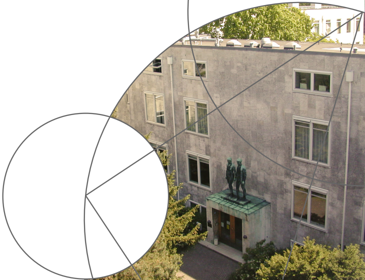
Faculty of Science

Characterizing and reducing artefacts

- caused by varying projection truncation

Leise Borg

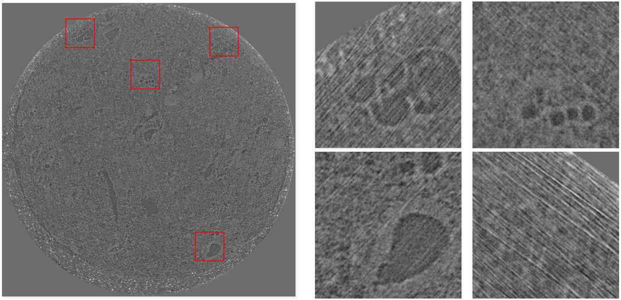


Outline

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

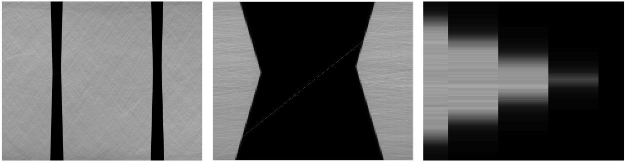
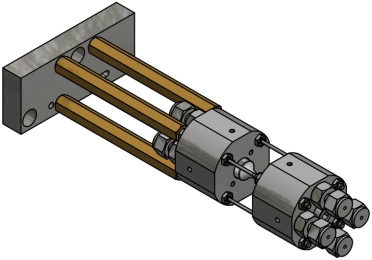


Figure: *Transmission sinogram, $T \in [0, 0.53]$, and two zooms*

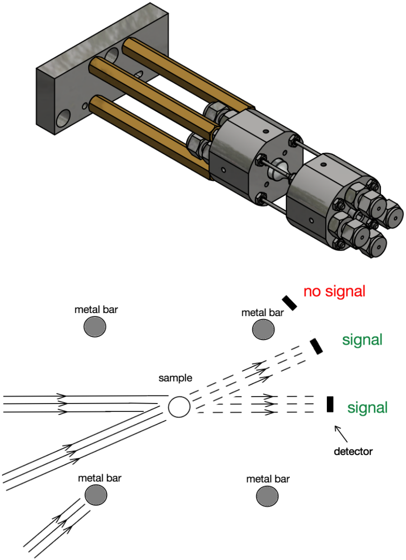
$$T = \frac{I}{I_0}$$

Fraction of photons reaching the detector.

