Implementing an exact algorithm for Helical CT:
Removing the cone-beam artefacts

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Introduction

3-dimensional computerised tomography is usually reconstructed using the naïve Feldkamp-Davis-Kress algorithm or FDK, which is not an exact reconstruction algorithm. This causes image errors, or artefacts that appear out of the central slice, and are especially visible near edges between horizontal layers - this is demonstrated in Figure 1.

To overcome these artefacts; one can perform multiple scans at different heights and combine the reconstructed volumes. However, exact reconstruction methods are necessary to remove them altogether. These algorithms will also reduce the scanning time which makes them very attractive. Such methods exist, and Alexander Katsevich provided an algorithm already in 2002[1]. His algorithm uses a helical scan-geometry, rotating the X-Ray source while moving it in parallel with the rotation axis - or, equivalently, scanning the object while rotating it and moving it parallel to its rotation axis. In this poster, we demonstrate that it is possible to perform and reconstruct such scans, with a Nikon XTEK scanner designed for circular scans.

Method

The helical scans were performed on a Nikon XTEK custom bay, with 1200 projections over just under two helical turns and a total vertical travel of 240mm. The sample consisted of aluminium and Perspex discs stacked on top of each other, and the scanner was programmed using Visual Basic macros, as explained in the poster by Parmesh Gajjar, et al. The reconstructions were performed using a modified version of the code Henry Tredgigo's used as his master's thesis[2], which is based on previous work by Adam Wunderlicht[3].

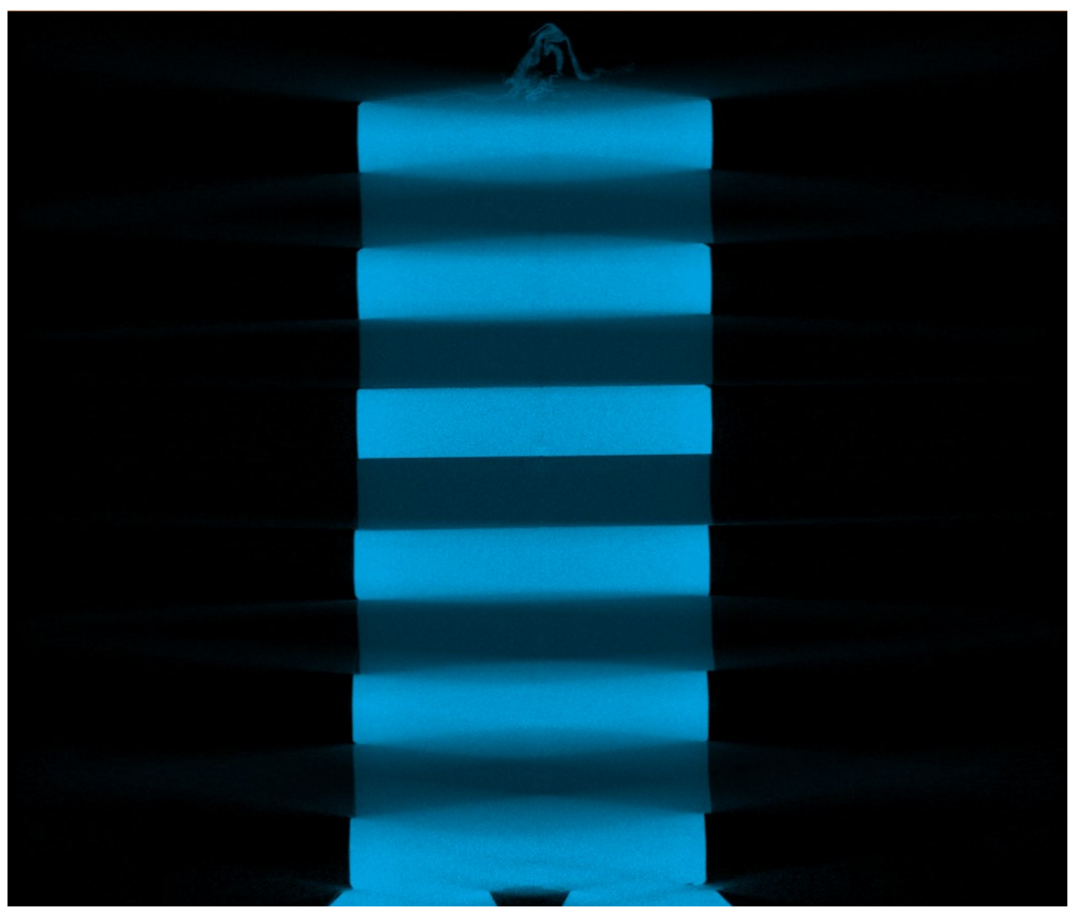

Figure 1: A vertical slice of a stack from a scan of Perspex and aluminium discs alternatingly stacked, reconstructed with FDK.

