PAUL SCHERRER INSTITUT

Anders Kaestner :: Paul Scherrer Institut

Introduction to Computed Tomography

Part VI: Artifacts

PAUL SCHERRER INSTITUT

Outline

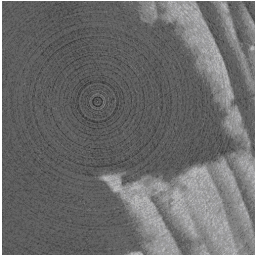
Lecture objectives

- Identify different types of image artifacts.
- Understand their origin and how to correct them.

Common artefacts

- **Rings** are caused by stuck or dead pixels. They have the same value for all projections
- **Lines** are caused by single pixels or groups pixels in a single projection
- **High contrast** these artifacts appear as star-like streaks originating from the high contrast object.
- **Motion** when the sample changes during acquisition.
- **Beam hardening** Polychromatic beam
- **Scattering** The beam is scattered

Ring artifacts



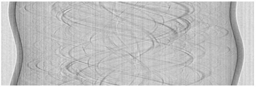
- Ring artefacts are very common in tomography.
- They are caused by a stuck, dead, or hot pixels.
- They appear as:
    - Lines in the sinogram
    - Concentric rings in the CT slices

Correction in the Radon space

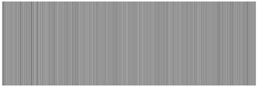
Projections Identify and remove spots that persists through projections.

Sinograms Identify lines parallel to the θ-axis

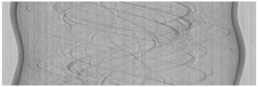
- Subtract first derivative of average projection form sinogram.
- Filter sinogram in Fourier domain (notch filter or wavelet filter).



$-$



$=$



$$\underbrace{s(u,\theta)} - \underbrace{\mathbf{1}^T \cdot (E_u[s] - median_N(E_u[s]))} = $$

Correction in the matrix

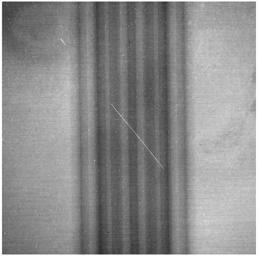
Correction procedure:

- Transform matrix to polar coordinates
- Detect lines
- Make replacement map
- Transform map to Carthesian coordinates
- Correct matrix

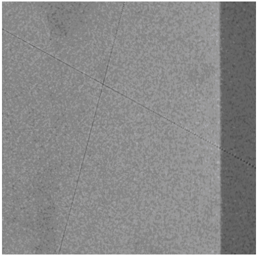
Advantage Good for testing different strengths

Disadvantage The coordinate transformations

Line artifacts



Projection



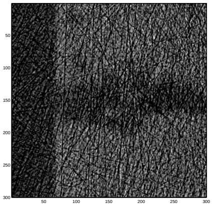
Reconstructed slice

- Line artifacts are more common with neutrons
- The origin of a line is a local spot in the sinogram.
- The orientation and position depends on when the spot was registered.

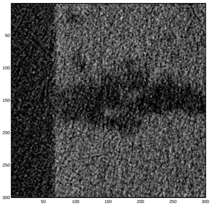
Correction of the lines

Correction method

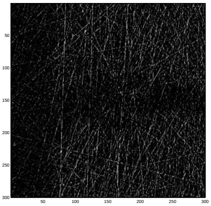
- Detect the spots on the projections – compute local variances
- Replacement *e.g.*
  $p_{corrected} = w(\sigma) \cdot p + (1 - w(\sigma)) \cdot p_{median}$ with $0 \leq w \leq 1$



Raw

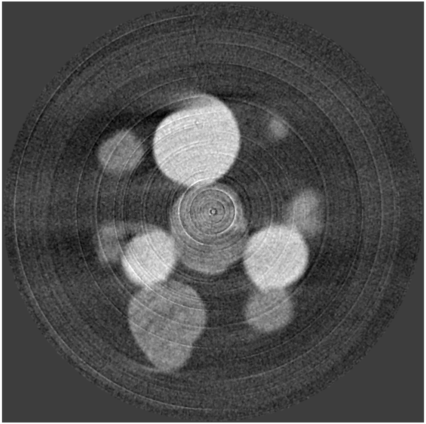


Corrected

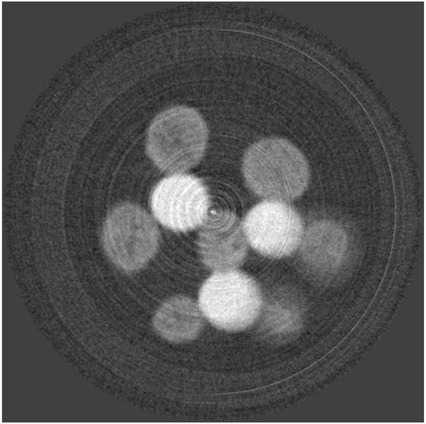


Difference

Motion artifacts



Sequential acquisition



Golden ratio acquisition

Suppressing the effect of motion

Dynamic processes are hard to observe with CT

- CT needs long scan times.
- If the interfaces move more than 1 pixel during the scan motion artifacts will appear.

The solution

- Increment the acquisition angle by the Golden ratio $\phi = \frac{1+\sqrt{5}}{2}$
- The sample will always be observed at ’orthogonal’ angles.

