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Parallelization on a 8-GPU server of iterative 3D reconstruction algorithm for dental X-ray tomography

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Abstract: In dental numeric 3D imaging, classic filtered backprojection (FBP) methods, for exemple, Feldkamp (FDK), is too sensible to the number of projections and noise, also limited in metal artifacts and beam-hardening reduction, so we use a 3D iterative least squares algorithm. Because of the huge size of 3D volumes (512^3 to 1024^3 voxels) and sinograms ($512 \times 512 \times 360$), it was too long to be applied in clinical medical imaging. However, thanks to the high performance of computing acceleration by GPU, its appearance in clinic is possible. In our iterative algorithm, we have two principal operations, projection and backprojection. According to our first results, the computation time of these operations on GPU is less in two orders ($/100$) than that on CPU, in particular for backprojection. With Multi-GPU (8 GPUs, Tesla C1060) in a Carri system's server, it decreases by a significant factor compared to single GPU. My Ph.D job consists of developing an iterative reconstruction method to reduce or remove the artifacts above, and obtain a segmentation of reconstructed volume as well.

Cone beam X-ray tomography

► **Description:** X-ray tomography consists of reconstruction of the unknown object from the detector data. We take it as an inverse problem.

► **Mathematical modelling:** Let f be an unknown object vector, g observation vector, H system matrix and ϵ noise vector.

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

► **Method:** an iterative least squares algorithm.

Iterative least squares(LS) algorithm

To estimate the unknown object f , we minimize the square errors as below.

$$\hat{f} = \operatorname{argmin}_f J_{LS}(f) = \operatorname{argmin}_f \|g - Hf\|^2 \quad (2)$$

the $n+1^{\text{th}}$ estimation update $\hat{f}^{(n+1)}$:

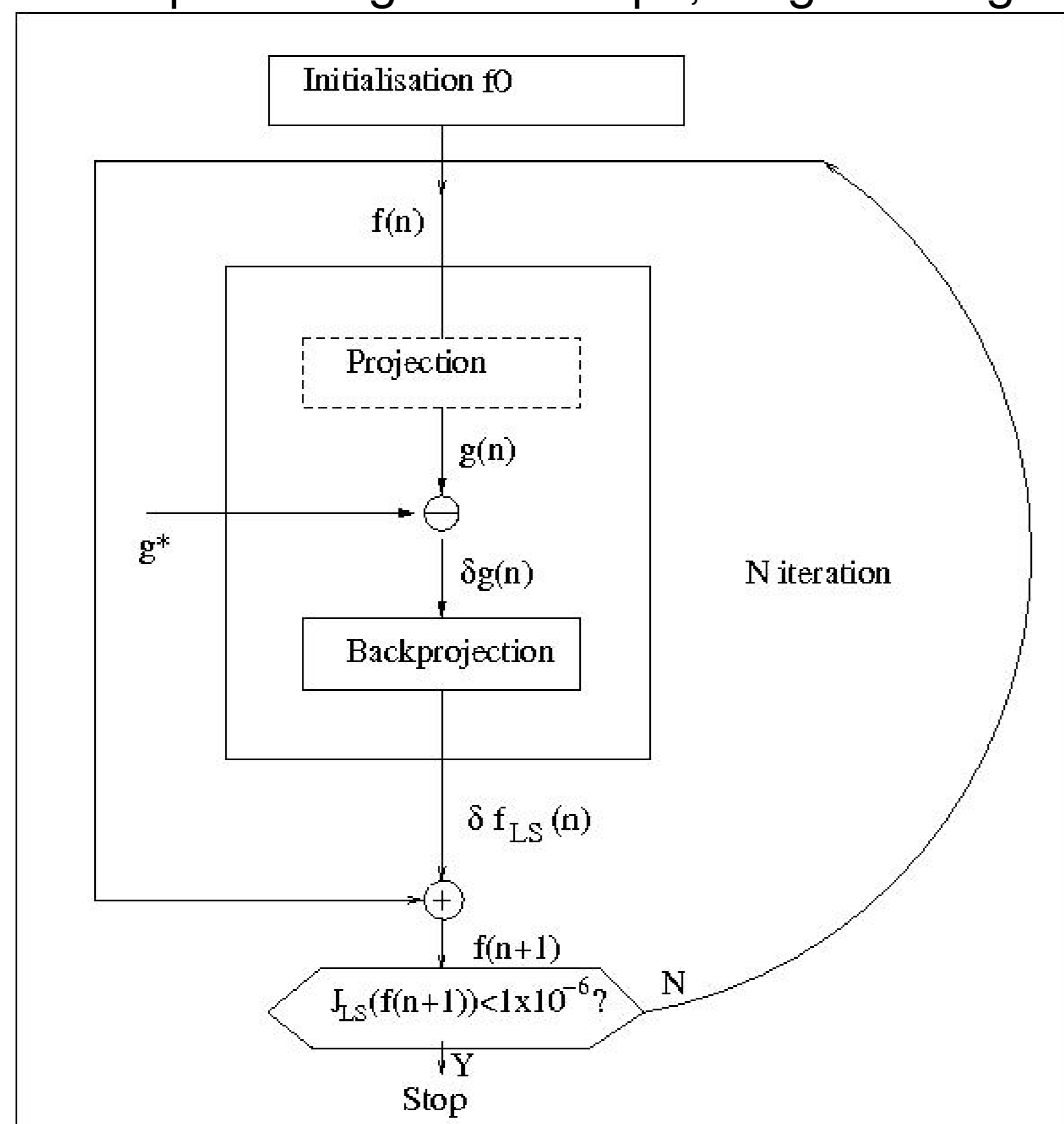
$$\hat{f}^{(n+1)} = \hat{f}^{(n)} - \alpha^{(n)} \cdot \nabla J_{LS}(\hat{f}^{(n)}) = \hat{f}^{(n)} + \delta f_{LS}(n) \quad (3)$$

