

GPU implementation of a 3D bayesian CT algorithm and its application on real foam reconstruction

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First International Meeting on Image Formation in X-Ray Computed Tomography, 6-9 June 2010, Salt Lake City, US



Few projections challenge

Challenge: 3D CT cone beam reconstructions from limited projections (like in dose reduction context) require alternative methods to standard analytical filtered backprojection.

Proposed method: A bayesian iterative algorithm based on a Gauss/Markov/Potts model.

Beyond limitations: Parallelization on a 8 GPUs server has allowed us to go beyond the computing time limitations.

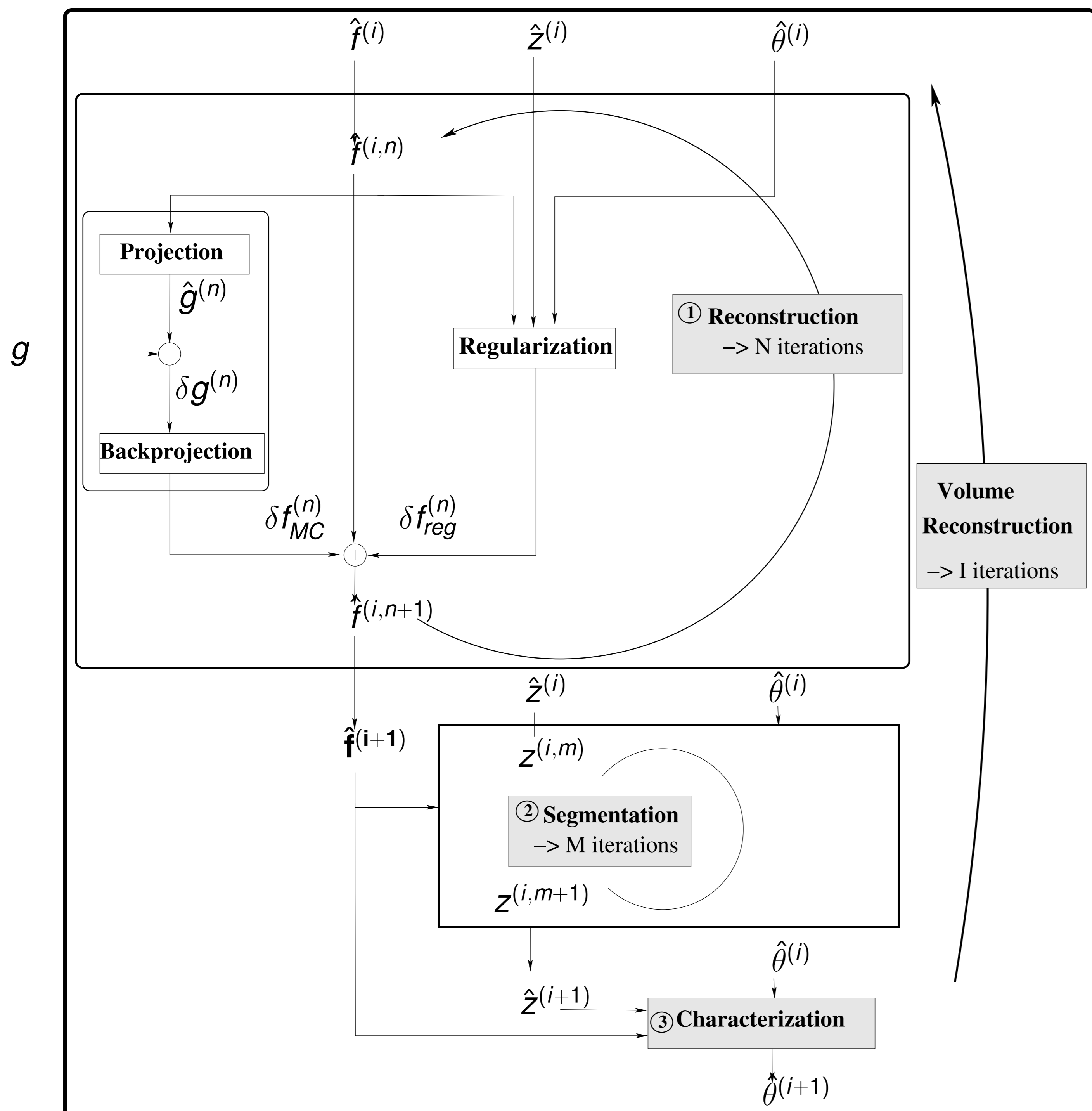
A bayesian approach

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

$$g = Hf + \epsilon \quad (1)$$

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 . It's :

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



Steps of the Iterative method:

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

$$f^{(i+1)} = f^{(i)} + \alpha [H^t(g - Hf^{(i)}) + \lambda D^t Df^{(i)}] \quad (3)$$

2) Segmentation step: Updating z by generating a sample from $p(z|f, \theta, g)$ with a sampling algorithm from a Potts-Markov model.

