Dynamic x-ray beam positioning for low-dose CT

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Andrew Mao and William Shyr, under the auspices of Professor J. Web Stayman

Introduction

We developed a system to automatically calibrate the patient's position within a CT gantry and dynamically position the x-ray beam filter during acquisition, conferring the benefits of low-dose CT with improved image quality for arbitrary patient positions. We evaluated our system performance using dose and noise measurements for multiple degrees of miscentering and two different beam filters.

The Problem

- A method to dynamically position x-ray beam filters for low dose CT acquisitions is needed in clinical scenarios in which manual centering of the patient within the bore is impractical.
- Traditional bowtie filters allow the reduction of dose received by the patient without loss of image quality, but patient miscentering results in decreased image quality and increased dose in some parts of the body.
- Modern industrial CT systems use static beam filters that are often simply removed in the emergency room to avoid miscentering issues. Clinical data has shown that elevation errors range from -6.6 to 3.4 cm (mean -2.3 cm) with up to 41% increase in surface dose and 22% increase in image noise [1].

The Solution

- Calibration is performed by taking 2D low-dose scout radiographs at two views (anteroposterior and lateral) 90° apart. The two views form a data vector g, and a six-parameter model of the object $\boldsymbol{x}$ that can be estimated via an optimization taking the form of

$$\underset{\boldsymbol{x}}{\operatorname{argmin}} \|\boldsymbol{P}\boldsymbol{x} - g\|^2$$

  where $\boldsymbol{P}$ is forward projection operator.
- The beam filter is then dynamically positioned at each frame during a CT scan using the analytically computed translation to match the center of the bowtie with the center of the phantom.