where

$$\nabla J_{LS}(\hat{f}^{(n)}) = 2H^t(g - H\hat{f}^{(n)}) \quad (4)$$

$$\alpha^{(n)} = \frac{1 \|\nabla J_{LS}(\hat{f}^{(n)})\|^2}{2 \|H \nabla J_{LS}(\hat{f}^{(n)})\|^2} \quad (5)$$

Simplified Least squares algorithm steps, let g^* be original data;



GPU & multi-GPU implementation of H & H^t operators

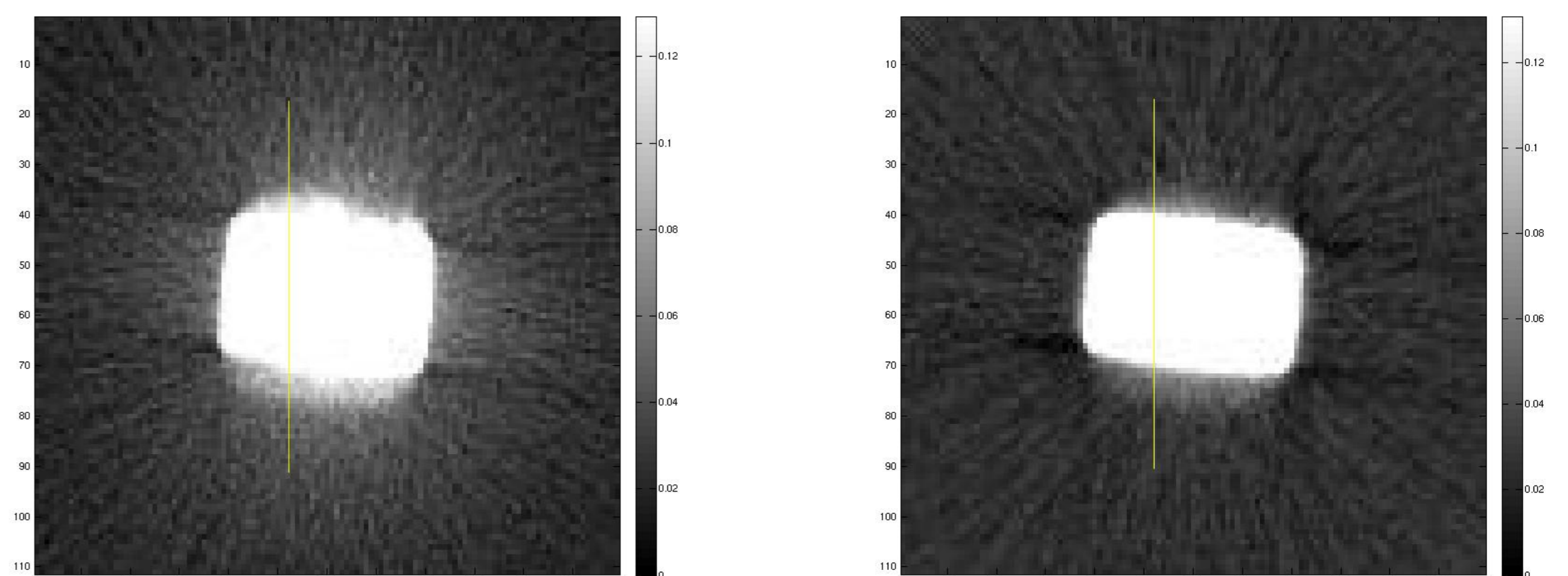
Compared to single GPU, the computation time of H & H^t operators with multi-GPU decreases by a significant factor roughly in proportion to the number of GPUs