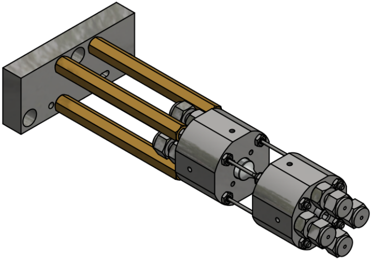
Experimental set-up

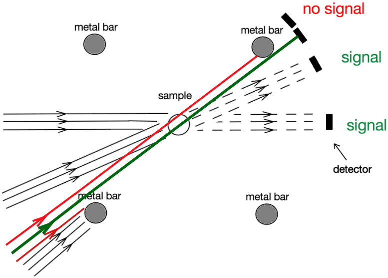


Experimental set-up



Experimental set-up





Outline

Transmission vs. regular sinogram

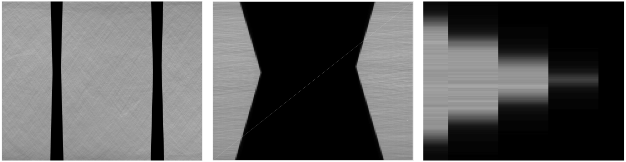


Figure: *Transmission sinogram, $T \in [0, 0.53]$*

- 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

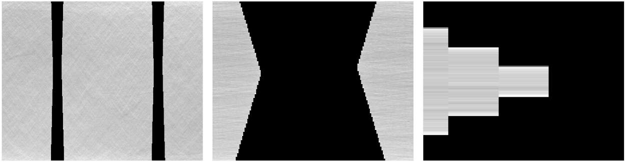


Figure: *Regular sinogram, $S \in [0, 1.43]$*

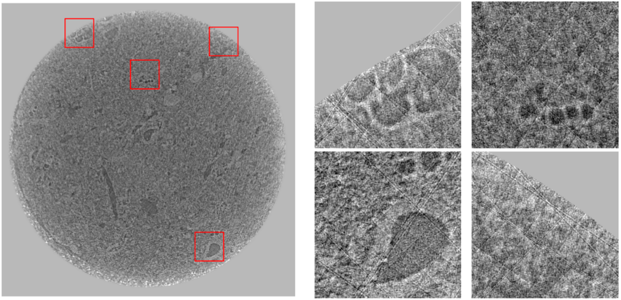
- Physical interpretation of the smooth transitions
- Relation between transmission sinogram (T) and regular sinogram (S):

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

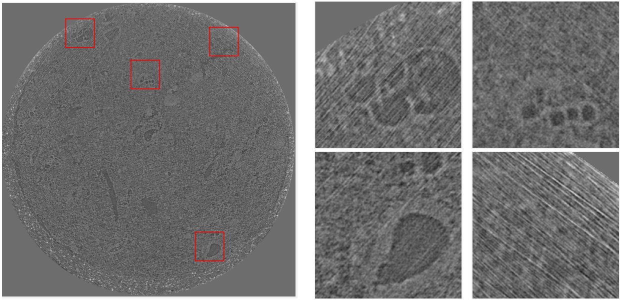
Introduction of a threshold

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

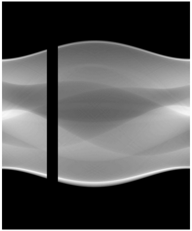


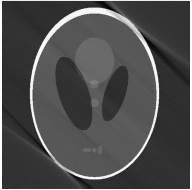
But where do the streaks come from?

Micro-local analysis[1]

Singularities:

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



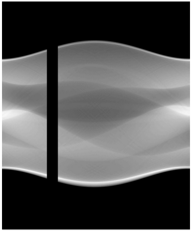


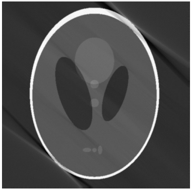
[1]Frikel, J and Quinto, E, T. "Characterization and reduction of artifacts in limited angle tomography", *Inverse Problems* (2013)

Micro-local analysis[1]

Streaks:

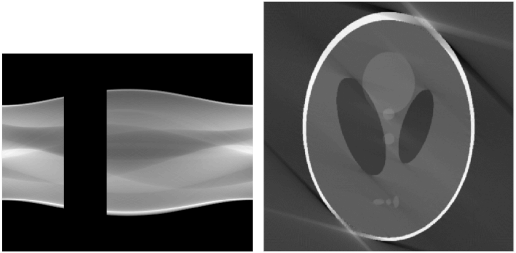
- are caused by the limited-angle cut-offs in the sinogram
- emerge only from edges in the image
- have an angle perpencicular to cut-off angles in the sinogram
- *can be reduced by smoothing the limited-angle cut-offs in the sinogram*



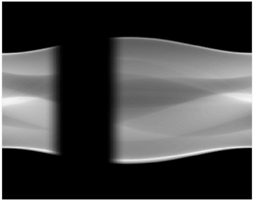


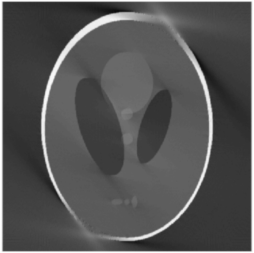
[1]Frikel, J and Quinto, E, T. "Characterization and reduction of artifacts in limited angle tomography", *Inverse Problems* (2013)

