Frequency–Combined Extended 3D Reconstruction for Multiple Circular Cone–Beam CT Scans

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Purpose:

To provide a new reconstruction method for 3D imaging using a multiple 360° circular cone-beam CT system. The straightforward approach for reconstructing such scans is to weight and average the FDK reconstructions from multiple circles. Doing so has two disadvantages: First, the cone-beam artifacts from the scan with the on the current position depending larger cone angle increase the artifact level at this position and second, using a FDK reconstruction the advantage of a reconstruction of an extended volume is not used. To overcome these two disadvantages was the purpose of this work.

Method:

The general idea of with work here is the combination of the algorithm of reference [1] and the one of reference [2] in order to develop an advantageous sequence scan recon-struction algorithm. The advantages arise first due to the fact that by using an FDK reconstruction only those parts of the volume are reconstructed that have a data support of 360°. We aim at reconstructing also the parts of the volume which have at least 180° of data support (see figure 1), which results in larger reconstruction volumes. The second part of the proposed approach regards the combination of the multiple scans. Regarding one circular cone-beam acquisition there are data missing in the frequency space. These missing data in the frequency space lead to cone-beam artifacts in the reconstruction. Voxels in the overlap region in a sequence of circular scans have, depending on the longitudinal distance to the midplanes, different missing cones for the different acquisitions. The combination of the different reconstructions of the same voxel is performed in frequency space where the parts of the different scans, which are not missing, are combined (see figure 2). This results in the lowest cone-beam artifact level since the complete frequency information of the scan with the smaller longitudinal distance is used and combined with the available frequency information of the other scan in order to reduce the effect of the noise.

Results:

For the evaluation of the proposed method we used a simulation setup as well as two different flat-panel cone-beam CT scanners (figure 3).

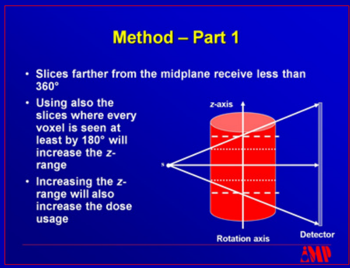

Figure 1: First part of the proposed method is the extended reconstruction of the single acquired scans.

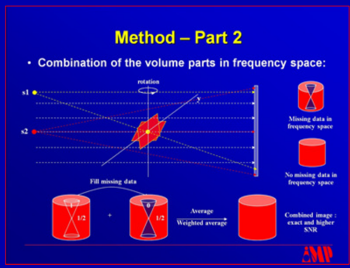

Figure 2: The extended volume parts are combined in the frequency space with weighting of the missing parts due to the cone angle.

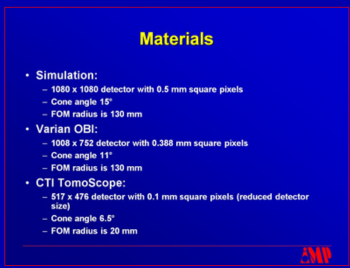

Figure 3: Scanners used for the simulation and the measurement study.

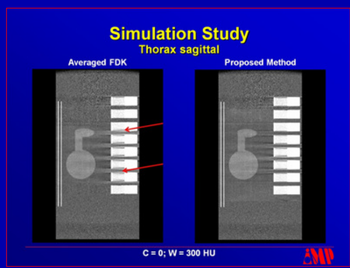

Figure 4: The figure shows the sagittal view of the Forbild thorax phantom. On the left hand side with the standard approach one can observe cone-beam artifacts (e.g. indicated by the arrows). The right hand side shows the reconstruction result of the proposed method where these artifacts are significantly reduced.

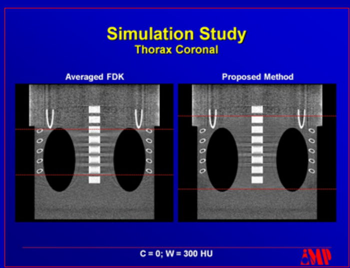

Figure 5: The figure shows the coronal view of the Forbild thorax phantom and compares the image quality of the standard approach and the proposed method. The red lines indicate the ranges where the different methods have a reduced noise due to the combined usage of the two scans.

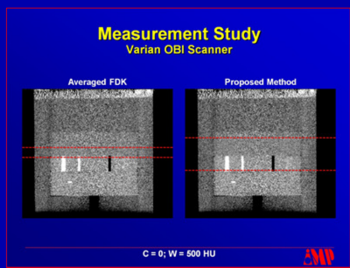

Figure 6: The figure shows the coronal view of the Catphan phantom which was acquired with the Varian OBI scanner. There the image quality of the standard approach and the proposed method is compared. The red lines indicate the ranges where the different methods have a reduced noise due to the combined usage of the two scans.

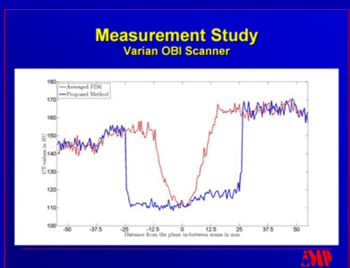

Figure 7: Noise plot through an area near the center of the Catphan phantom. Comparison of the averaging of the FDK reconstructions with the proposed method.

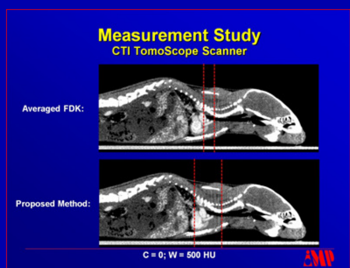

Figure 8: The figure shows the sagittal view of a measurement of a mouse scanned with the CTI TomoScope scanner. The red lines indicate the ranges where the different methods have a reduced noise due to the combined usage of the two scans.

For the evaluation first the simulation study has been performed using the Forbild thorax phantom. Figure 4 compares the sagittal view of the standard straightforward approach of averaging the two FDK reconstructions with the proposed method. There, one can clearly see that the strength of the cone-beam artifacts is significantly reduced in the case of the proposed method. Furthermore, one can see that the proposed method has a significantly larger region where the combination of both scans leads to reduced noise. The effect of the increased overlap is shown more clearly in figure 5 where the coronal view of the thorax phantom can be seen.

In the second experiment we used the measurement data from the Varian OBI scanner. There a Catphan phantom was measured with two circular scans. Figure 6 compares with a coronal view the noise reduction of the proposed method with the straightforward volume combination. There one can see that the noise reduction area is significantly increased. To show this more quantitatively in figure 7 a noise profile over the different *z*-positions is shown.

As final experiment a measurement of a mouse performed with the CTI TomoScope scanner was used. The results are shown in figure 8. Also here one can see that the proposed method increases the overlap and therewith the dose usage and reduces the cone-beam artifacts at the same time.

Conclusion:

A new method for the reconstruction of sequence scans from multiple circular scans has been proposed. The method has two advantages: first the amount of cone-beam artifacts is significantly reduced and the second advantage is that the area of the noise reduction is significantly increased. Except for these advantages, the proposed method shows the same image quality as the standard approach. Therefore, switching from the standard approach to the proposed method for the sequence scan reconstruction would only lead to advantages.

References:

[1] R. Grimmer et al.: "Cone-beam CT image reconstruction with extended z range," Med. Phys., vol. 36, pp. 3363 – 3370, July 2009.

[2] J. Beak et al.:"A new method to combine 3D reconstruction volumes for multiple parallel circular cone beam orbits," Med. Phys., vol. 37, pp. 5351 – 5360, October 2010

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