Evaluation of geometry and size dependence for a polynomial water precorrection approach in C-arm computed tomography

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Aims and objectives

Even if the image reconstruction of a computer tomography measurement is a simple linear mathematical problem nonlinear physical effects occur like beam hardening. They appear as streak and cupping artifacts. A simple possibility to treat cupping artifacts in computed tomography is empirical water precorrection [1,2]. In this work the correction quality in dependence on the geometry of the measured object is evaluated.

Methods and materials

The polychromatic raw data q should be transformed to equivalent monochromatic data p by a polynomial correction function (see Fig. 1 on page 3).

$$p=P(q)= c_1*q^1+c_2*q^2+\dots+c_N*q^N$$

Due to physical reasons the zeroth order can be neglected. Because the inverse Radon transformation R^{-1} is a linear function, the coefficients can be determined in the image domain.

$$f(r)=c_1*R^{-1}(q^1)+c_2*R^{-1}(q^2)+\dots+c_N*R^{-1}(q^N)$$

Water phantoms of arbitrary size and transverse geometry can be used for the calibration. To reduce noise influence a smooth reconstruction filter and slice averaging is used. A binary 2D template t(r) is generated setting all water pixels to 1 and a weight image w(r) avoiding influences of materials with unknown attenuation (see Fig. 2 on page 3). The minimization problem

$$\#d^2r\ (f(r)-t(r))^2w(r)=min$$

leads to a linear system, which can be solved by Gaussian elimination.

The correction vector is used to calculate the corrected image (see Fig. 3 on page 3).

Water phantom projections were simulated using flat panel cone beam geometry and an Tucker spectrum [3] with 90 kVp and 0.6 mAs. The simulation calculates the line integrals with knowledge of the physical material properties. Scattering is not considered. Different geometries and sizes of phantoms were compared. The CONRAD framework [4] was used for simulation and reconstruction.

Images for this section:

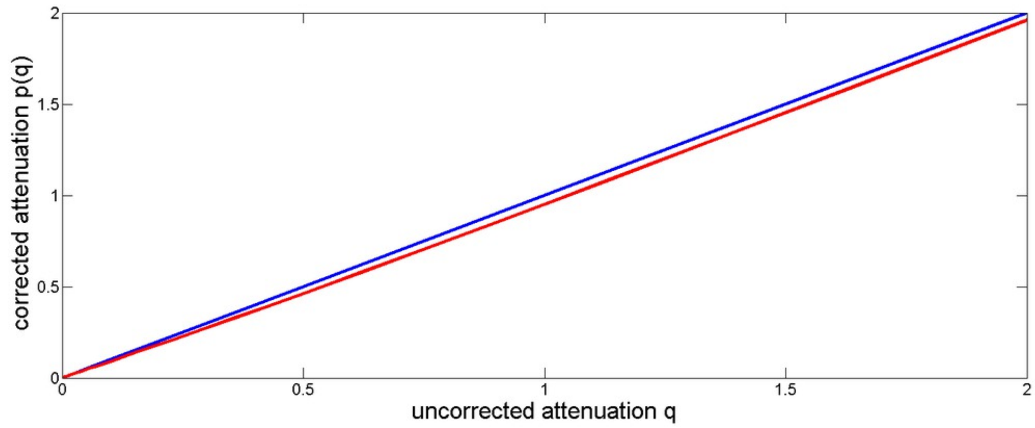

Fig. 1: Example for a correction function: corrected attenuation values p=P(q) (red) and linear, uncorrected attenuation values q (blue)

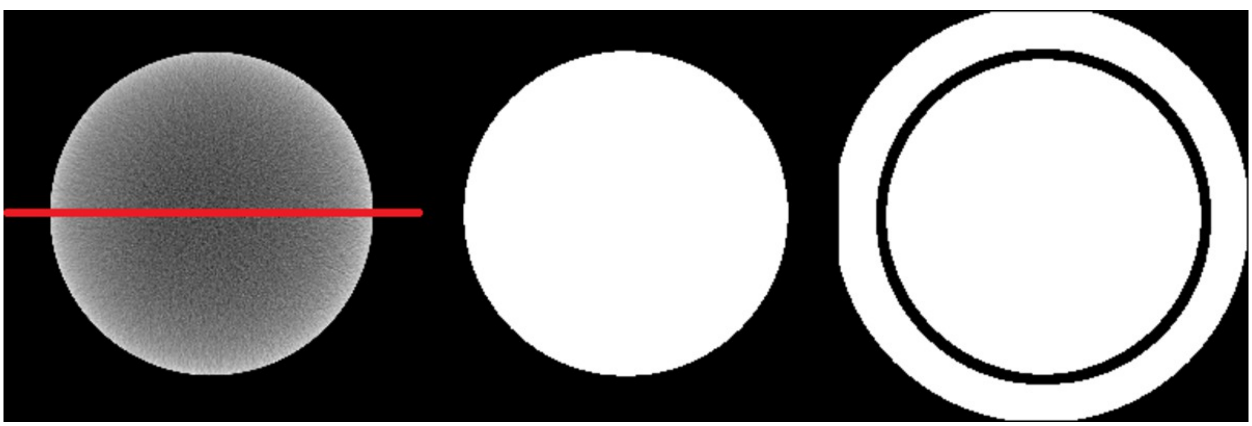

Fig. 2: Empirical water precorection (left: reconstructed and averaged slices of the water cylinder; center: binary template t(r); right: weighting image w(r))

