Comparison between a new Reconstruction Algorithm (OPED) and Filtered Backprojection (FBP) for MDCT Data

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ABSTRACT

Previously the Orthogonal Polynomial Expansion on the Disk (OPED) algorithm was presented. Further, in prototype experiments in combination with the CT D`or geometry feasibility was demonstrated. In this study we implemented OPED with a clinical Scanner, and evaluated the potential using phantom studies.

All studies were acquired on a Siemens Somatom 64 (Erlangen, Germany) scanner, where raw projection data were reconstructed with the conventional FBP reconstruction and the OPED algorithm. OPED allows one to use fan beam geometry directly without any additional procedures such as interpolation or rebinning if using the CT D`or geometry. In particular, OPED describes an approximation of the image function as a sum of polynomials using Chebychev polynomials. For performance evaluation, the Catphan phantom 600 was imaged. OPED Images where reconstructed using C++ and MATLAB® .We measured uniformity, MTF and CNR for different dose levels and compared these to standard FBP images reconstructions with different filter kernels.

The integration and interpretation of the MDCT projection data for the OPED algorithm was accomplished. Reconstruction time is about 6 s on Quad-Core 3 GHz Intel Xeon processor. Typical artifacts are reduced when applying OPED. Using OPED the MTF maintains constant over the whole FOV. Uniformity and CNR are equal compared to FBP.

Advantages of OPED were demonstrated by applying the algorithm to projections images from a clinical MDCT scanner. In the future, we see OPED applications for low-dose or limited angle geometries to reduce the radiation dose while improving diagnostic quality of the reconstructed slices.

Keywords: CT, image reconstruction, OPED, performance, FBP

1. PURPOSE

New algorithms and technologies continue to be invented that reduce radiation exposure while maintaining diagnostic quality in CT. One of these algorithms is OPED, which is an acronym for Orthogonal Polynomial Expansion on the Disc[1-3]. OPED is based on a second order expansion with Chebyshev polynomials to relate the object to its Radon transforms. The input geometry are non equally spaced parallel data, which can be directly obtained by reordering fan beam data. Its computing time has been shown to be comparable to the conventional Filtered Backprojection (FBP) algorithm[4]. With fast implementation the performance can be improved up to about 20 - 30 times[5]. In addition, prototype experiments with CT D`or geometry and OPED have demonstrated feasibility[6-8]. In this study we implemented the OPED method for fan beam data from a clinical MDCT scanner and evaluated its potential.

Medical Imaging 2012: Physics of Medical Imaging, edited by Norbert J. Pelc, Robert M. Nishikawa, Bruce R. Whiting,
Proc. of SPIE Vol. 8313, 83133K · © 2012 SPIE · CCC code: 1605-7422/12/$18 · doi: 10.1117/12.911214

2. MATERIALS AND METHODS

OPED is based on the formalism of expansion of a function f (x,y) on the basis of orthogonal polynomials on unit disc B: = {(x,y), $x^2 + y^2 \leq 1$}. According to this formalism, the function f has to be supported by B and be square-integrable on B. The approximation of f based on its N Radon projections is given by the following main formula of OPED:

$$Af(x,y) = \frac{1}{N}\sum_{\vartheta=0}^{N-1}\sum_{k=0}^{N-1} C_{\vartheta,k} U_k(x cos\Phi_\vartheta + sin\Phi_\vartheta),$$

where

$$C_{\vartheta,k} = (k+1)\frac{1}{\pi}\int_0^{\pi} P_\vartheta f(\Psi) \sin{(k+1)\Psi} d\Psi,$$

and $U_k(t)$ is the Chebyshev polynomial of the second kind. Details for the derivation of the main formula (1) can be found in Xu[2]. $P_\vartheta f$ ($\boldsymbol{\Psi}$) denotes the Radon projection of the function f onto the boundary of the disc B characterised by the projection angle $\boldsymbol{\Phi}_\vartheta$, $\boldsymbol{\Phi}_\vartheta = \vartheta\pi/N$ (see Figure 1, left).

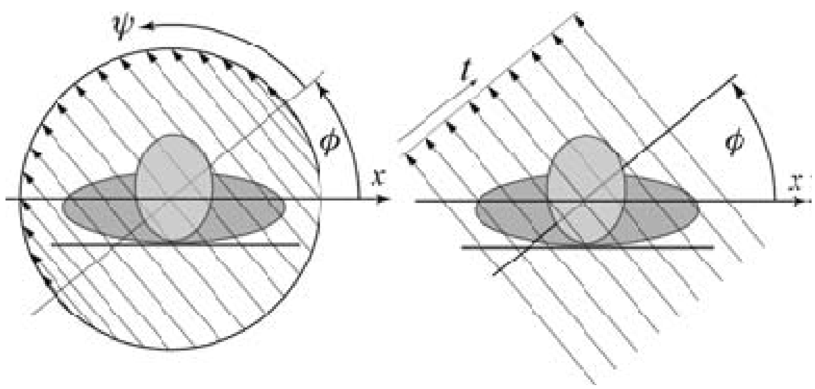

Figure 1. left: OPED-projection, right: FBP-projection.