3) Characterization step: Updating the hyperparameters using $p(\theta|f, z, g)$. This step can be done either analytically or by sampling from known probability laws such as Gaussians or Inverse Gamma.

GPU implementation of the H and H^t operators

Goal: Acceleration of the projection (Hf) and backprojection ($H^t \delta g$) which are the most time consuming operators.

GPU acceleration: Thanks to an implementation on Graphic Processing Unit we reach a two orders of magnitude acceleration.

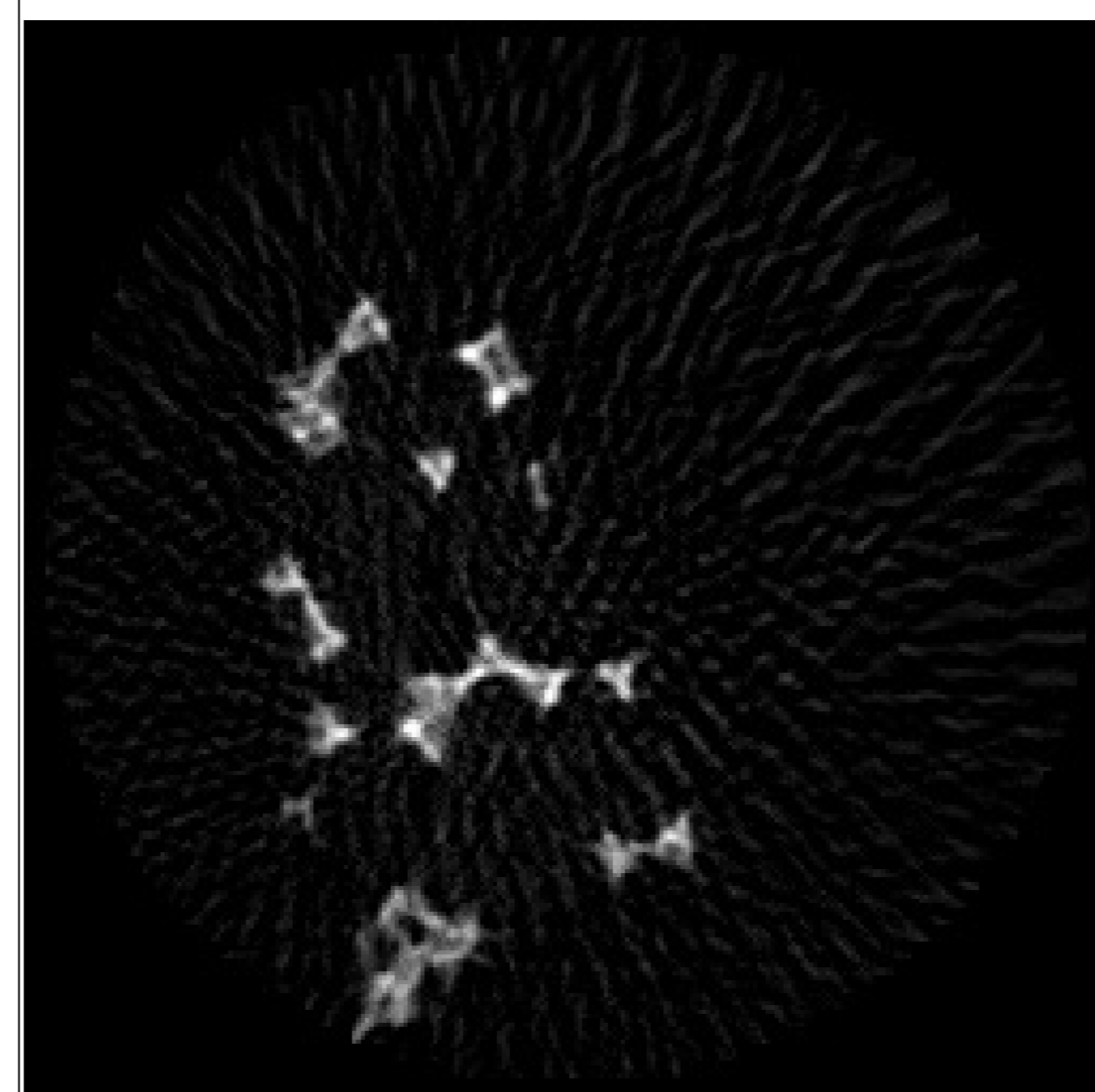
Operator	Time
Projector	755 ms (128 ms for CPU/GPU memory transfer)
Backprojector	234 ms (133 ms for CPU/GPU memory transfer)