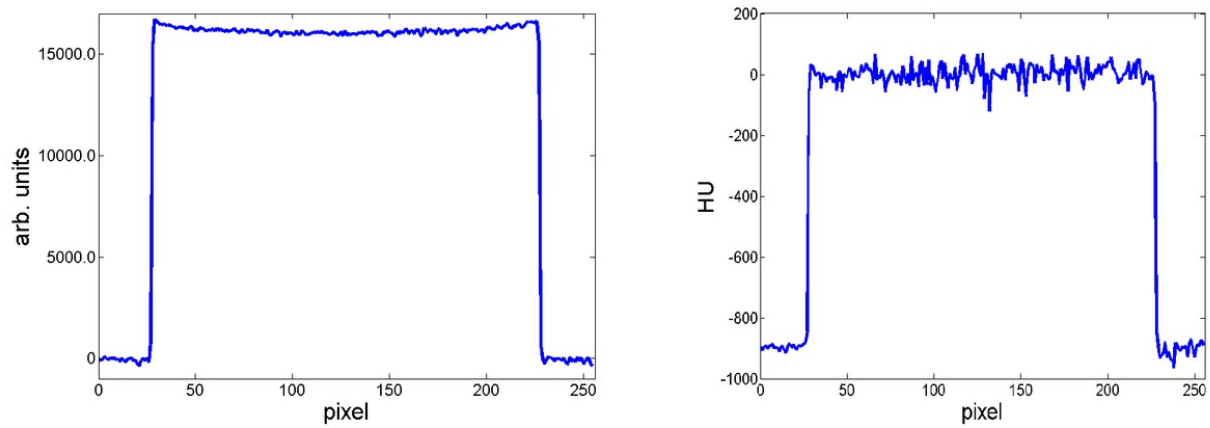

Fig. 3: Profile plots: averaged slices profile along the red line in Fig. 2 with obvious cupping (left); corrected image profile unaveraged without cupping(right)

Results

At first the resulting correction vectors for simulated phantoms with different geometrical shapes but same cross sectional area (±0.9%) are compared:

	cylinder (d=200 mm)	**elliptical clinder** (a=120 mm; b=83.33 mm)	**box** (a=178 mm)
c_1	0.9765	0.9492	0.8909
c_2	0.0102	0.0217	0.0787
c_3	0.0029	-0.0032	-0.0211
c_4	-0.0010	0.0003	0.0020

In addition to the geometry dependence also the size-dependent correction vector changes are investigated:

cylinder (diameter d)	d=100 mm	d=200 mm	d=240 mm
c_1	0.9765	0.9430	0.5497
c_2	0.0102	0.0327	0.3350
c_3	0.0029	-0.0073	-0.0861
c_4	-0.0010	0.0007	0.0074

Images for this section:

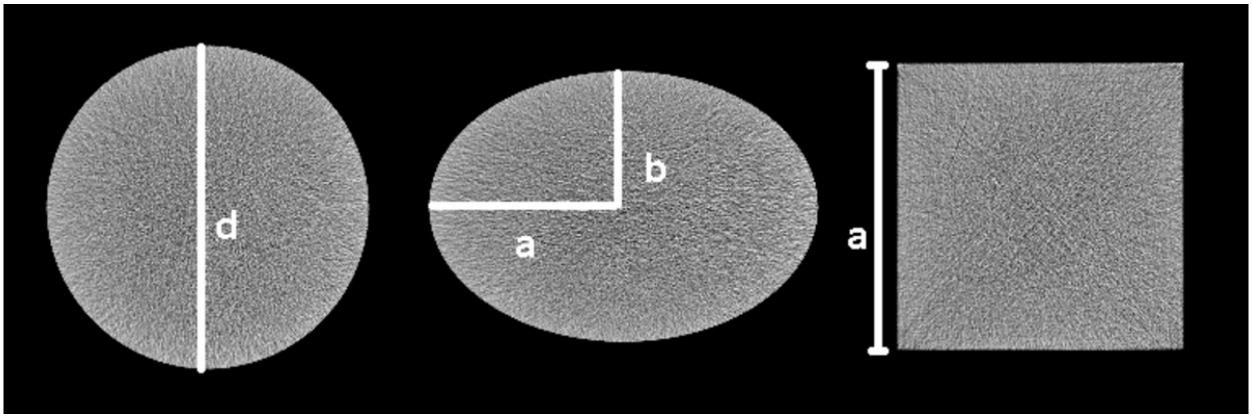

Fig. 4: Geometries: cylinder (d=200mm), elliptical cylinder (a=120mm, b=83,33mm), box (a=178mm)

Conclusion

For different geometries deviations in the resulting correction are determined. The more the calibration phantom´s geometry is cylindrical the lower is the difference between the corrected and a simply linearly calculated reconstruction.

Also the size of the calibration water phantom is important. As expected, objects with small diameters lead to a very small correction because of their low attenuation. The calibrated attenuation range therefore is smaller and a linear extrapolation is needed for measurements of bigger objects of similar material.

To obtain the optimal calibration a phantom should be used that is as similar as possible to the later measured object.

Further research shall be done with real measurement data to investigate also the influence of scattering.

Personal information

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