Micro-local analysis - applied

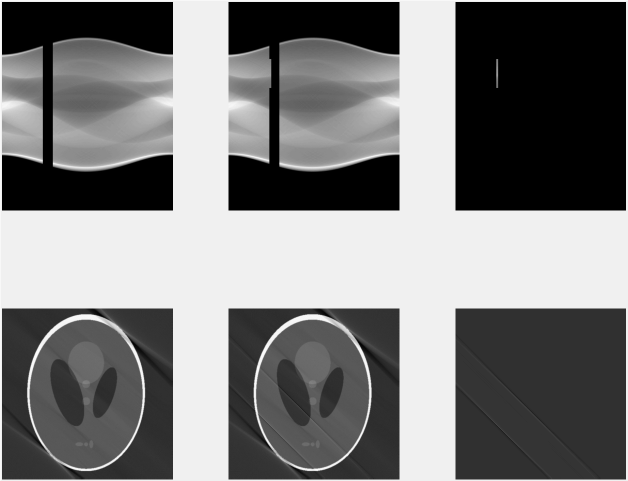


Micro-local analysis - applied





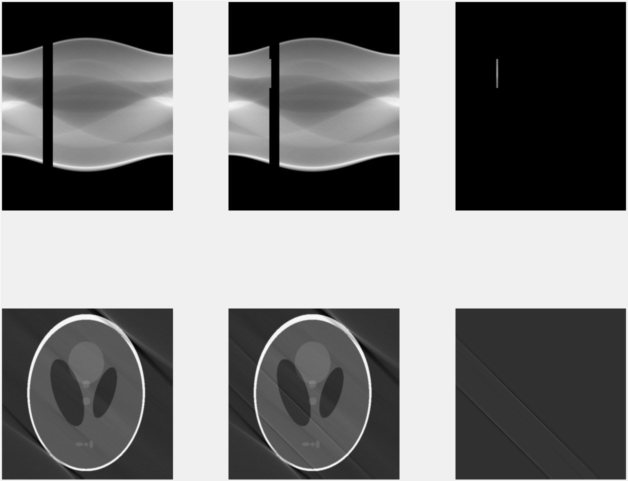
Where do the streaks come from?



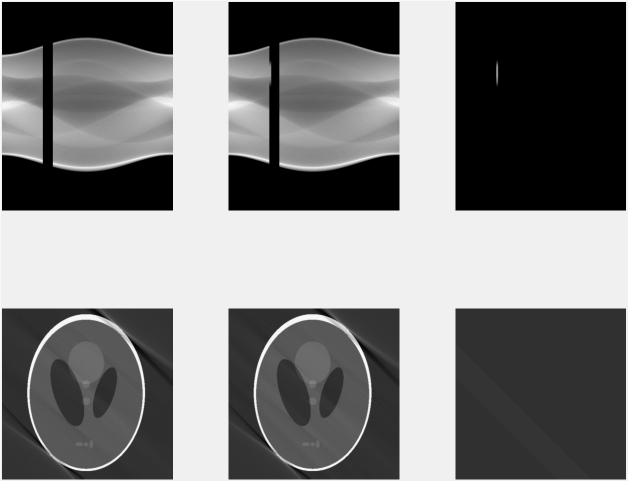
Probable solutions

- 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*.