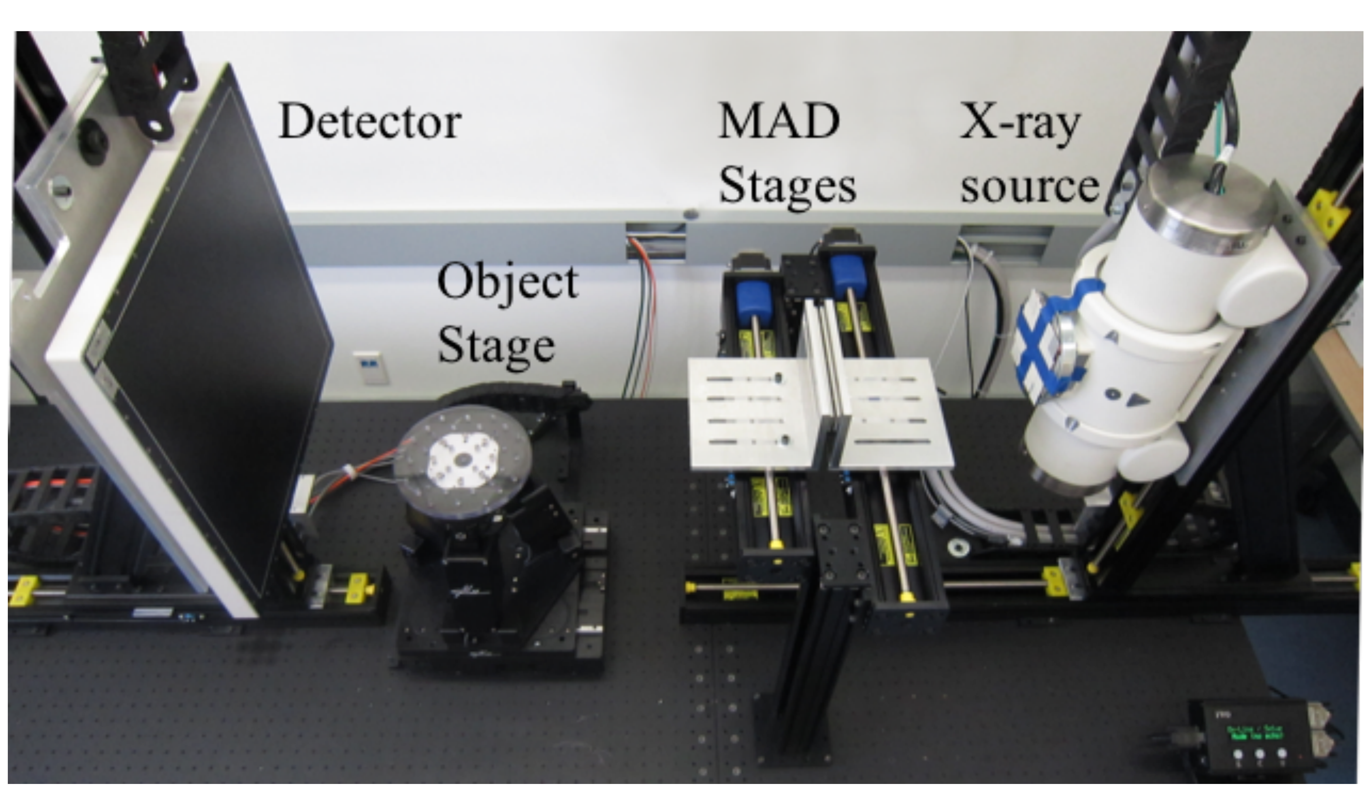

Figure 1: CBCT Test Bench.

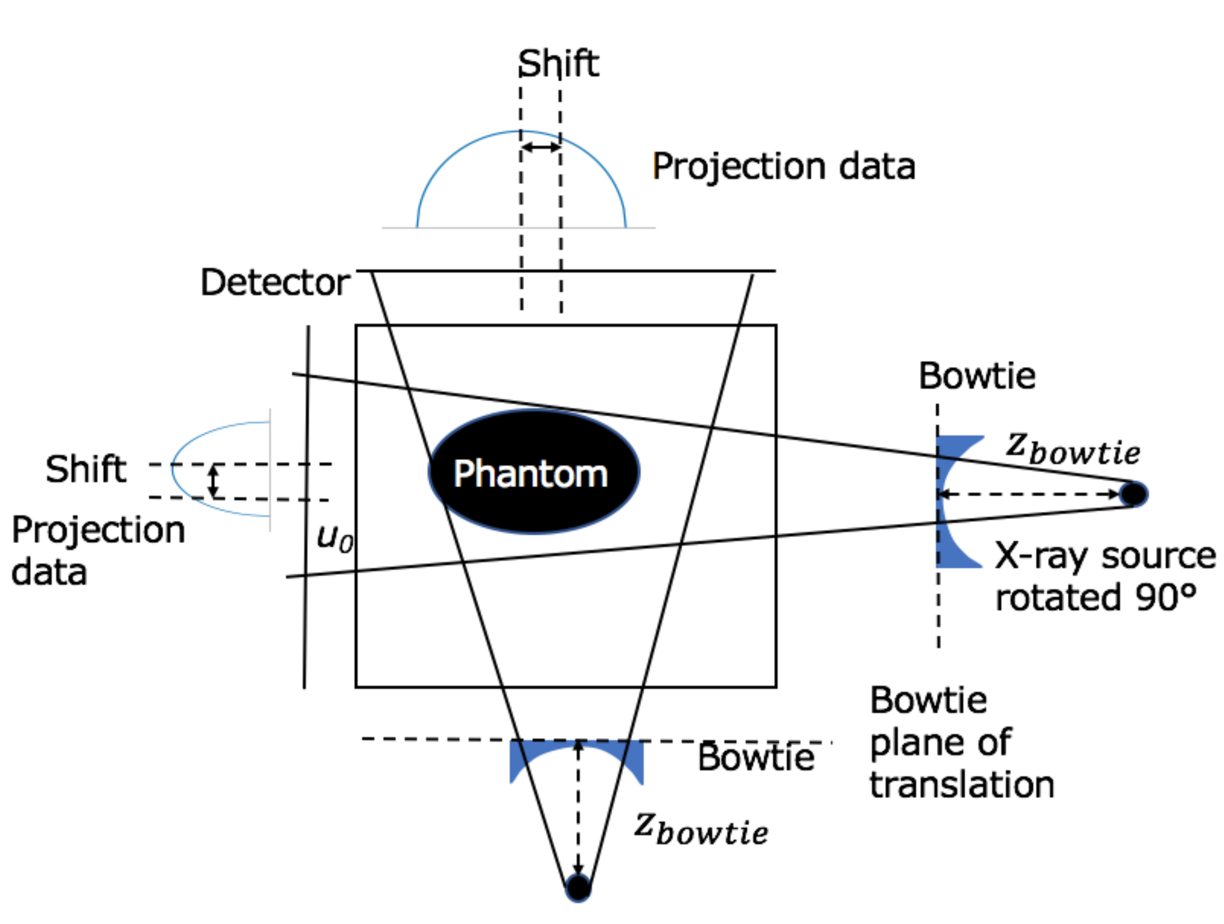

Figure 2: Imaging geometry.

