







A B-spline based and computationally performant projector for iterative reconstruction in tomography - *Application to dynamic X-ray gated CT* -

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ABSTRACT

Data modelization in tomography is a key point for iterative reconstruction. The design of the projector starts with the representation of the object of interest, decomposed on a discrete basis of functions.

Standard models of projector such as ray driven [4], or more advanced models such as distance driven [1], use simple cubic voxels, which result in modelization errors due to their anisotropic behaviour. Moreover approximations made at the projection step increase these errors. Long, Fessler and Balter [2] reduce approximation errors by projecting the cubic voxels more accurately. However anisotropy errors still hold. Spherically symmetric volume elements (blobs) [6] eradicate them, but at the cost of increased complexity.

We propose a compromise between these two approaches by using B-splines as basis functions. Their quasi-isotropic behaviour allows to avoid projection inconsistencies, while conserving local influence [3] [8]. Small approximations transform the exact footprint (projection of the basis function) into a separable function, which does not depend on the angle of projection, and is easier and faster to integrate on detector pixels. We obtain a more accurate projector, with no additional computation cost.

Such an improvement is particularly of interest in the case of dynamic gated X-ray CT, which can be considered as a tomographic reconstruction problem with very few projection data, and for which we show some preliminary results, with an original method of iterative reconstruction, using spatio-temporal regularization of the "space + time" sequence, and making no use of motion estimation.

1. B-SPLINE NUMERICAL PROJECTOR FOR ITERATIVE RECONSTRUCTION $f(x) = \sum x_k \beta_k^d(x) = \sum x_k \beta^d(x - x_k)$

R1. COMPUTATIONAL PERFORMANCES

1 single projection on 1 core of a Quad-Core AMD Opteron(tm) Processor 8378 2.4GHz. => Computation times are measured as a function of image size

20



Standard staircase voxels => coarse representation of the continuity







R2. 2D FAN BEAM RECONSTRUCTIONS: COMPARISON WITH THE DISTANCE DRIVEN MODEL [1]

Optimization scheme

Reconstruction with a Quasi-Newton optimization algorithm, minimizing the following criterion [12]:



600

400







R3. 2D X-RAY "GATED" DYNAMIC TOMOGRAPHY Simulation

- Periodically moving object (period 5 seconds).



We approximate the **footprint** of a voxel k by a separable B-spline of the same degree, scaled by

magnification and distorsion factors and centered on the projected center of the basis

-0.418

- 0.366 - 0.314

- 0.261 - 0.209 - 0.157

- 600 simulated projections on 360° with acquisition time of 120 seconds

=> 24 periods of motion.



Reconstructions of simulated data



Frame 13 of reconstructed sequences

Preliminary reconstructions on real data

- Data acquired at the Centre Léon Bérard, Lyon, France, on a Elekta Synergy conebeam CT, with a flat panel detector of 512x512 pixels.





Reconstruction

function.

- 25 frames of a single period, hence repeated 24 times and each one associated with 24 projections regularly spaced on $360^\circ \Rightarrow$ a pure gated X-ray CT case with extremely angularly undersampled data.

Global reconstruction of the sequence with *spatio-temporal regularization* (here a 3D total variation) to take into account the temporal correlation between frames, without any motion information but its periodicity and its temporal continuity.



CONCLUSION

We have developed a new type of projector, based on B-splines as quasi-isotropic basis functions. This last was designed to be computationally tractable for iterative reconstruction. We have shown its performances on 2D fan beam reconstructions. We have also studied its behaviour in the context of dynamic gated X-ray tomography. Preliminary results have shown that the accuracy of the projector is a key point to deal with this lack of data in the reconstruction process, and to make the best use of available information, which could help to avoid motion estimation, provided that we add an adequate global spatio-temporal regularization to the iterative reconstruction scheme.

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