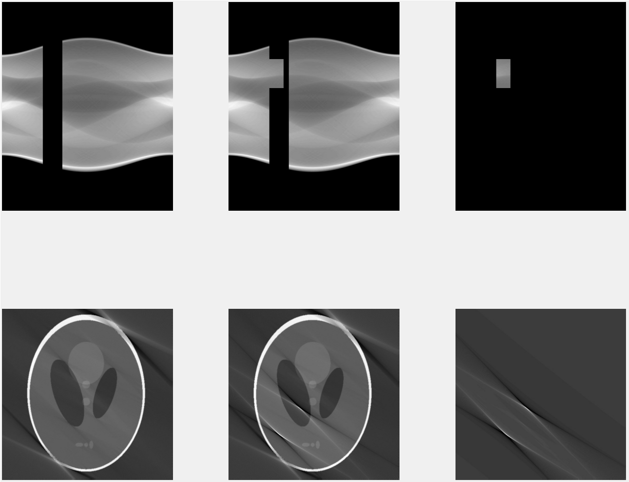
Smoothing - before



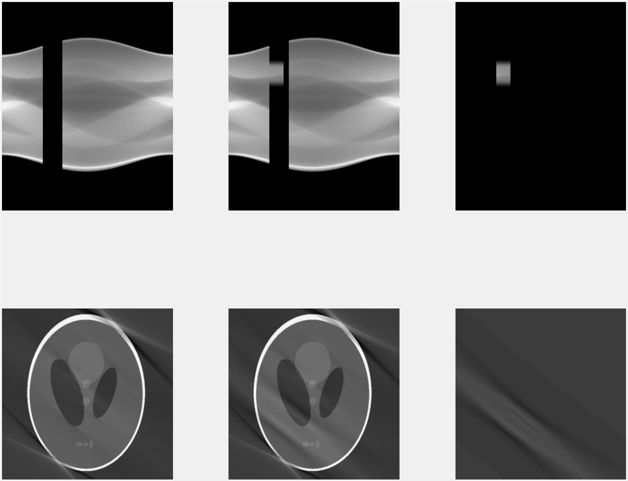
Smoothing - after



Smoothing - before

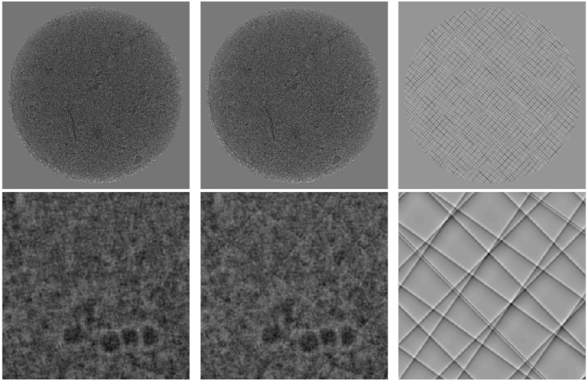


Smoothing - after

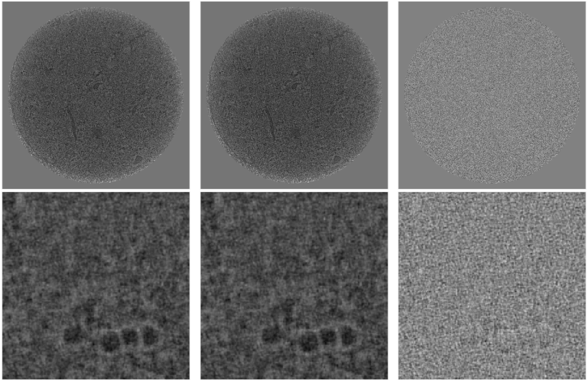


Outline

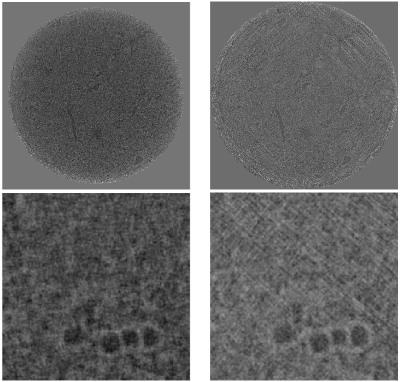
Smoothed vs. unsmoothed



Smoothed vs. standard LA



Smoothed vs. vendor



Outline

Discussion

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

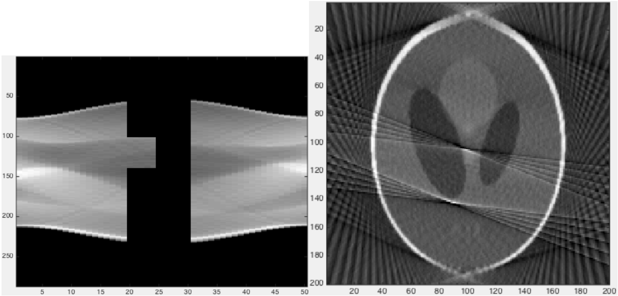


Figure: FBP reconstruction.

Comparison between FBP and Cimmino

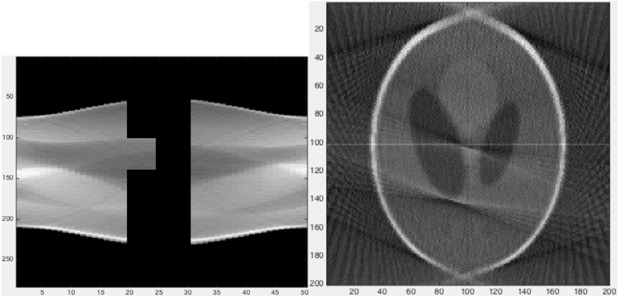


Figure: Cimmino. Zeros in sinogram.

