Iterative Reconstruction Approach to Minimize Metal Artifacts in a Rotating Turntable CT System

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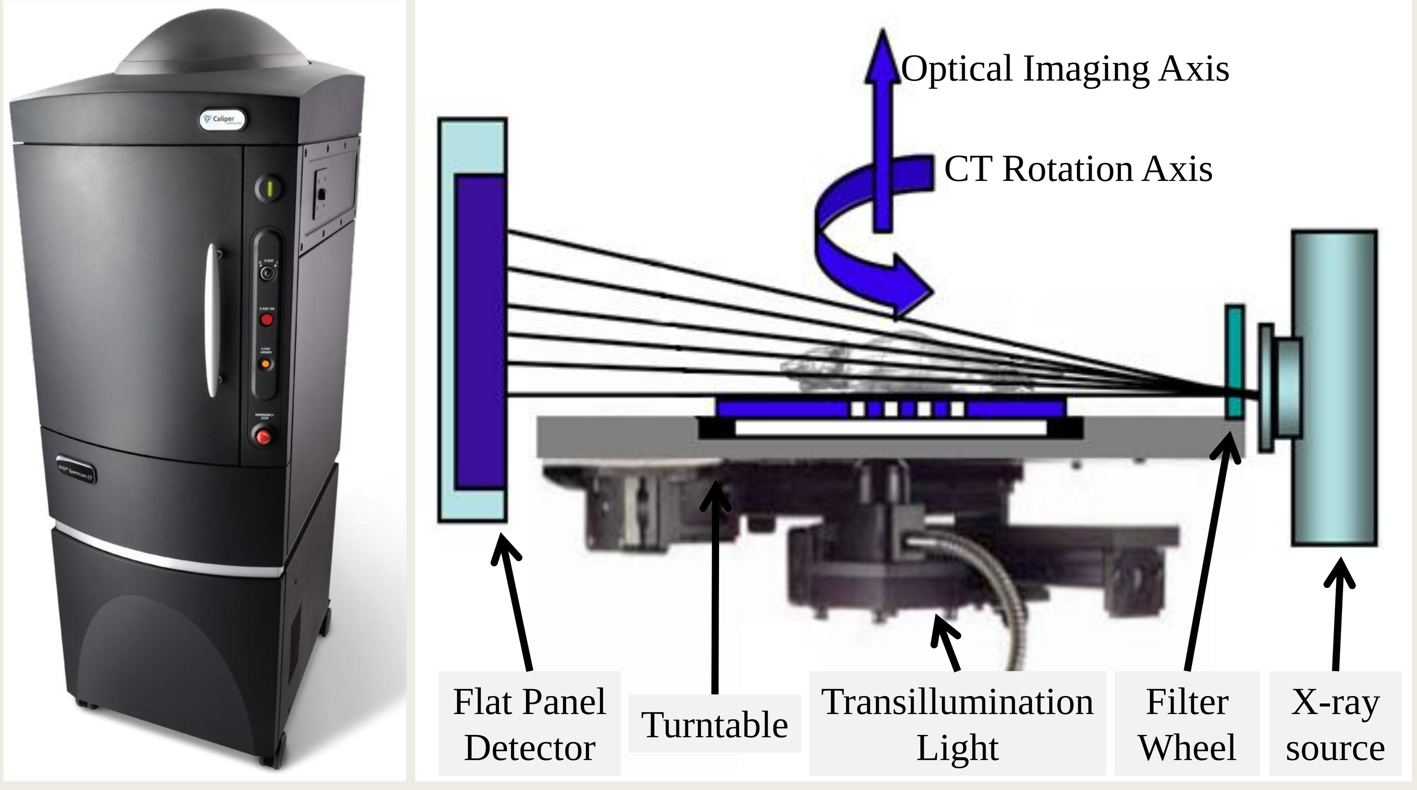
1 Introduction

Visualization and quantification of Computed Tomography (CT) scans is ideally performed on artifact free images. Materials with a high linear attenuation coefficient, such as metal, cause significant artifacts in the reconstructed image. Unfortunately, the use of metal is unavoidable in some orthopaedic and dental models and with some animal tracking systems.

Many iterative reconstruction approaches used in the past remove metal from the sinogram before the final reconstruction. These sinograms are geometry dependent, but the algorithms have not been tested for the rotating turntable geometries used in some preclinical uCT systems. These preclinical uCT systems also have specific image processing needs to facilitate specific co-registration applications.

