework, acting as a proximal operator. The optimization will alternate between strict data consistency with EIT measurements (CEM likelihood, possibly multi-frequency) and AI-guided regularization. The resulting reconstructions will be compared against conventional EIT methods.

Candidate profile:

1. Master's student (M2) or final-year engineering student in signal/image processing, applied physics, applied mathematics, machine learning, and/or related fields.
2. Proficiency in Python and MATLAB is required; familiarity with deep learning frameworks (PyTorch or TensorFlow) is desirable.
3. Experience with inverse reconstruction algorithms (EIT or MWI) would be an asset.
4. A strong interest in the interactions between AI and physics is expected.

Practical information:

Duration and dates: 6 months in 2026

Remuneration: Approx. 600 € per month

Location: SATIE – UMR 8029, ENS Paris-Saclay, CNRS, Université Paris-Saclay, 4 avenue des Sciences, 91190 Gif-sur-Yvette, France.

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A PhD extension could be envisaged, depending on funding opportunities and the candidate's motivation.

References :

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- [5] Goren, N., Avery, J., Dowrick, T., Mackle, E., Witkowska-Wrobel, A., Werring, D., & Holder, D. (2018). Multi-frequency electrical impedance tomography and neuroimaging data in stroke patients. *Scientific Data*, 5(1), 1-10.