Helical artefacts

Katsevich's algorithm is an exact reconstruction algorithm, and will therefore remove the cone-beam artefacts, but this algorithm is unfortunately in some sense a double-edged sword. Figure 2 demonstrates that small errors in the geometry can have a detrimental effect. The artefacts seen in this figure comes from a scan with a helical radius (distance from X-Ray source to the scanned object) of 190mm, and the helical radius was wrong by 0.4mm and the cone-centre hit the detector about 3mm off centre.

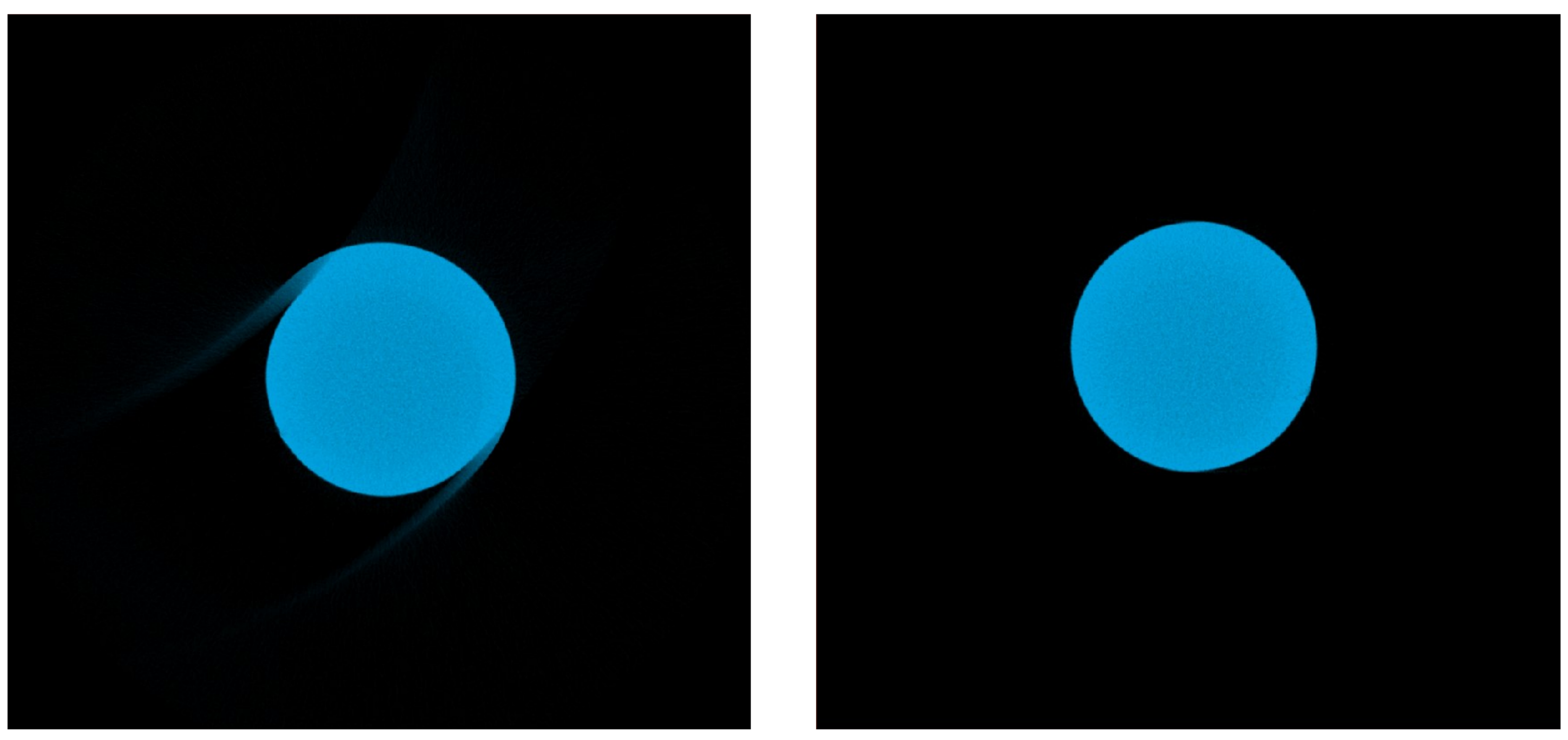

Figure 2: To the left: Horizontal slice with detector misaligned by about 3mm and a helical radius error of about 0.4mm. To the right: Horizontal slice with corrected geometry

Removing the artefacts

There is not any merit in performing helical scans if there are such big artefacts, and much effort was therefore put into finding methods of removing them. We found that the sensitivity in helical radius is only significant for high magnification, and we did not have to correct it much for scans with low magnification. The detector misalignment, however, was not dependent on magnification factor and had to be corrected in every scan. The misalignment can be digitally corrected, and we developed an algorithm that calculates the horizontal detector misalignment well and gives a good idea of the vertical detector misalignment.