The key features of this work include:

- Evaluating sinogram interpolation approaches for the rotating turntable μCT geometry
- Comparison of sinogram interpolation algorithms
- Assessment of the impact that metal artifact reduction has on automatic processing of the subject surface

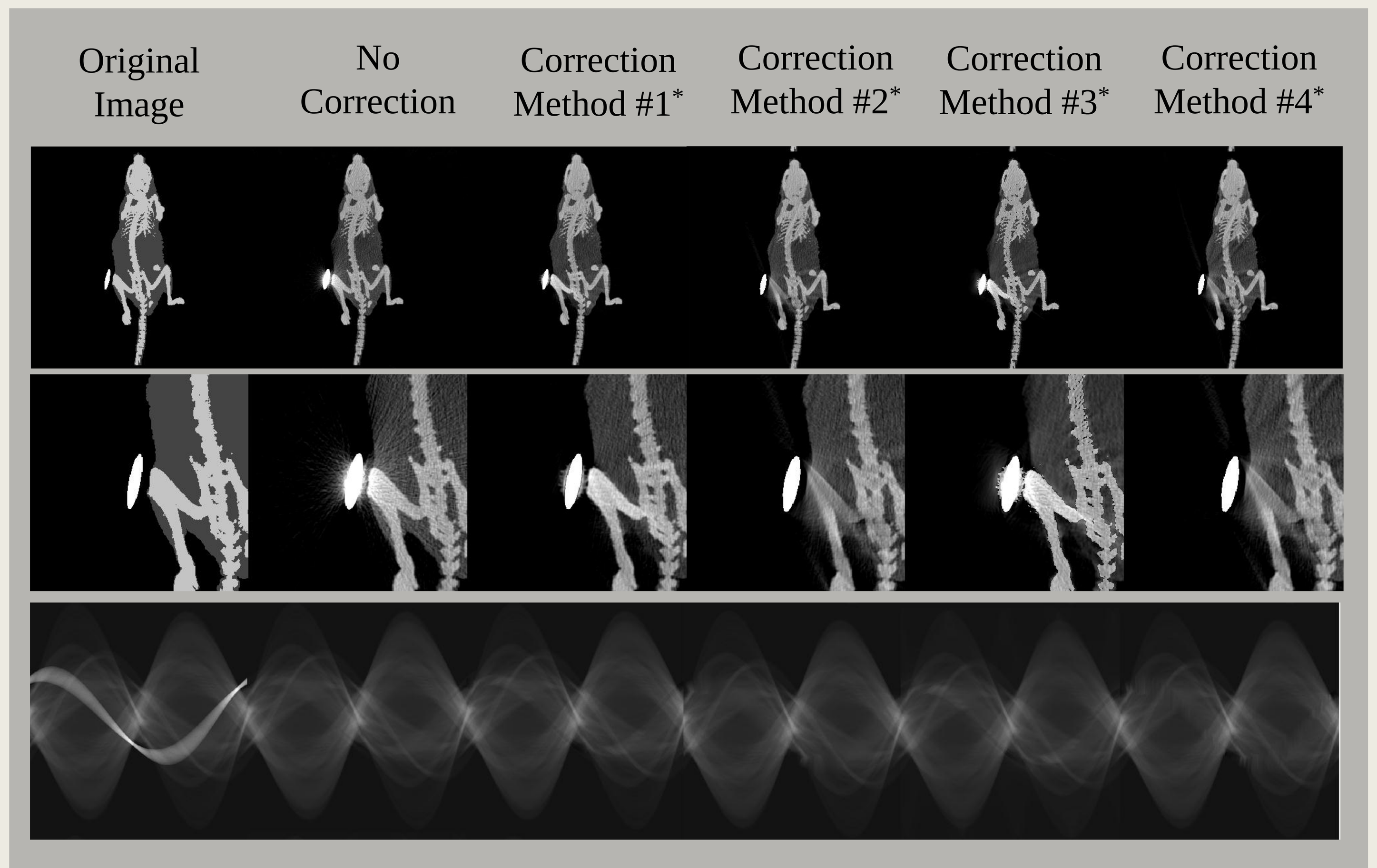


The IVIS® Spectrum CT (left) contains a light tight imaging chamber for optical imaging as well as a CT subsystem with a rotating turntable geometry (schematic at right). A 50 kVp, 1mA X-ray source is used to create a half cone geometry and an automated filter wheel moves in and out of the beam to adjust the source spectrum. Projection images are acquired using a CMOS based flat panel detector (75 μm pixel pitch) as the mouse rotates continuously through 360° during the scan. A transillumination lamp below the stage can be used for acquisition of fluorescence data.

