Characterizing and reducing artefacts
- caused by varying projection truncation

Leise Borg
Outline

1. Background
2. Analysis
3. Results
4. Discussion
5. Future work
Introduction

- Porous chalk samples of size $\sim 1 - 2$ mm.
- Monochromatic, parallel X-ray beam
- Micro-CT
Vendor reconstruction (a type of FBP)
Transmission sinogram

Figure: Transmission sinogram, $T \in [0, 0.53]$, and two zooms

$$T = \frac{l}{l_0}$$

Fraction of photons reaching the detector.
Experimental set-up
Experimental set-up
Characterizing and reducing artefacts

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Experimental set-up

university of copenhagen department of computer science

metal bar

no signal

signal

detector

metal bar

sample

metal bar

metal bar

metal bar

signal
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Transmission vs. regular sinogram

Figure: *Transmission sinogram*, $T \in [0, 0.53]$

- Physical interpretation of the smooth transitions
- Relation between transmission sinogram ($T$) and regular sinogram ($S$):

\[ S = -\log(T) = -\log\left(\frac{I}{I_0}\right) \]
Introduction of a threshold

Figure: Regular sinogram, $S \in [0, 1.43]$

- Physical interpretation of the smooth transitions
- Relation between transmission sinogram ($T$) and regular sinogram ($S$):

$$S = \begin{cases} 
0 & \text{if } -\log(T) > 1.43, \\
-\log(T) & \text{otherwise}
\end{cases}$$
Introduction of a threshold

Some of the data we don’t consider as being trustworthy due to scattering effects and some penetration of the metal bar. In the sinogram (S) there are now zeros where data is missing. This is also the case for standard LA-problems, such as in mammography. This is not considered a problem since back-projecting zeros adds nothing to the reconstruction.
Our reconstruction calculated by FBP
Vendor reconstruction
But where do the streaks come from?
Micro-local analysis

Singularities:

- are density jumps
- can be described by the tuple, \((x, \xi)\), where \(x\) is the singular position and \(\xi\) is the singular direction (normal to the edge).
- We can only expect to reconstruct singularities \((x, \xi)\), where \(\xi \in \phi\) (\(\phi\) is the angular range where data has been recorded)

\(^1\)Frikel, J and Quinto, E, T. ”Characterization and reduction of artifacts in limited angle tomography”, *Inverse Problems* (2013)
Micro-local analysis

Streaks:

- are caused by the limited-angle cut-offs in the sinogram
- emerge only from edges in the image
- have an angle perpendicular to cut-off angles in the sinogram
- can be reduced by smoothing the limited-angle cut-offs in the sinogram

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1 Frikel, J and Quinto, E, T. ”Characterization and reduction of artifacts in limited angle tomography”, Inverse Problems (2013)
Micro-local analysis - applied
Micro-local analysis - applied
Where do the streaks come from?
Probable solutions

- Micro-local analysis: Sinogram smoothing in the *angular direction*.
- Each of the tips have singularities in the detector direction: Sinogram smoothing in the *detector direction*.
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Smoothing - before

Images showing the effect of smoothing before and after processing.
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Smoothing - after

![Image of smoothed data](image-url)
Smoothing - before
Smoothing - after
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Smoothed vs. unsmoothed
Smoothed vs. standard LA
Smoothed vs. vendor

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Smoothing in detector direction:
- Removes streak artefacts
- Does not handle overexposure in the parts of the image where extra data is present
Comparison between FBP and Cimmino

Figure: FBP reconstruction.
Comparison between FBP and Cimmino

Figure: Cimmino. Zeros in sinogram.
Comparison between FBP and Cimmino

Figure: Cimmino. Rows removed.
Comparison between FBP and Cimmino

Figure: Cimmino. Rows removed, nonneg. constr.
Comparison between FBP and Cimmino

- Overexposition is handled by the algebraic method.
- Zeros in a sinogram do not represent missing data. This is not an issue in standard limited-angle problems. But for the special limited-angle problem, it is.
- However, time and space matters.
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What we did:

Mapping of values above threshold $c_S$ (below $c_T$):

- Zeros do not represent missing data
- Removed the inherent (wanted!) smoothness

$$S = \begin{cases} 
0 & \text{if } -\log(T) > c_S, \\
-\log(T) & \text{otherwise}
\end{cases}$$
So let’s take a step back:

**Figure**: Transmission sinogram, $T \in [0, 0.53]$

First order Taylor of $-\log$ around 1:

$$-\log(x) \sim 1 - x$$
Preliminary results: Taylor expansion

Figure: First order Taylor of -log around 1 (leaving out the constant terms): $-\log(x) \sim 1 - x \rightarrow -x$
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Thanks for listening :)
Taylor expansion
Smoothing