As one can see in Figure 1 (left), the projection for OPED is parameterised with angle parameter c.For FBP (the most common algorithm used in the tomographic reconstruction of clinical data), the projection is parameterised with a length parameter t (see Figure 1, right). As a consequence, uniform discretisation of the projection in c results in nonequally spaced rays for OPED, while for FBP uniform discretisation in t results in equally spaced rays (Figure 1).

All studies were performed with projection images from a Siemens Somatom 64 (Erlangen, Germany) scanner and reconstructed with the conventional FBP and OPED algorithms. For performance evaluation, the Catphan phantom 600 was imaged. Measurements were performed using 120 kV and different mAs settings (50, 100, 200, 300, 550) in sequential mode. FBP images were reconstructed using the commercial implementation with a field of view (FoV) of 225 mm and a matrix of 512x512 pixels with a slice thickness of 0.6 mm and 5 different kernels (B10s, B30s, B50s, B70, B80s). Projection data were exported from the scanner for offline OPED reconstruction. OPED Images where reconstructed with the same FoV, matrix and slice thickness with 3 different acuity settings (0, 100, 200). The OPED algorithm was implemented using C++ and MATLAB® .We measured uniformity, MTF and CNR for different dose levels and compared these to standard FBP images.

3. RESULTS

The integration and interpretation of the MDCT projection data for the OPED algorithm was accomplished. Reconstruction time is about 6 s on Quad-Core 3 GHz Intel Xeon processor.

3.1 UNIFORMITY

Uniformity is shown to be equivalent for OPED and FBP. The noise level of OPED ranges somewhere between B30s and B50s. Where as noise is not constant in FBP slices, noise is constant across the entire FoV of OPED reconstructions.

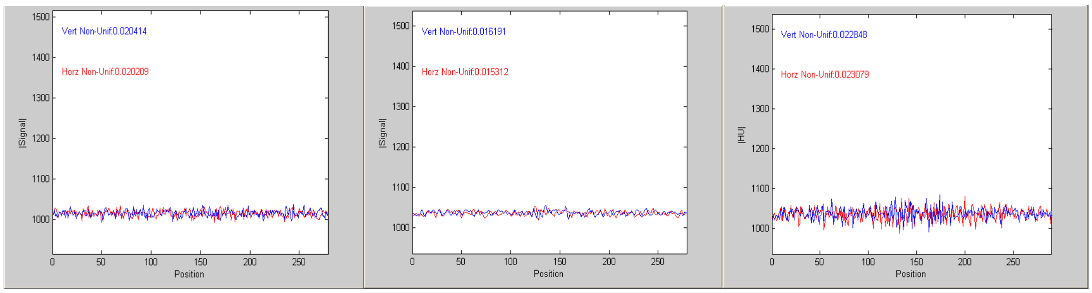

Figure 2: Profileplots measured in the uniformity modul of the Catphan 600 Phantom. Left: OPED reconstruction with acuity 0; Middle FPB reconstruction with Filter B30s; Right: FBP reconstruction with Filter B50s. All images where reconstructed from the same rawdata set.

3.2 CONTRAST TO NOISE

CNR is comparable between OPED and FBP reconstructions. OPED is superior to B50s but inferior to smoother kernels.