2 2D Simulations to Compare Artifact Reduction & Interpolation Methods

The DRASIM[1] simulation package was used to assess artifacts in images that include tissue, metal (iron) and, in some cases, bone. Four different sinogram interpolation methods were evaluated:

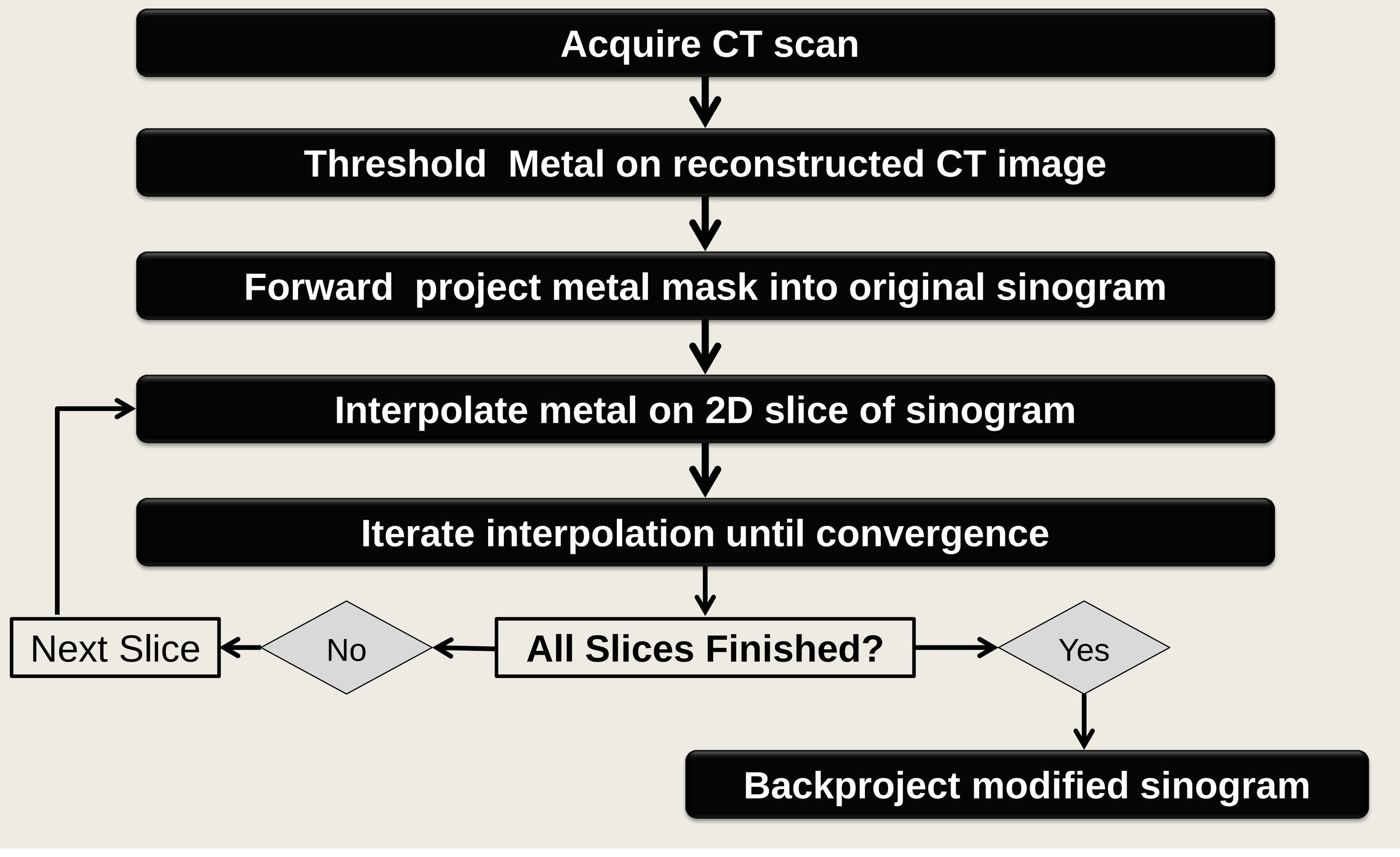
1. Karimi et al.[2] – 3 layer model (bone, tissue, metal), 3 reconstructions, artifact deletion
2. Basic – Sinogram inpainting using isotropic diffusion, 2 reconstructions (see Section 3 below)
3. Wei et al. [3] – 2 layer model (bone, metal), 3 reconstructions, image addition
4. Mazin et al. [4] – 2-layer model (bone, tissue), 3 reconstructions



Images showing the oiginal image before forward projection (left colume), the results with no correction (second column) and the subsequent correction approaches. Methods #2 and #4 appear to correct the metal artifacts well. Similar results were seen for other use cases of either 3 metal beads and/or without the skeleton.

