Comparison of Scatter Correction Methods for CBCT

Author(s):
Suri, Roland Erwin; Virshup, Gary; Kaissl, Wolfgang; Zurkirchen, Luis

Publication date:
2010

Permanent link:
https://doi.org/10.3929/ethz-a-007587136

Comparison of Scatter Correction Methods for CBCT

Roland E. Suri (1), Gary Virshup (2), Wolfgang Kaissl (1)

(1) Varian Medical Systems Imaging Laboratory GmbH, Täfernstrasse 7, CH-5405 Baden-Dättwil, Switzerland
(2) Varian Medical Systems, Ginzton Technology Center, 2599 Garcia Ave, Mountain View, CA, USA, 94043

In contrast to the narrow fan of clinical Computed Tomography (CT) scanners, Cone Beam scanners irradiate a much larger proportion of the object, which causes several times more X-rays scattering. If this scatter is not corrected, the reconstructed images exhibit artifacts: The middle area of the object becomes darker than the outer area, as the density in the middle of the object is underestimated. We compared three methods of correcting for scatter artifacts. 1) A heuristically-estimated constant was subtracted from each projection image (Uniform Scatter Fraction). 2) A beam-hardening-type correction followed by comparing with a cylindrical norm. 3) A combination of both. 4) Using the projections, the object dimensions were estimated in order to compute the scatter with a physical model. In our preliminary results, the first method significantly reduced scatter artefacts. Method two and method three lead to similar image quality and effectively reduced scatter artifacts.

Keywords: Algorithms (ALG), CT, Scatter (SCAT)

Preferred presentation type: Oral presentation

Description of Purpose

In Cone Beam Computed Tomography (CBCT) the whole area of interest is irradiated. This causes scatter contributions to the measured projections which are typically between 40 % and 95 % of the minimal pixel intensity for object sizes ranging from 20 cm diameter to 40 cm diameter (without bowtie and without grid). The distribution of the scatter over the projection is rather uniform (about 15 % deviation from average). Since in the reconstruction algorithm the logarithm of the measured intensities is taken, the scatter fraction impacts the reconstructed image, which is large where the object is thick and small where the object is thin. Therefore, in the reconstructed images the middle area of the object appears darker than it should. This reasoning leads to a simple heuristic method for correcting scatter, which is here called the Uniform Scatter Fraction method. From each projection a uniform image is subtracted with an amplitude that depends on the projection minimum and on the object size. Even if it may be inaccurate, this method should improve the image quality if it is compared to not using a scatter correction at all.

Our CBCT system is already using other methods that reduce the impact of scatter on image quality even if they were not specifically designed for this purpose: A beam-hardening correction is performed and the beam-hardening corrected projections are compared with a cylindrical norm of similar size as the object. Therefore, we were interested in the question whether adding the Uniform Scatter Fraction method to correct for scatter would improve image quality.

Methods

1) The Uniform Scatter Fraction method assumes that the scatter in each projection is uniform distributed over the image. A uniform distributed scatter is always less than the minimum of the projection. The fraction of the scatter contribution to this minimum is assumed to be a linear function of the average object diameter. Further multiplicative parameters were used to model the influence of grid and bowtie. These model parameters were estimated using about 50 scatter measurements. To exclude contributions from metal markers to the projection minimum, the projection mimimum was defined as the middle of the pixel percentile with the lowest count values.

2) For the Beam Hardening Correction the projection of a cylindric phantom of known size was measured

and these measured absorptions were rescaled to fit the theoretical values. The beam-hardening-corrected projections of a cylindrical norm (of similar size than the object) were divided by the beam-hardening-corrected projections of the object.

3) To combine both methods, the scatter was subtracted from all projections before further processing: The scatter-corrected projections were used for the Beam Hardening Correction, the Single Norm Calibration and for reconstructing the scan of the object.

4) For each projection, the object thickness was estimated using the known absorptions and its position was estimated using the couch height. The scatter was then computed with a physical model.

