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Uncertainty Quantification of Inclusion Boundaries

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Computed tomography (CT) imaging is the task of reconstructing a positive attenuation field (in the form of an image) from a finite number of projections (e.g., sinograms). CT reconstruction is often followed by an image segmentation step to partition the image into piecewise smooth/constant regions. The boundaries between such regions often carry valuable information.

In this talk, we will describe a Bayesian framework for reconstructing the boundaries of piecewise constant regions in the CT problem in an infinite-dimensional setting. Since the regularity of boundaries carries crucial information in many inverse problem applications, e.g., in medical imaging for identifying malignant tissues or in the analysis of electroencephalogram for epileptic patients, we characterize the regularity of the boundary by means of its fractional differentiability. The proposed Bayesian formulation has a hierarchical structure, which simultaneously estimates the boundary and its regularity. In addition, we quantify the uncertainties in the estimates.

Our approach is goal oriented, meaning that we directly detect the discontinuities from the data, instead of reconstructing the entire image. This drastically reduces the dimension of the problem, which makes the application of Markov Chain Monte Carlo (MCMC) methods feasible.

We will show that the proposed method provides an excellent platform for challenging X-ray CT scenarios (e.g., in case of noisy data, limited angle, or sparse angle imaging). Furthermore, this framework can be extended to reconstruct 2D surfaces, track the changes of the boundaries, and handle other types of noise.
This work has been published or submitted, see [1, 2].

(joint work with Babak M. Afkham, Nicolai A. Riis, Per Christian Hansen)

References

[1] B. M. Afkham, Y. Dong, P. C. Hansen, Uncertainty Quantification of Inclusion Boundaries in the Context of X-Ray Tomography, SIAM Journal on Uncertainty Quantification 11 (2023), 31-61.
[2] B. M. Afkham, N. A. Riis, Y. Dong, P. C. Hansen, Inferring Features with Uncertain Roughness, Submitted, http://arxiv.org/abs/2305.04608.

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