PhD in Bayesian Tomographic Image Reconstruction

Announcement

The CRCINA and LS2N in Nantes, France, are seeking a talented and highly motivated student for a PhD position. The PhD subject is about positron emission tomography (PET) image reconstruction within the domain of statistical inference.

Keywords: inverse problems, medical imaging, Bayesian inference, sampling methods, Monte Carlo Markov Chain, Metropolis-adjusted Langevin algorithms.

Context and objectives

Positron emission tomography (PET) is a quantitative nuclear imaging modality widely used in oncology for cancer staging and follow-up of the therapy. However, PET data do not directly lead to images and a complex inverse tomographic problem has to be solved. Current image reconstruction techniques are mostly based on the formulation of an optimization problem with a data fidelity term and a regularization or penalty term, which can be viewed as Bayesian maximum a posteriori (MAP) based methods. The resulting images are a compromise between noise and bias and typical measurements extracted from such images may be characterized by a significant error. The precise knowledge of this error for each subject may be of great interest but its computation is a real challenge. The development and comparison of methods for the computation of such errors associated with PET image reconstruction is the subject of this PhD.

The particularities of the problem are the following:

- each PET datapoint can be modelled as a sample of a Poisson distribution whose parameter is driven by the projection of the image plus an additive background signal,
- PET images represent concentrations of radioactivity and are thus constrained to be positive,
- usual penalties in PET are convex and differentiable [1],
- the data and the image are of high dimensions (10^8-10^9 data entries and 10^7-10^8 image voxels) so the projection matrix cannot be stored and is computed on-the-fly.

In the context of a Bayesian formulation of the problem, the high dimensions of PET reconstruction and correlation of variables lead to difficulties in the exploration of the posterior distribution (*e.g.* [2]). As a fast convergence is required for clinical applications, methods incorporating local gradient information such as Metropolis-adjusted Langevin algorithms (MALA)

will be considered [3, 4, 5]. The developed algorithm will be compared to other stochastic methods that are designed for the exploration of the surrounding of the MAP, such as Bayesian bootstrap [6].

All algorithms will be evaluated based on simulated data and real patient data from the PET/CT and PET/MR clinical systems installed at the University Hospital of Nantes.

Requirements

The candidate must hold a master degree (or an equivalent) in Applied Mathematics, Computer or Data Science or any related field. He/she should enjoy working in a multidisciplinary environment with physicists, numerical scientists, mathematicians and physicians. Good programming skills, knowledge in inverse problems and/or medical physics are a definite plus.

Host partners

- University Hospital of Nantes, Nuclear Medicine Department,
- CRCI2NA, Nuclear Oncology Team, Nantes,
- LS2N, SIMS team, Nantes.

Supervision

- Dr Jérôme Idier (jerome.idier@ls2n.fr)
- Dr Simon Stute (simon.stute@chu-nantes.fr)
- Dr Nasrin Taheri (nasrin.taheri@chu-nantes.fr)

Schedule

- Start fall 2023, 3 years duration

References

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