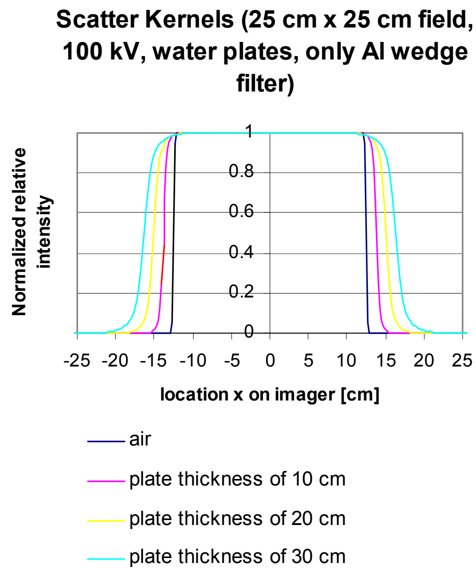

Figure 1. Scatter Kernel for a squared field of 25 cm times 25 cm and different Plexiglas plates. These kernels were estimated by fitting a physical scatter model by scatter measurements on a Varian Acuity system (data by Waldemar Ulmer, Varian, Baden).

Results

The same projection data were reconstructed with and without using the Uniform Scatter Fraction method for scatter correction. Without scatter correction, and by using neither a beam hardening correction nor a single norm image, a cupping of about 60 HU values occurred (Figure 2).

(A) No Scatter Correction (B) With Scatter Correction

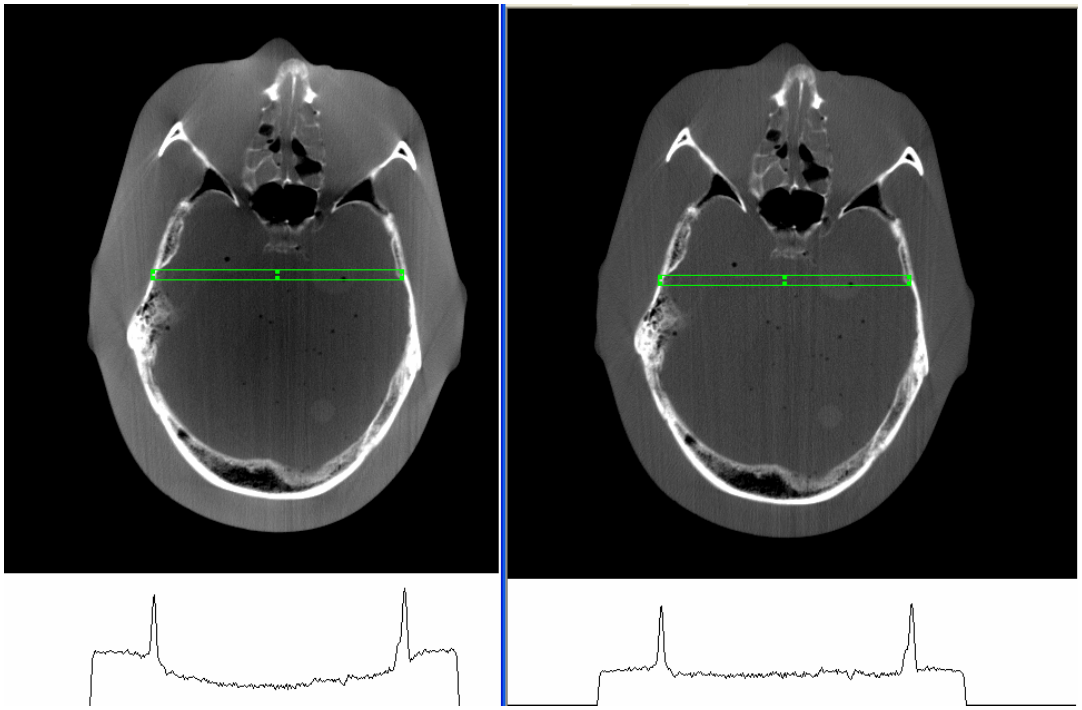

Figure 2. Two reconstructions using the same projections of a head phantom (no Beam Hardening Correction, no Single Norm, no filter, no bowtie, no grid, 125 kV, 80 mA, 10 ms). The reconstruction used a modified Blackman filter, 512x512 resolution, and 2.5 mm slices. Reconstruced by the Varian CBCT Application using a constant Air Norm Image. (A) Without scatter correction a cupping of about 60 HU values occurred (see bottom graph that shows average of the area between the green horizontal lines of the green rectangle). (B) Scatter correction with Uniform Scatter Fraction method eliminated the cupping. A Scatter Fraction of 7/12 was used that was detemined by exploration.

