CNR improvement in a sparse-view cone-beam computed tomography using an anti-scatter grid

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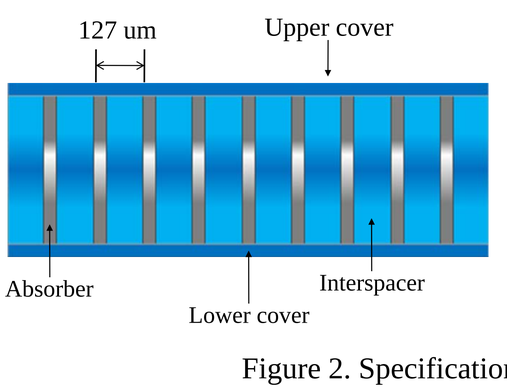
Purpose

- In x-ray cone-beam CT (CBCT) imaging, scatter is a physical process which constitutes a critical factor for degrading image contrast. It has been under our research interest that clinicians' demand for image quality particularly including contrast in such as prostate imaging or brain imaging is high compared to the ones that are available in commercial CBCT systems.
- Using an anti-scatter grid is one of the methods that directly suppresses scatter recorded in the detector thus improving contrast in radiography. However, its use in CBCT has not been successful in increasing the contrast-to-noise ratio (CNR) mainly because the noise related to the Poisson statistics of photons is increased while contrast is improved as well.
- The purpose of the study was to demonstrate a CNR improvement is feasible when an anti-scatter grid is used in CBCT.

Method

- We suggest a novel method of reducing the number of projections and increasing the exposure in each projection by using grid in CBCT to suppress noise, thereby retaining the total dose, in the iterative image reconstruction framework that is inspired by compressed sensing theory. A total-variation minimization algorithm was employed for image reconstruction from sparse-view data.
- We carried out a simulation study to test a feasibility of the proposed method. Projections of the XCAT phantom were taken at 720- and 120- views, the formers of which incorporate larger amount of scatter and more noise compared to the latters that simulate the use of an anti-scatter grid. The full-view data (720-views) have been fed into the FBP algorithm for image reconstruction, and the sparse-view data (120-views) into the TV algorithm.
- The water equivalent CATPhan phantom was used for the experiment to see the cupping artifact reduction by using the proposed method. In the conventional method, 600 projections without an anti-scatter grid were taken for 360° scan with the X-ray source of 105 kVp with 10 mA, and FBP algorithm was used for image reconstruction. Whereas, in the proposed method, 300 projections with an anti-scatter grid were taken for 360° scan with the X-ray source of 105 kVp with 20 mA, and TV algorithm was used for image reconstruction.
- The resolution CATPhan phantom was used for comparing the resultant images of conventional method and proposed method. The experiment conditions were the same with CATPhan experiment scheme.



- Type: converging to source
- Size: 337 × 328 mm
- Lines/Inch: 200
- Ratio: 10:1
- Focal distance: 100 cm
- Material: Absorber (strip): Pb, Interspacer: Al

Figure 2. Specification of anti-scatter grid for experiment

Figure 2. Water equivalent CATPhan phantom

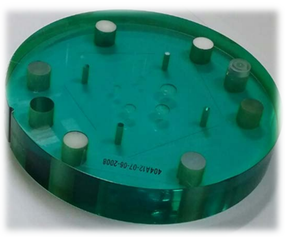


Figure 3. Resolution CATPhan phantom

Conventional method	Proposed method
- Without a grid	- With a grid
- 600 view (360° scan)	- 300 view (360° scan)
- 105kVp, 10mA	- 105kVp, 20mA
- Feldkamp, Davis, and Kress (FDK) reconstruction algorithm	- Total-Variation minimization reconstruction algorithm

TABLE 1. Experimental condition and geometry

Result

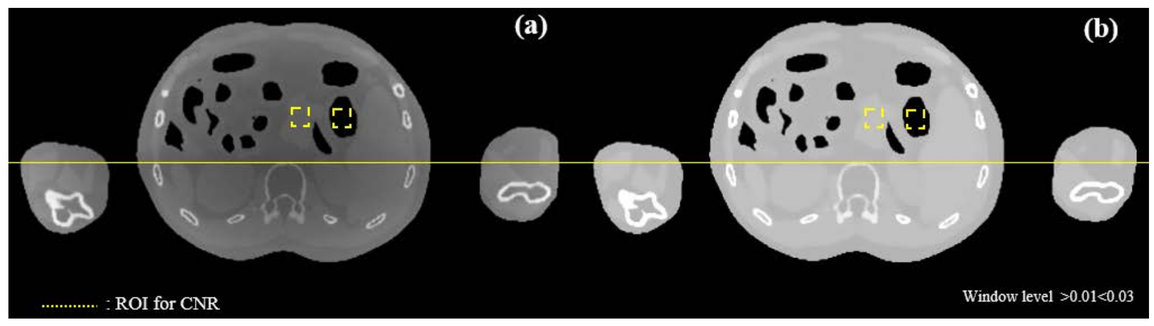


Figure 4. Simulation Reconstruction images of XCAT phantom (a) conventional method, and (b) proposed method.