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

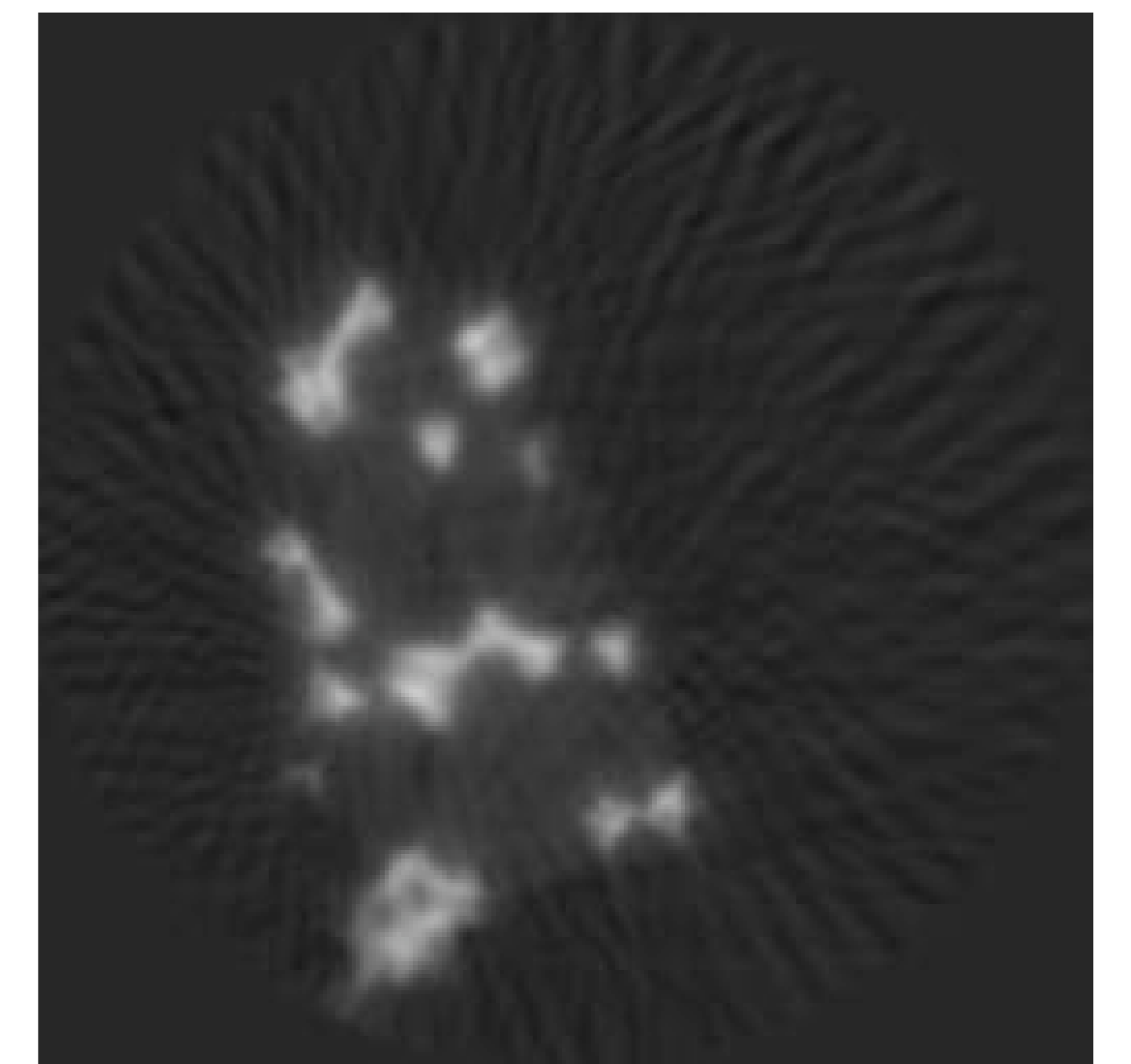
8 GPUs server: Thanks to the use of a multi GPU server, another acceleration factor (linearly proportional to the number of GPU used) has been reached on 1024^3 volume reconstruction.