Outcomes and Results

- We performed experiments to evaluate the system using a 16 cm CTDI phantom at miscentering positions of 0 cm, 2 cm, and 4 cm to the left of isocenter.
- We observed more uniform noise distributions (Fig. 3) and significantly reduced dose variation within the phantom using our dynamic system. Dose values are reported as % differences with respect to the perfectly centered object.

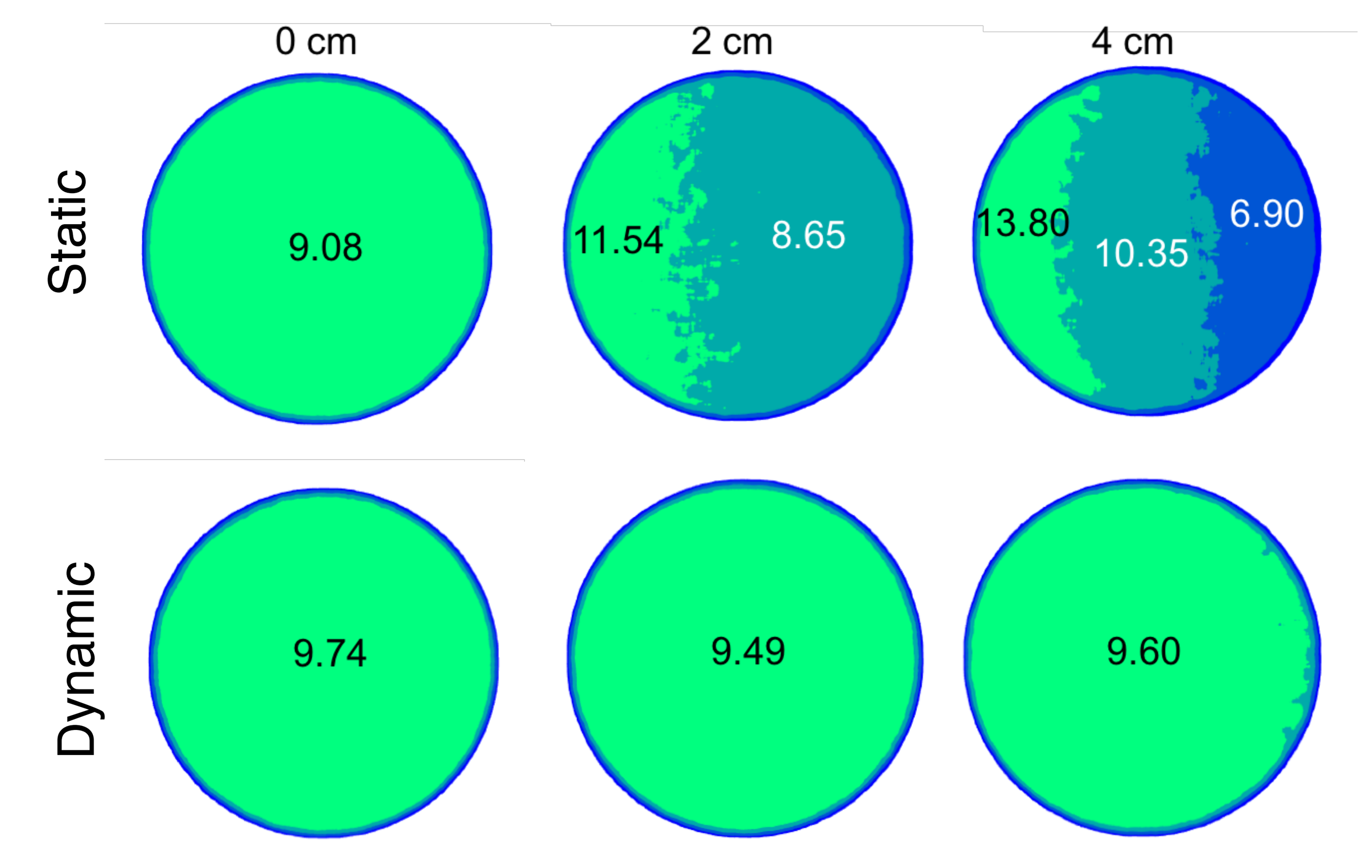

Figure 3: Contour plots comparing noise distributions between dynamic and static bowtie acquisitions. Noise values are on the order of 10^{-4}.