Operation	Computation time(/s)	
	1GPU	8 GPUs
Backprojection	10.9	2.0(✓5)
Projection	213	28.5(✓7)

Reconstruction time of volume 1024^3 from 256 projections [1]

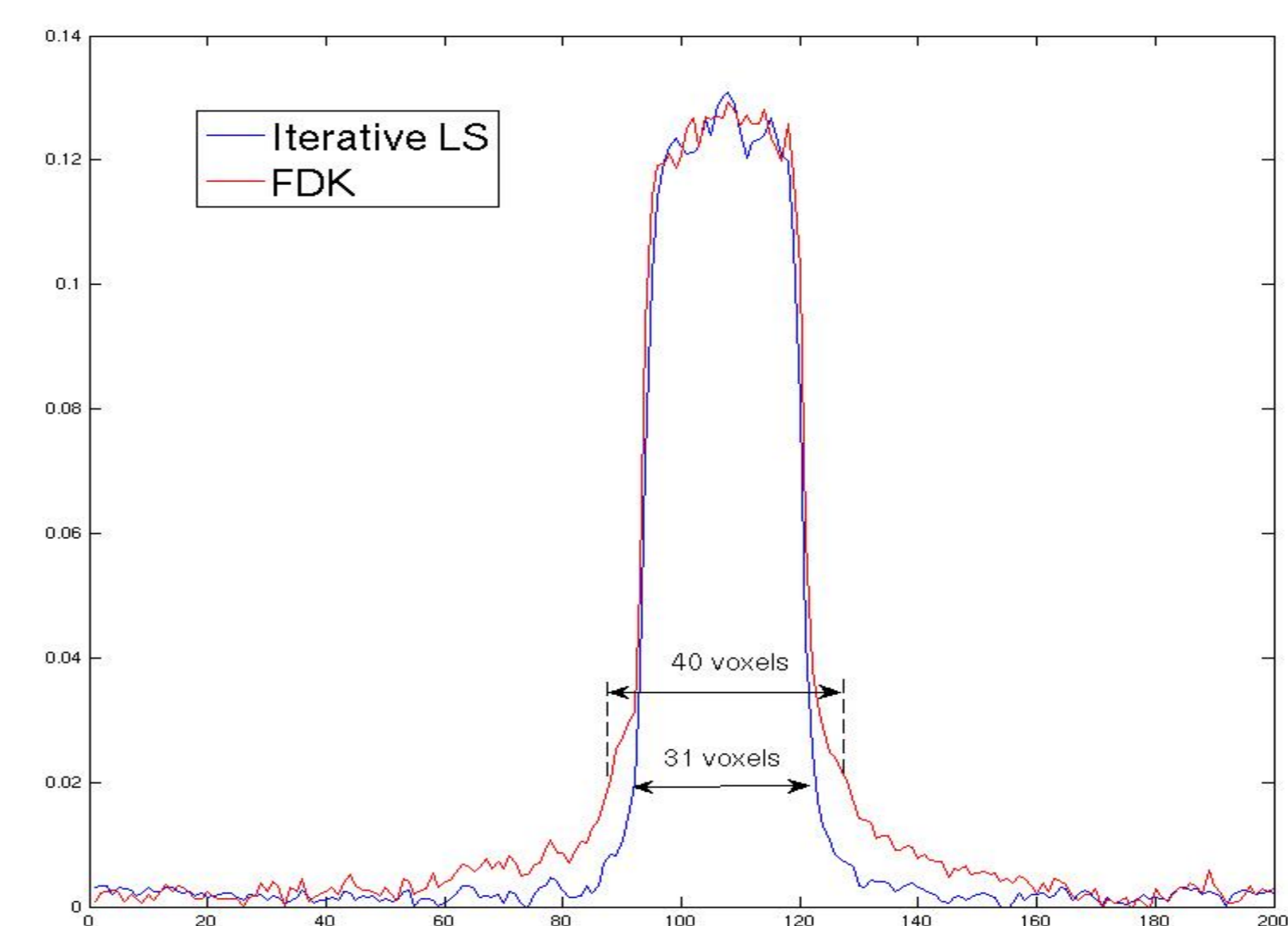
Reconstruction by FDK & iterative LS

We used the real data of fake tooth, provided by