The Varian CBCT Application offers to correct for the beam hardening and to normalize the projections by a cylindric norm. Both may reduce scatter artifacts. Therefore, the scatter-corrected projections were used for the beam hardening, to normalize the projections, and to reconstruct the scan. This combined method (method three) did not lead to a visible quality improvement as compared to using only beam hardening and norm corrections (method two) (Figure 3).

No Scatter Correction   With Scatter Correction

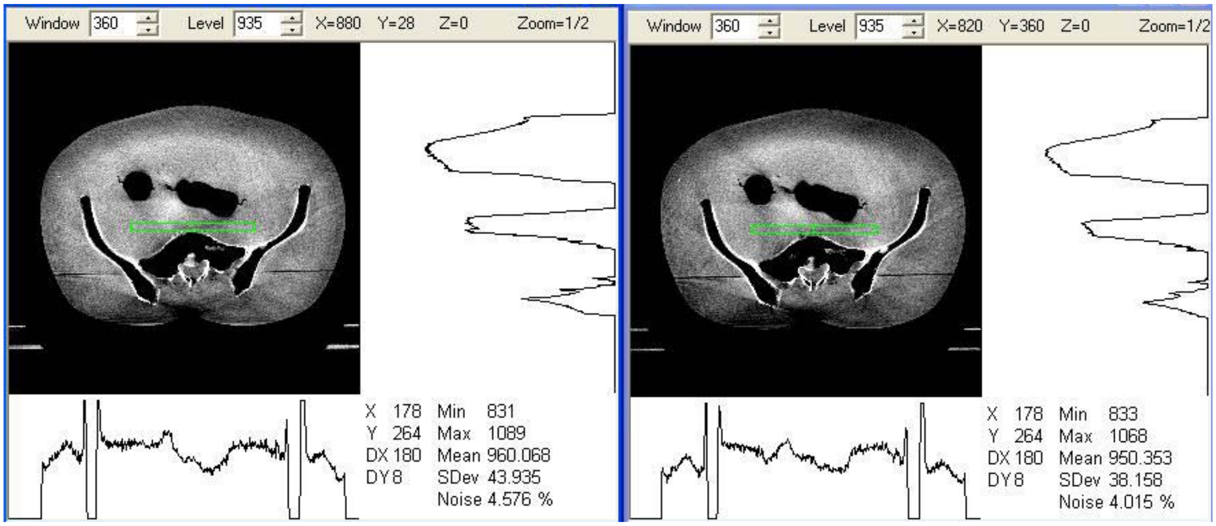

Figure 3. Comparison between without (left) and with (right) scatter correction for the same body phantom. No obvious difference was found in the quality of both images. Both methods similarly reduced cupping, but did not correct for fluctuations of the Hounsfiled Unit (HU) values over the slice. The HU values of the main phantom material had an inaccuracy of about 40 HU over the image (see bottom graph that shows average of the area between the green horizontal lines of the green rectangle for a window of 360 HU). The scatter correction was performed taking the pixel value with the 2000th lowest counts and multiplying this value by 0.75. The scans were taken with 125 kV, 80 mA, 13 ms, half fan, bowtie, and grid.

Conclusions

Reducing scatter artifacts in projections that were not corrected by any other method (method 1) was quite simple as compared to reducing scatter artifacts if the projection had already been corrected by other correction methods (method 3). The accuracy and stability of the used heuristic scatter correction method may not be sufficient for the second purpose. We estimate that for half fan scans with bowtie and grid, our current heuristic scatter model has an average error in estimating the scatter of about 30 %, which translates to a cupping in the order of 70 HU. If this cannot be improved, it is not sufficient to correct Varian CBCT images using standard settings, as they have typically much better HU value accuracies. For this reason, we are working on a scatter correction method that uses a physical scatter model to improve the accuracy of the scatter estimate.

This work has not been submitted elsewhere.