Foam reconstructed (CEA-LIST real data set)

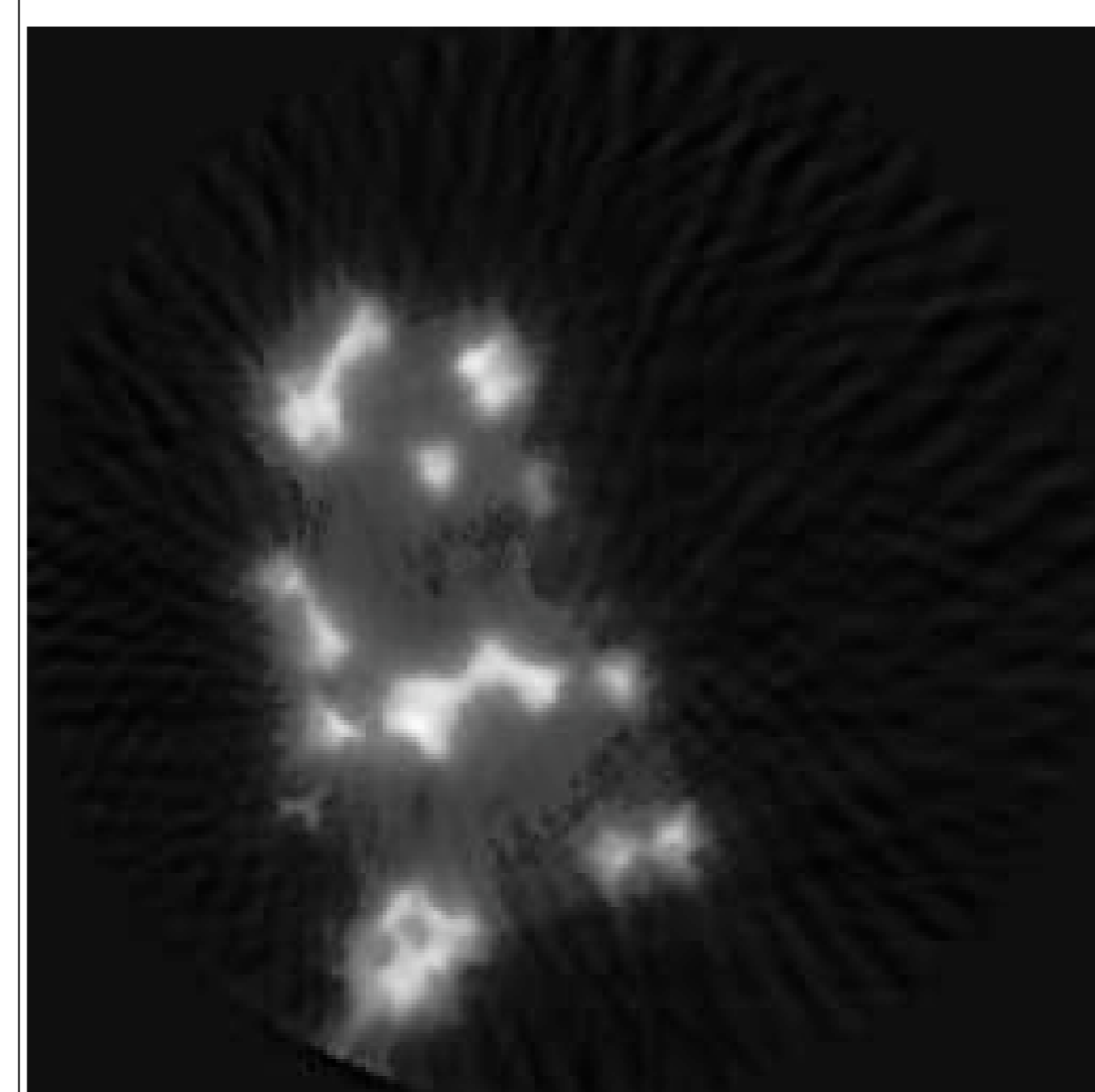
The data set is coming from a study on water kinetics in open-cell nickel foams using x-ray microtomography. The experiments are conducted on a small sample size (1 mm^3 foam) to estimate the thin geometry and model the water behavior at a scale of few pores.



Slice reconstructed with a FDK method



Slice reconstructed with a non bayesian method



Slice reconstructed with our method (after 50 iterations)



Segmentation obtained during iterative reconstruction

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 of the regularization parameters
- **Technologic transfer with an industrial partner**