Trophy, Carestream dental, and reconstructed the volume with Feldkamp and our iterative least squares algorithm.



Reconstructed slice of fake tooth (FDK)

Reconstructed slice (LS, iter60)

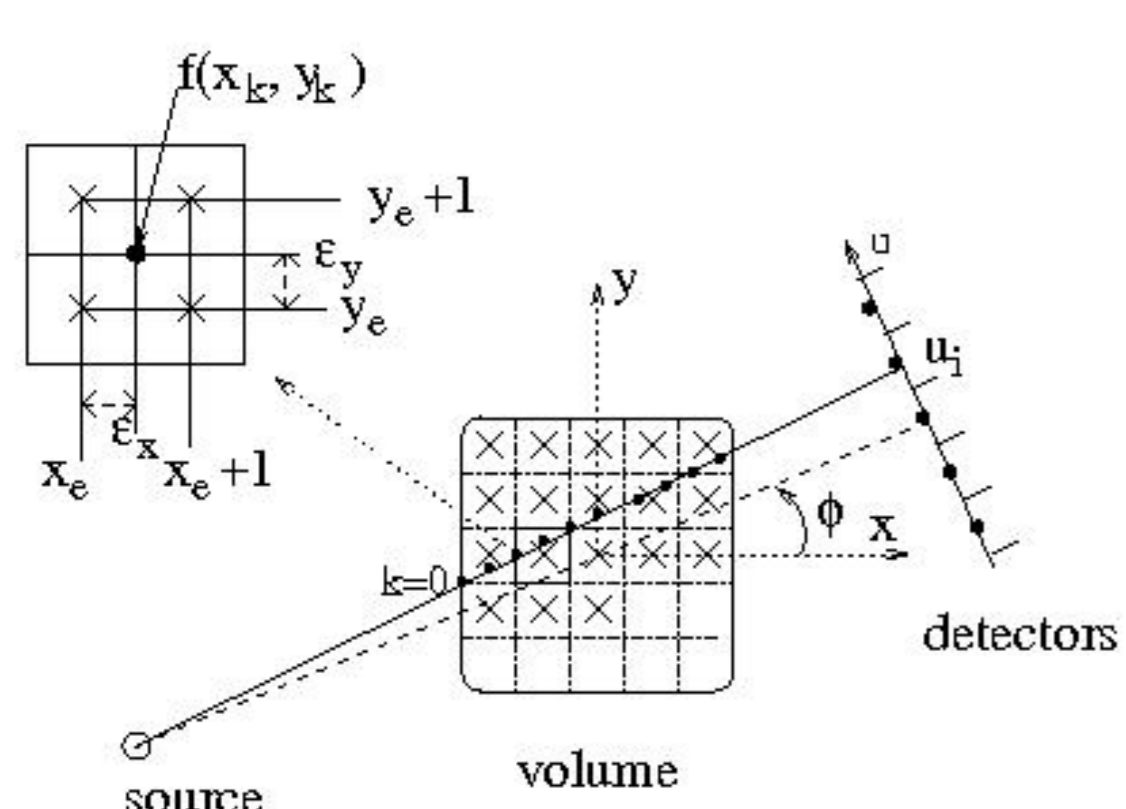


Profile of reconstructed slice (yellow lines in the top figures)