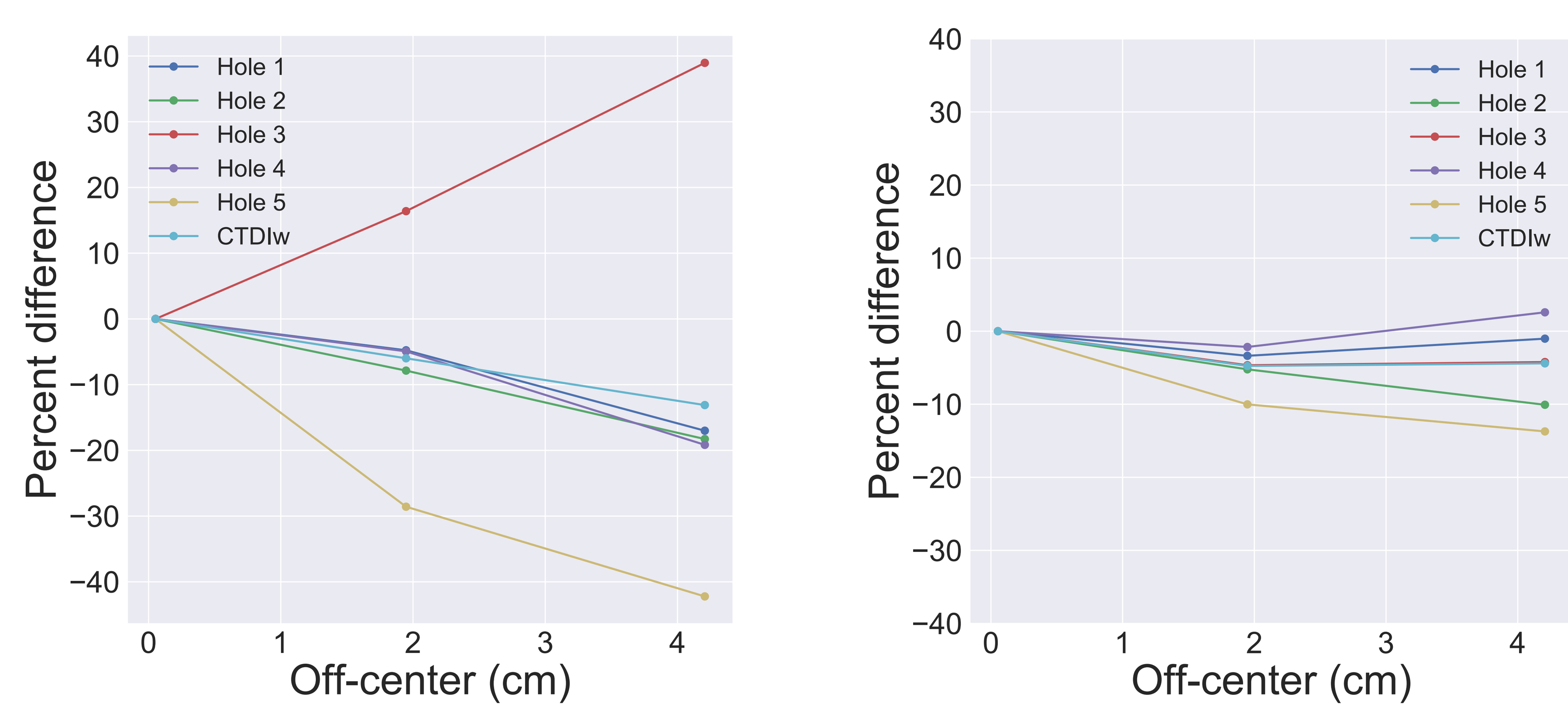

Figure 4: Percent change in dose measurement comparing static and dynamic beam filter systems.

Future Work

- Improve compatibility of trajectory calculation with a wider variety of beam filters with non-traditional profiles
- Continue to perform validation experiments through the summer on split bowties and MADs

Lessons Learned

- CT image acquisition and reconstruction pipeline
- Making CTDI dose measurements

Credits

- Andrew – Software development
- William – System evaluation

Support by and Acknowledgements

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References

[1] Toth, T., Ge, Z. and Daly, M. P. (2007), The influence of patient centering on CT dose and image noise. *Med. Phys.*, 34: 3093-3101. doi:10.1118/1.2748113