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NON-LINEAR X-RAY CT RECONSTRUCTION FROM REAL DATA

Y. Goussard[1], **B. Hamelin**[1], **D. Gendron**[1], **J.-P. Dussault**[2] **& S. Pérez**[1]

[1]Institut de génie biomédical, École Poytechnique de Montréal, Montréal, Canada
[2] Département d'informatique, Université de Sherbrooke, Sherbrooke, Canada.

X-ray computed tomography (CT) performs adequately in the vast majority of clinical situations. However, in specific cases, it falls short of the required precision (e.g., for characterization of very small structures or in the presence of highly absorbing materials). In order to overcome these difficulties, it is generally necessary to cast the reconstruction problem in an estimation framework which presents significant challenges, among which : (*i*) the complexity of the geometry of modern scanners and the very large size of the corresponding data sets, and (*ii*) the non-linearity of the data formation model in the presence of highly absorbing materials.
These challenges had to be met for the development of X-ray CT vascular imaging for follow-up of patients having undergone stent placement. The key elements for the derivation of an efficient method were : (*i*) minimal approximations to the geometry of the data formation model, associated with a simplified yet explicit model of the nonlinear interactions between X-rays and highly absorbing materials ; (*ii*) development of efficient structures for data storage (observed data, object, projection matrix), suited for fast implementation of elementary matrix operations involved in most reconstruction methods (e.g., projections and backprojections) ; (*iii*) representation of the unknown object on a non-homogeneous grid in order to reduce the computation load ; (*iv*) determination of the major sources of uncertainty and selection of appropriate stochastic models thereof, the end result being a simple yet robust additive Gaussian model ; (*v*) choice of a MAP estimator with edge-preserving priors along with an estimation scheme which overcomes the numerical ill-conditioning that results from the non-homogeneous representation of the object ; (*vi*) selection of an efficient minimization algorithm, the somewhat surprising finding being that general purpose procedures, such as the bound-constrained limited-memory quasi-Newton solver l-BFGS-B, generally outperform methods commonly used for CT reconstruction.
The impact of several of the above elements will be illustrated on real-data examples.