[OMTE 2008/2009] GPU speed-up of a 3D Bayesian CT algorithm : reconstruction of a real foam

Nicolas Gac, Asier Rabanal, Alexandre Vabre, Ali Mohammad-Djafari

digiteo
Research in science and technology of information

Forum 2010
www.digiteo.fr

Nicolas Gac[1], Asier Rabanal[1], Alexandre Vabre[2] and Ali Mohammad-Djafari[1]

[1] L2S (UMR 8506 CNRS - SUPELEC - Univ Paris Sud 11), F-91192 Gif-sur-Yvette.
[2] CEA-LIST, F-91191 Gif sur Yvette.

Nº 45

[OMTE 2008/2009] GPU speed-up of a 3D Bayesian CT algorithm : reconstruction of a real foam

1 Few projections challenge

Challenge: 3D CT cone beam reconstructions from limited number of projections (like in dose reduction context) require alternative methods to standard analytical filtered backproprojection method.
Proposed method: A Bayesian iterative algorithm based on a Gauss-Markov-Potts prior model.
Beyond limitations: Parallelization on a 8 GPUs server has allowed us to go beyond the computing time limitations.

2 A Bayesian approach

Inverse problem: Getting the object f from the projections data g collected from a cone beam 3D CT:

$$\boldsymbol{g} = \boldsymbol{H}\boldsymbol{f} + \epsilon \tag{1}$$

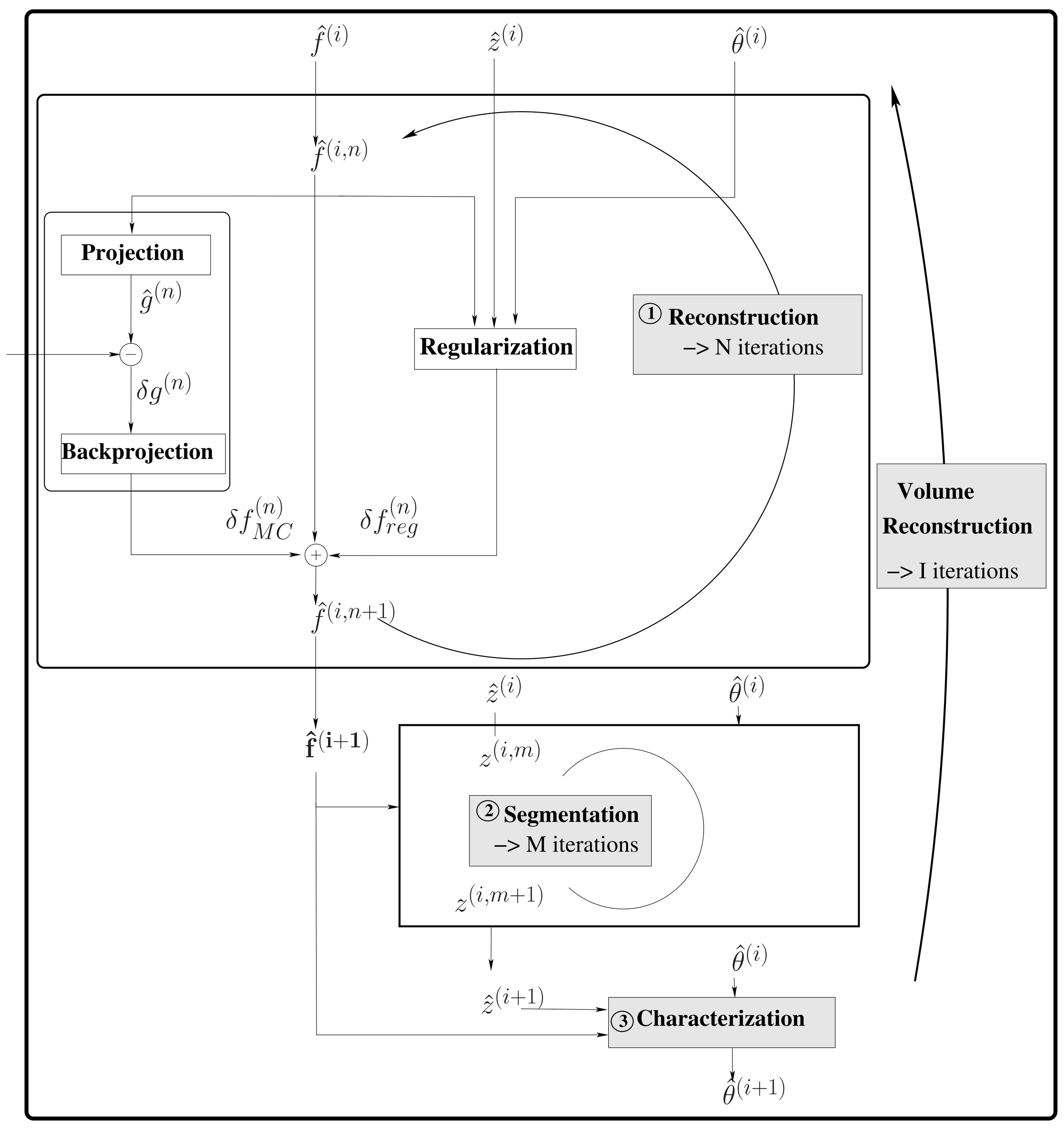
Prior model: Object f(r) is composed of K regions $\mathcal{R}_k$ corresponding to K materials labeled by a hidden variable z(r)=k. A Markov/Potts model corresponding to the compactness of materials is used for z. It's A Gaussian model corresponding to the homogeneity of materials is used for each region $\mathcal{R}_k$.