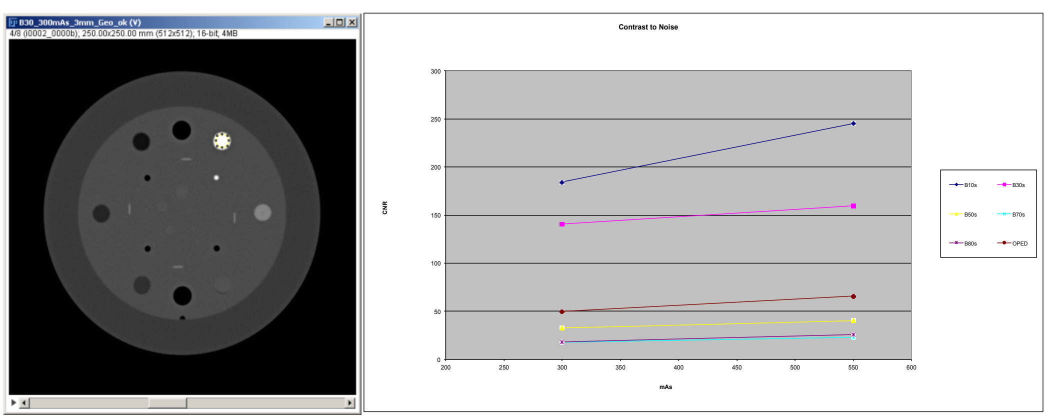

Figure 3: CNR at two dose levels (300, 550 mAs) measured with teflon (990 HU) and PMP (-200 HU)

3.3 MTF

MTF was measured using the point-source of the Catphan phantom. The performance of OPED is equivalent to the B30s kernel but can be boosted to the performance of the high-resolution kernels B70s or B80s. The acuity parameter of OPED allows to boost the higher partial frequencies. This modifies the MTF in a similar fashion to different kernels in FBP at the cost of higher noise. Like in FBP the noise increased using higher acuity – levels.

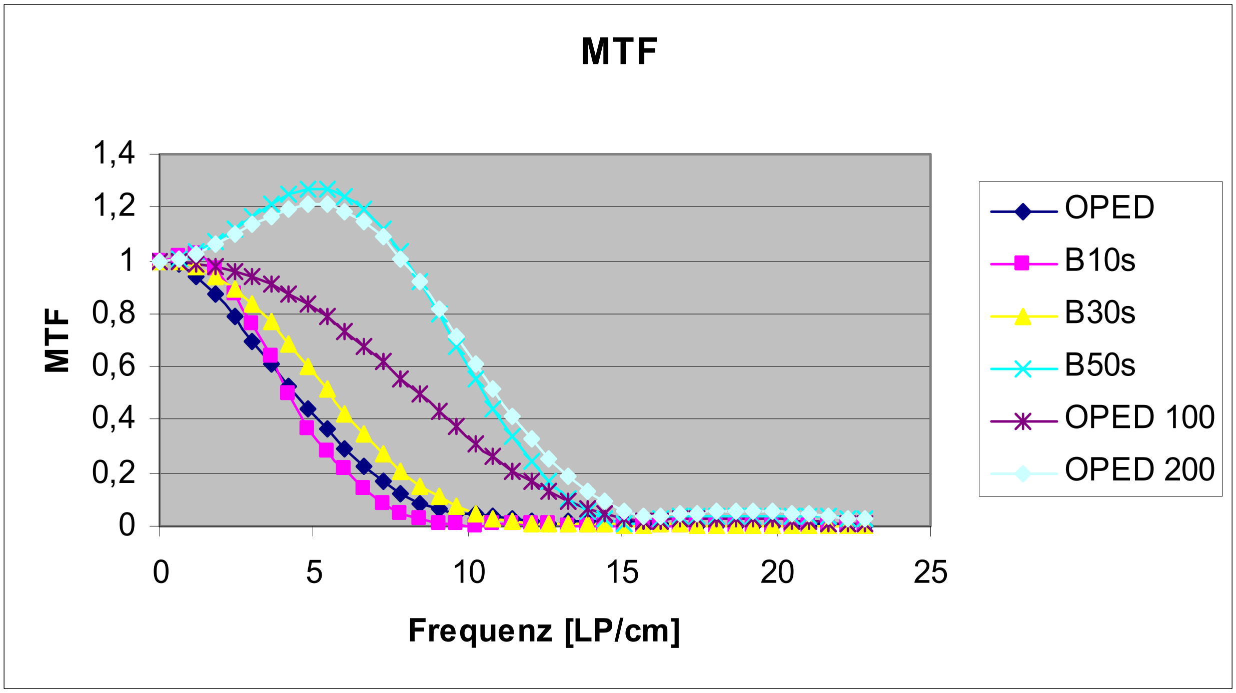

Figure 4: MTF of OPED and FBP reconstructions for several filter kernels and acuity-levels. All images where calculated from the same rawdata.

3.4 VISUAL COMPARISON

OPED images show comparable quality to standard reconstruction of a CT-scanner. In high contrast images some artifacts are reduced with OPED, but other artifacts are added (see figure 4). Low-contrast objects are better visualized with OPED. Edge artifacts are also reduced. In general the noise pattern appears with a finer granulation (as illustrated below).

