Mathematically-founded deep learning methods for image reconstruction in Compton camera SPECT

PhD proposal, CREATIS, Lyon, France

Keywords Medical Imaging, SPECT, Compton camera, Deep Learning, Optimization.

Supervision:

- Voichita MAXIM, full professor, INSA Lyon, TomoRadio group, CREATIS Laboratory
- Etienne TESTA, senior associate professor, Claude Bernard University Lyon1, IP2I Labratory

---

Context and Objectives

Single Particle Emission Computed Tomography (SPECT) imaging is undergoing a significant revival, driven by new clinical needs -particularly in oncology - and recent advances in detector technology. Within this context, the TomoRadio team at CREATIS is opening a fully funded three-year PhD position aimed at developing mathematically-grounded deep learning methods for image reconstruction tailored to a novel Compton camera system. This project is part of the HORIZON-EURATOM AIDER project(Advanced Imaging DEtector for targeted Radionuclide therapy), an international collaborative project between partners in France, Spain, Italy, Germany. It aims to design and validate a new Compton camera prototype along with cutting-edge image reconstruction algorithms. The successful candidate will contribute to the development of deep learning functionalities within CoReSi [1], an open-source reconstruction code, leveraging the framework of convergent Plug-and-Play methods for inverse problems [2, 3].

Work Plan

The following key steps are expected to be completed:

1. **Initial Evaluation Using Simulated Data.**
   Reconstruct images using the current version of CoReSi. Post-process these images with deconvolution methods to correct for the system's point spread function (PSF), also known as partial volume correction. This phase will assume a spatially invariant PSF and explicitly account for Poisson noise statistics.

2. **Extension to Spatially Variant PSF**.
   Develop new deconvolution approaches that incorporate spatially varying PSFs, under realistic conditions of high Poisson noise—a critical step toward clinical applicability.

3. **Joint Reconstruction and Resolution Recovery**.
   Move beyond post-processing by integrating PSF correction directly into the reconstruction process. This will involve implementing resolution recovery strategies within CoReSi to jointly perform image reconstruction and deblurring.

4. **Evaluation and Generalization**.
   Assess the proposed methods using progressively more realistic simulated data, followed by real data acquired by the project's experimental partners. This phase will also address robustness to measurement uncertainties and detector imperfections.

Scientific Contributions Expected

- Design of convergent deep learning–based Plug-and-Play priors adapted to Compton SPECT.
- Novel strategies for handling spatially varying PSF and Poisson noise in deconvolution.
- Integration of joint reconstruction and resolution recovery into an open-source framework.
- Validation on both simulated and real datasets, in collaboration with leading European partners.

Candidate Profile: We are looking for a highly motivated candidate with a solid background in applied mathematics, physics or signal/image processing. Familiarity with deep learning and scientific programming with Python and PyTorch is highly desirable. Experience with resolution of inverse problems, optimization, physical modeling will be a strong asset.

How to apply? Interested candidates are invited to submit the following documents:

- A detailed curriculum vitae (CV), including academic background, research experience, and relevant technical skills
- Academic transcripts for both undergraduate and graduate studies.

Please send your application to voichita.maxim@creatis.insa-lyon.fr
Application deadline: 12/05/2025.
Shortlisted candidates may be invited for an online interview.

References

[1] Vincent Lequertier, Etienne Testa, and Voichiţa Maxim. CoReSi: a GPU-based software for Compton camera reconstruction and simulation in collimator-free SPECT. *Physics in Medicine & Biology*, 70(4):045001, 2025.

[2] Thibaut Modrzyk, Ane Etxebeste, Elie Bretin, and Voichita Maxim. Fast deconvolution using a combination of Richardson-Lucy iterations and diffusion regularisation. In *32nd European Signal Processing Conference (EUSIPCO)*, pages 1901–1905. IEEE, 2024.

[3] Thibaut Modrzyk, Ane Etxebeste, Elie Bretin, and Voichita Maxim. A convergent Plug-and-Play Majorization-Minimization algorithm for Poisson inverse problems. 2025.