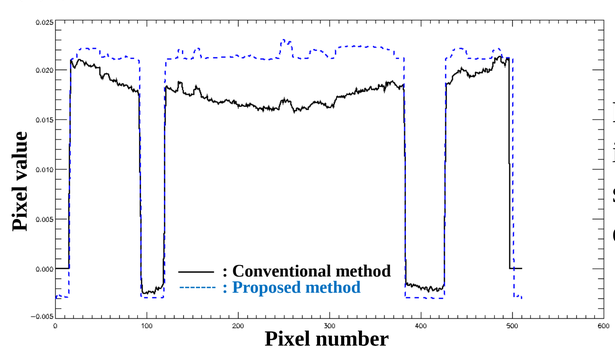


Figure 5. Midline profiles of reconstruction images using (a) conventional method (black straight line), and (b) proposed method (blue dot line) of simulation study.

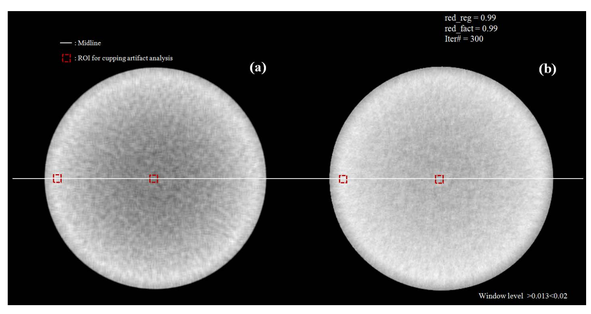


Figure 6. Reconstruction images of water equivalent CATPhan phantom using (a) conventional method, and (b) proposed method.

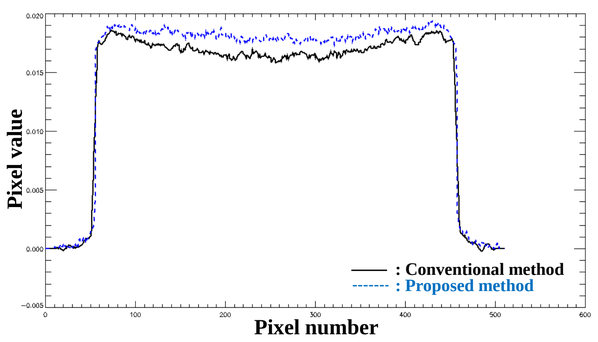


Figure 7. Midline profiles of reconstruction images of water equivalent CATPhan phantom using (a) conventional method (black straight line), and (b) proposed method (blue dot line) of simulation study.

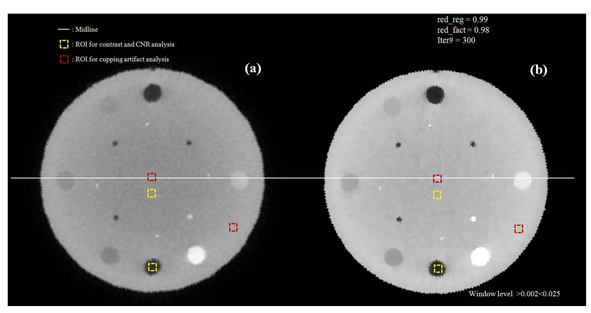


Figure 8. Reconstruction images of resolution CATPhan phantom using (a) conventional method, and (b) proposed method.

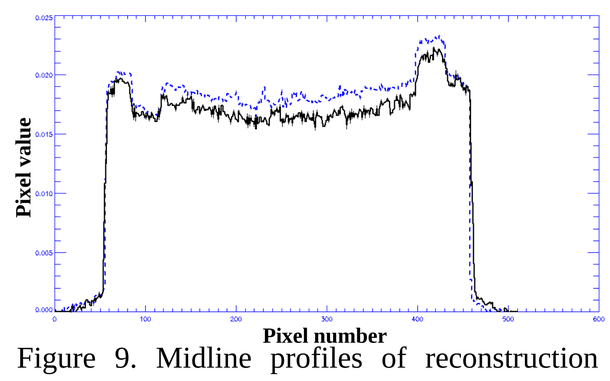


Figure 9. Midline profiles of reconstruction images of resolution CATPhan phantom using (a) conventional method (black straight line), and (b) proposed method (blue dot line) of simulation study.

- In simulation study, cupping artifacts has been enhanced and contrast has increased. Quantitatively, contrast has been increased by a factor of 1.50.
- In experiment of water equivalent CATPhan phantom, cupping artifacts has been enhanced. Quantitatively, image (a) in Fig. 6 has higher t_{cup}(%) value than (b) by a factor of 2.12 where t_{cup}(%) stands for the degree of cupping artifact.
- In experiment of resolution CATPhan phantom, contrast has been increased by a factor of 1.28, and CNR has been increased by a factor of 1.13. Also, image (a) in Fig. 8 has higher t_{cup}(%) value than (b) by a factor of 1.46.

Conclusions

- We proposed the method of sparse view cone-beam CT with the use of an anti-scatter grid to improve CNR without additional radiation dose to the patient. The results from simulation study and experiments have shown that by using proposed method, contrast and CNR have increased and the magnitude of cupping artifacts decreased compared to the conventional method.

References

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