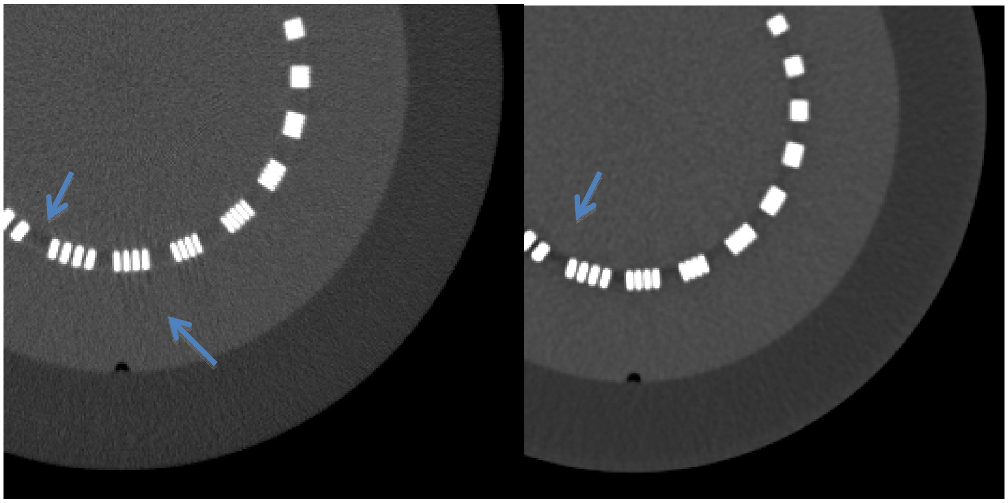

Figure 5: OPED reconstruction with acuity 0 (left) and FBP reconstruction with filter B30s (right). Both images are windowed at w: 1000 HU, L: 300 HU. OPED images show comparable quality to standard reconstruction of a CT-scanner. Some artifacts are reduced with OPED, but other artifacts are added (bar pattern on the left image).

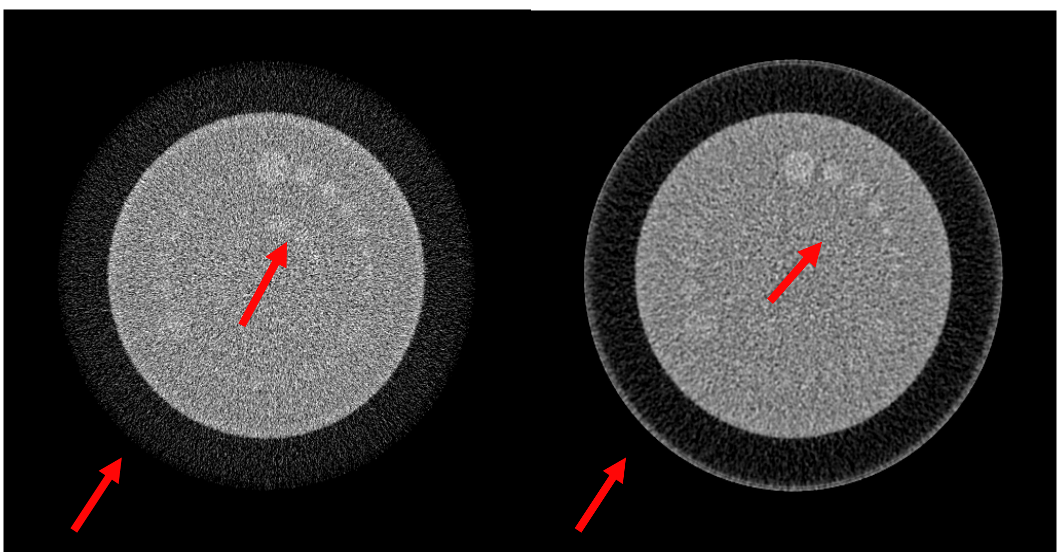

Figure 6: OPED reconstruction with acuity 0 (left) and FBP reconstruction with filter B30s (right). Both images are windowed at w: 100 HU, L: 50 HU. Low-contrast objects are better visualized with OPED. Edge artifacts are also reduced.

4. CONCLUSION

The integration and interpretation of the MDCT projection data for the OPED algorithm was accomplished. Reconstruction time is about 6 sec on a Quad-Core 3 GHz Intel Xeon processor. Typical artifacts are reduced when applying OPED. MTF, uniformity and CNR are equivalent when compared to FBP.

Images of competitive quality were reconstructed using the OPED algorithm from the same projection data. Advantages of OPED were demonstrated by artifact reduction. In the future, we see OPED applications for low-dose or limited angle geometries to reduce the radiation dose while improving diagnostic quality.

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