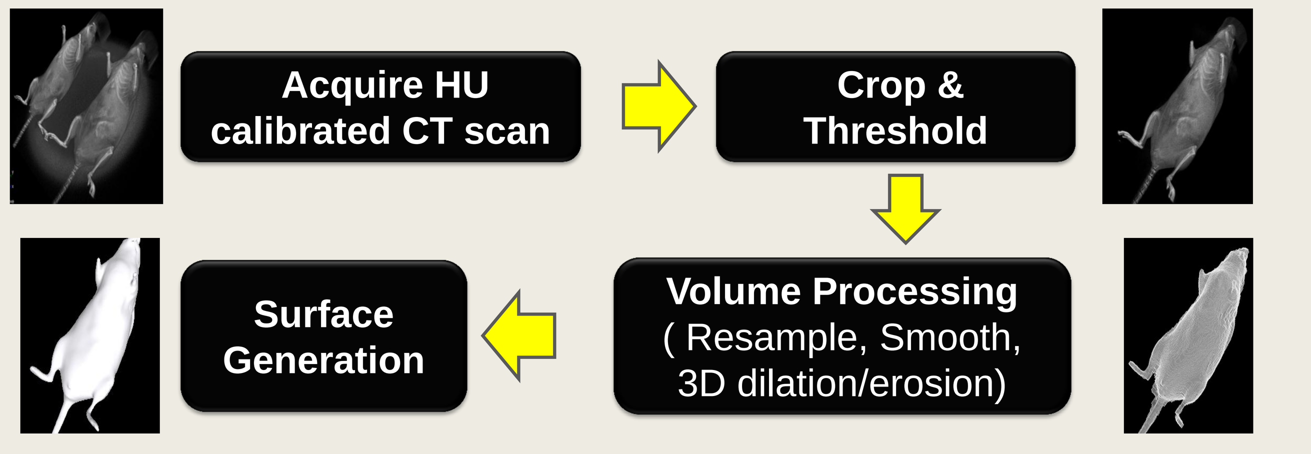
3 Interpolation on 3D CT Image

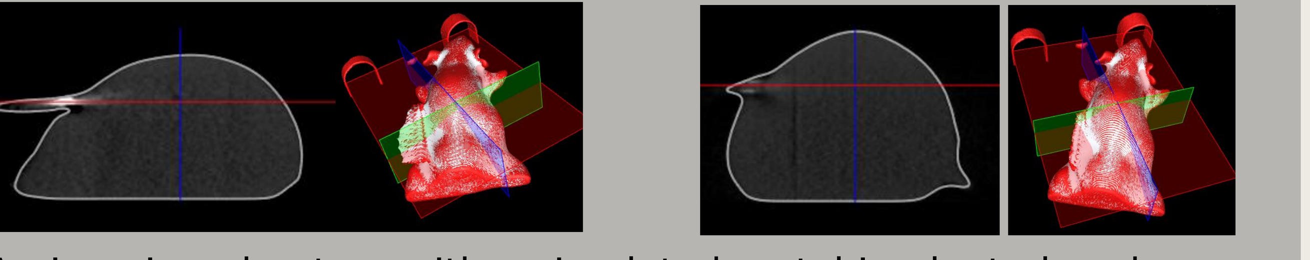
To test the image inpainting algorithms on a real dataset, the basic interpolation approach (Method #2) was implemented using this general algorithm:



4 Surface Generation

For multiodality imaging in the IVIS® SpectrumCT, the skin surface is segmented from the CT volume (and subsequently input into diffuse optical tomography reconstructions) using the following algorithm:





An imaging phantom with a simulated metal implant placed subcutaneously was imaged. Surfaces generated from images reconstructed with the image inpainting methods show a much smoother surface.

5 Summary

The rotating turntable geometry uses a different geometry than traditional gantry based CT systems. In this work, metal artifact reduction algorithms used in traditional CT systems were compared in simulations and appear to work well for this geometry. An iterative reconstruction algorithm with a basic interpolation approach was implemented and, when iterated across all sinogram slices, also appears to reduce artifacts for a 3D CT dataset. The resulting surface generated from these images with reduced artifacts are smoother and more accurate, which is important when mapping optical signals onto these surfaces in the subsequent diffuse optical tomography reconstruction algorithms.

6 References

1) Fung et al., Proc SPIE 7961, Med Imaging 2011: Phys Med Imaging, 79613D2
2) Karimi et al., Med Phys 39 (2012) 5857-5868
3) Wei et al., Phys Med Biol 49 (2004) 5407-5418
4) Mazin et al., Am Assoc Phys Med Mtg 2009 SU-EE-A4-03
5) Oliveira et al., *VIIP, 2001.*

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