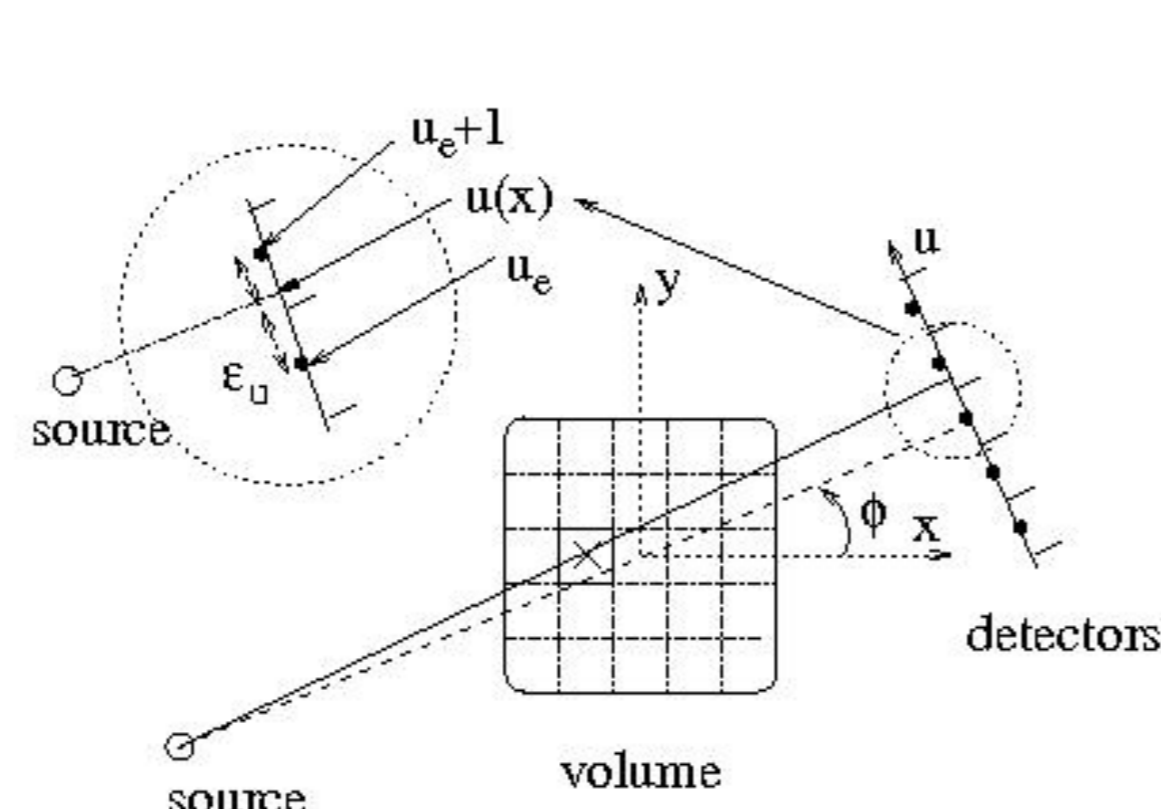
Future work

- Optimization of our iterative algorithm with a more accurate model
- Development of an iterative algorithm of metal artifacts reduction
- Method of beam-hardening reduction
- Method of simultaneous reconstruction and segmentation of volume
- Acceleration of all our iterative algorithms on multi-GPU

[1] N. Gac et al, "Multi GPU parallelization of 3D bayesian CT algorithm", *Forum on recent developments in Volume Reconstruction techniques 2011*, Poitiers, France.



Regular sampling projection (H)



Voxel-driven backprojection (H^t)