$$p(f(r)/z(r)) = k) = \mathcal{N}(m_k, n_k) \tag{2}$$

Steps of the Iterative method:
1) Reconstruction step: Updating $\boldsymbol{f}$ by computing $\boldsymbol{f}^{(i+1)} = \arg\max_{\boldsymbol{f}} \{p(\boldsymbol{f}|\boldsymbol{z}, \theta, \boldsymbol{g})\}$. This is done by using a gradient type optimization algorithm:

$$\boldsymbol{f}^{(i+1)} = \boldsymbol{f}^{(i)} + \alpha \left[\boldsymbol{H}^t(\boldsymbol{g} - \boldsymbol{H}\boldsymbol{f}^{(i)}) + \lambda \boldsymbol{D}^t \boldsymbol{D} \boldsymbol{f}^{(i)}\right] \tag{3}$$

2) Segmentation step: Updating $\boldsymbol{z}$ by generating a sample from $p(\boldsymbol{z}|\boldsymbol{f}, \theta, \boldsymbol{g})$ with a sampling algorithm from a Potts-Markov model.
3) Characterization step: Updating the hyperparameters using $p(\theta|\boldsymbol{f}, \boldsymbol{z}, \boldsymbol{g})$.



3 GPU implementation of the H and H^t operators

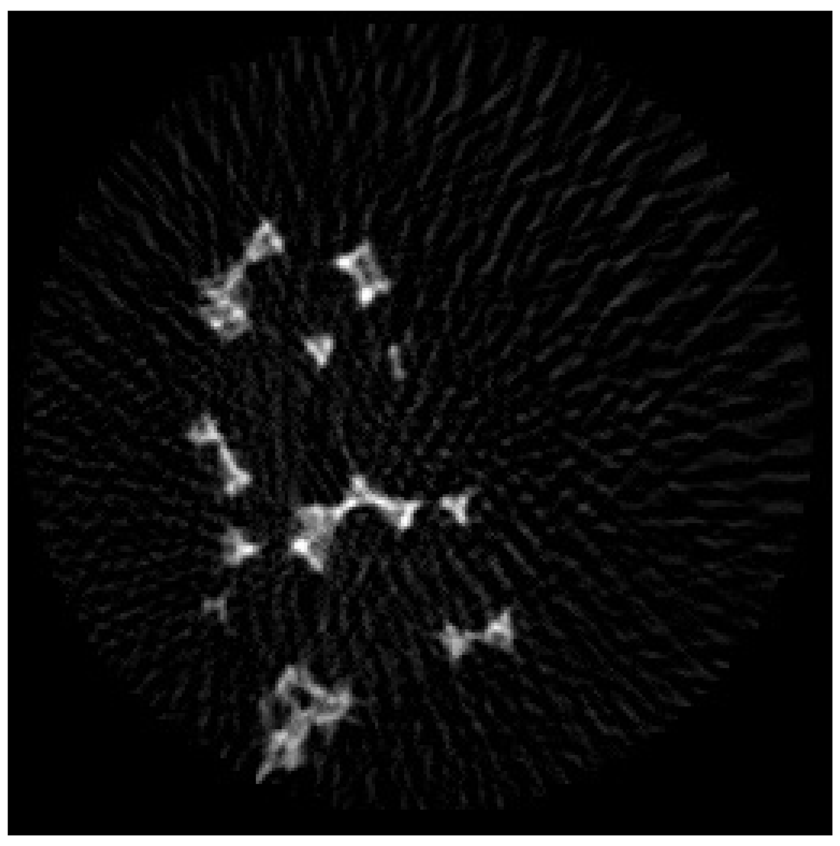
Goal: Acceleration of the projection step ($\boldsymbol{H}\boldsymbol{f}$) and backprojection step ($\boldsymbol{H}^t\delta\boldsymbol{g}$) wich are the most time consuming operators.
GPU acceleration: On GPU, we reach a two orders of magnitude acceleration.