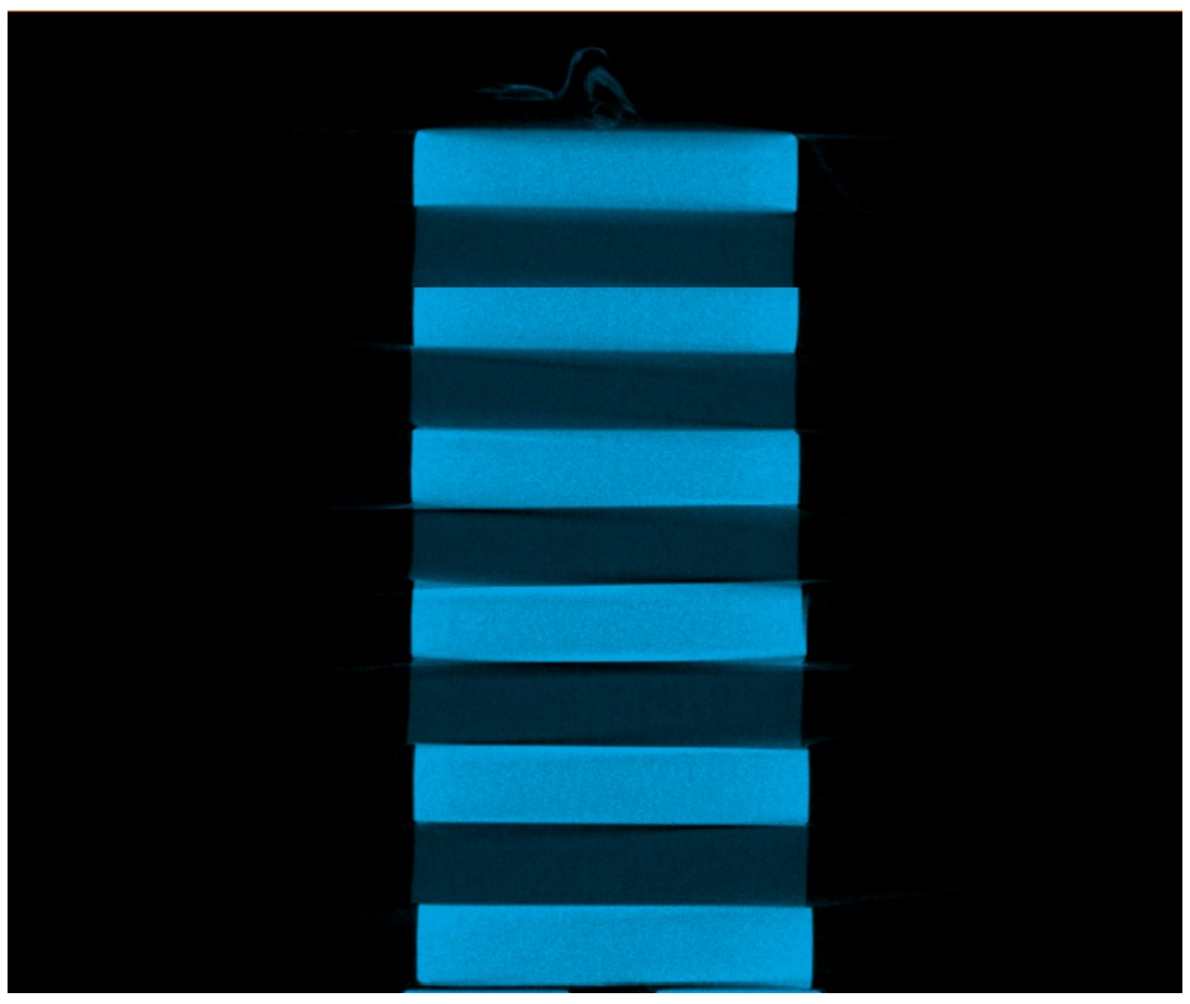

Figure 3: A vertical slice of a stack from a scan of Perspex and aluminium discs alternatingly stacked, reconstructed by Katsevich's algorithm with slightly wrong vertical detector shift.

Conclusion

Katsevich's algorithm is clearly superior to FDK, but implementing it on a scanner designed for circular CT scans posed some difficulties. These difficulties come from a high sensitivity to detector-screen alignment and, for high magnification, inaccurate helical radius, both of which creates unfortunate artefacts. We developed a method of automatically correcting the detector-screen placement, but further work is still needed to automate the helical radius correction.

References:

[1] Alexander Katsevich. Theoretically exact filtered backprojection-type inversion algorithm for spiral CT. *SIAM Journal on Applied Mathematics, 62(6):2012–2026, 2002.*

[2] Henry F.J. Tregidgo. The Implementation and analysis of Katsevich Reconstruction for helical CT. *MSc. thesis, The University of Manchester, 2013.*

[3] Adam. J. Wunderlich. The Katsevich Inversion Formula for Cone-Beam Computed Tomography. *MSc. dissertation, Oregon State University, 2006.21*