Comparison between FBP and Cimmino

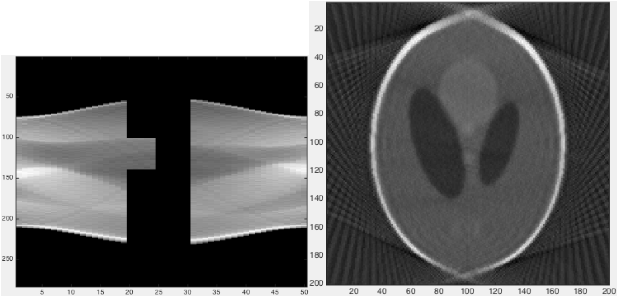


Figure: Cimmino. Rows removed.

Comparison between FBP and Cimmino

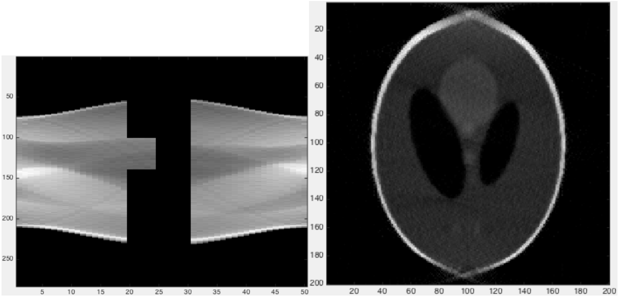


Figure: Cimmino. Rows removed, nonneg. constr.

Comparison between FBP and Cimmino

- Overexposion 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.

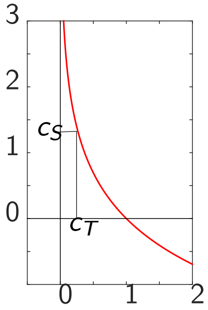
Outline

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:

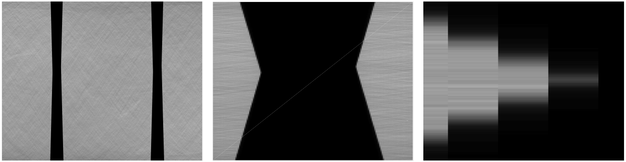


Figure: *Transmission sinogram,* $T \in [0, 0.53]$

First order Taylor of -log around 1:

$$-\log(x) \sim 1 - x$$

Preliminary results: Taylor expansion

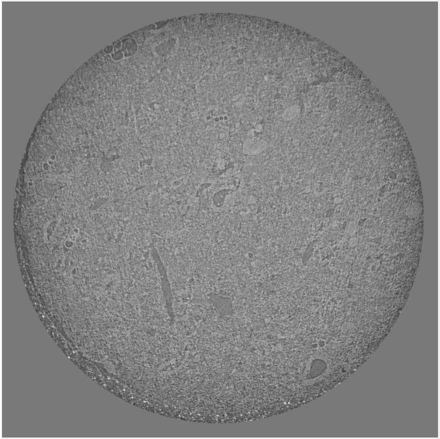
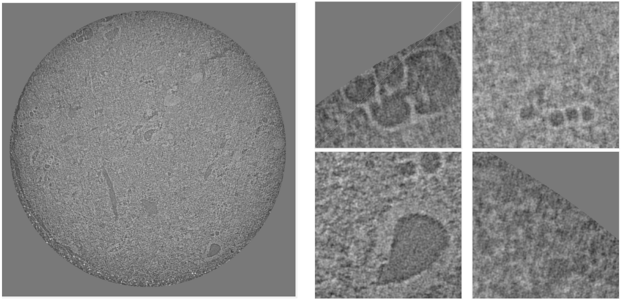


Figure: First order Taylor of -log around 1 (leaving out the constant terms): $-\log(x) \sim 1 - x \to -x$

Thanks for listening :)

Taylor expansion



Smoothing