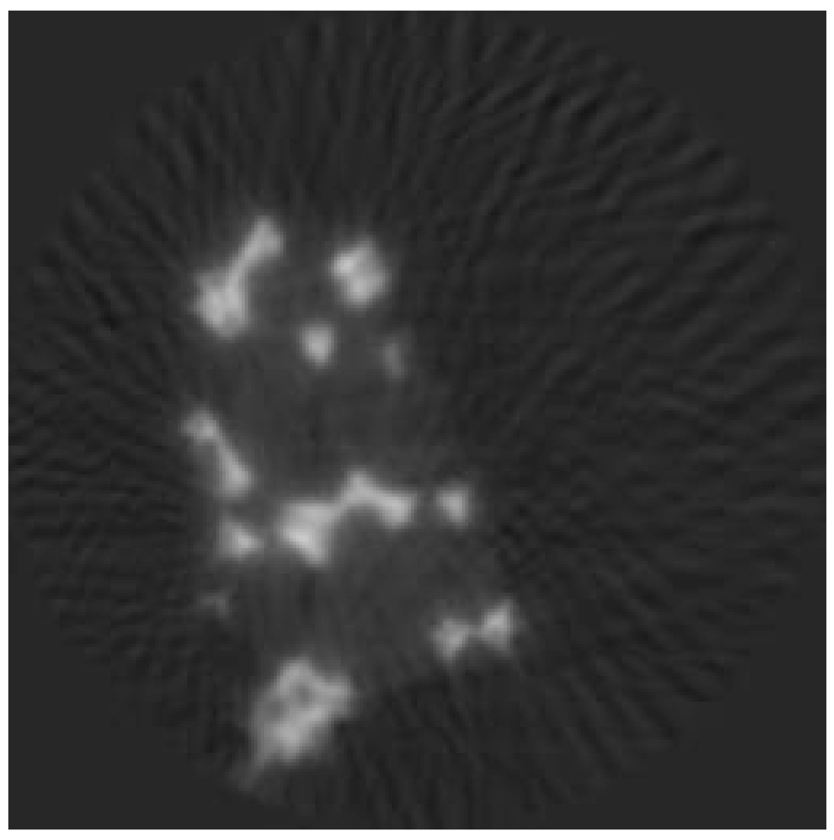
Projector	755 ms (128 ms for CPU/GPU memory transfer)
Backprojector	234 ms (133 ms for CPU/GPU memory transfer)

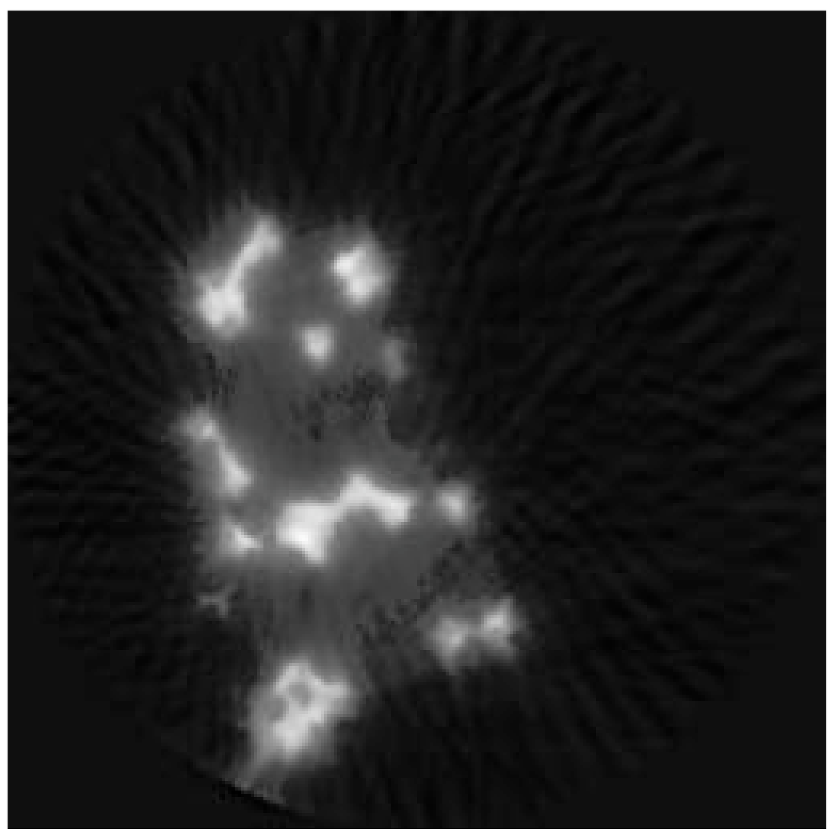
Reconstruction time on a GTX 295 ($96 * 256^2$ data)

8 GPUs server: Thanks to the use of a multi GPU server, an acceleration factor linearly propotional to the number of GPU used) has been reached on 1024^3 volume reconstruction.

4 Foam reconstructed (CEA-LIST real data set)


Reconstruction with a FDK method


Reconstruction with a non bayesian method


Recontruction with our method


Segmentation obtained

5 Future works

- Optimization of our Gauss/Markov/Potts method
- Optimization of the CPU/GPU memory transfer
- Parallelization on the 8 GPU server of other operators (3D convolution, Potts sampling...)
- Semi automatic setting ot the regularization parameters
- **Technologic transfer with an industrial partner**

îledeFrance
L2S Supélec UNIVERSITÉ PARIS-SUD 11 CNRS
digiteo Research in information sciences and technologies
cea list

Emails: nicolas.gac@lss.supelec.fr, alexandre.vabre@cea.fr, djafari@lss.supelec.fr