[Köhler, 2004, Kaestner et al., 2011]

Cupping

Definition

Cupping is a phenomenon that appears as a drop of attenuation coefficients in large homogeneous bodies. The main origins are:

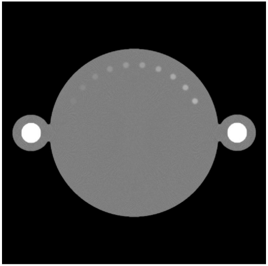
Beam hardening
: when the radiation attenuation depends on energy.

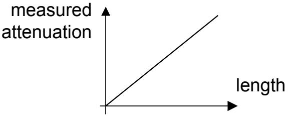
Scattering
: background scattering adds a bias.

Cupping due to Beam hardening

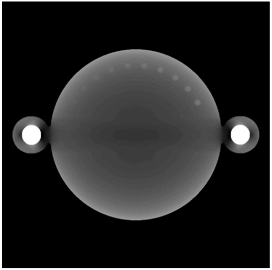
The attenuation depends on energy

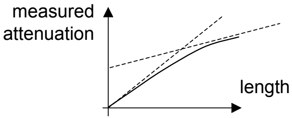
Monochromatic





Polychromatic



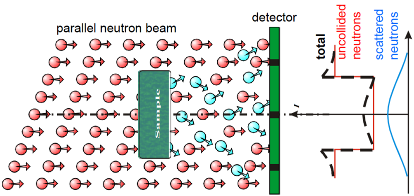


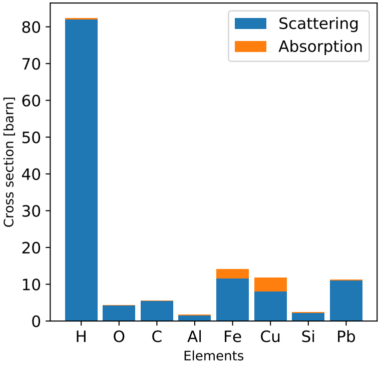
Attenuation for neutrons

The attenuation law assumes the intensity to be absorbed. . .

This is not true for neutrons!!!

Most neutrons are scattered

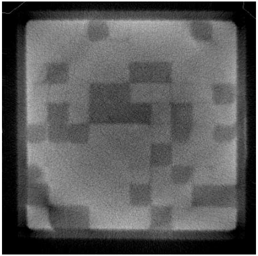




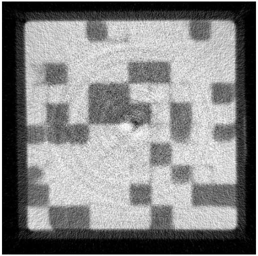
Background and sample scattering

Scattered neutrons are bad for

- Quantitative imaging
- Segmentation algorithms



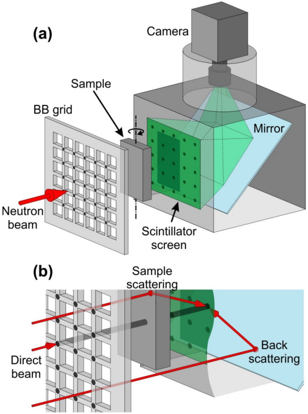
Uncorrected



Corrected by QNI [Hassanein, 2006]

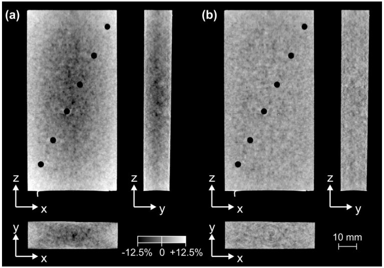
Scattering correction next generation

Measurements



Correction and result

- Estimate scattering profile using black bodies.
- Correction using revised projection normalization

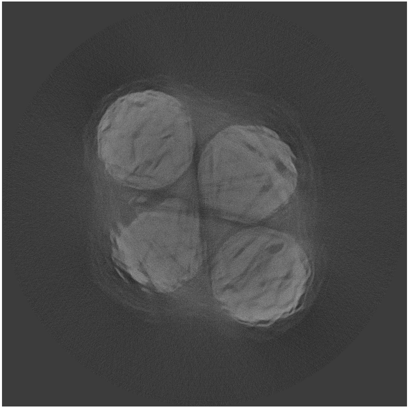


[Boillat et al., 2018]

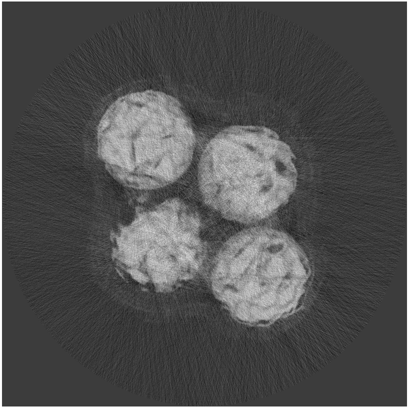
Demonstrating the effect of BB correction

Samples: Cylinders of bone. Scanned at ICON.

Normalized



Scatter corrected with BB



Data courtesy of E. Törnquist, Lund University

Summary

- Artifacts are a natural part of an imaging experiment
- By knowing their origin, they can be
  - avoided
  - corrected/suppressed

References I

Boillat, P., Carminati, C., Schmid, F., Grünzweig, C., Hovind, J., Kaestner, A., Mannes, D., Morgano, M., Siegwart, M., Trtik, P., Vontobel, P., and Lehmann, E. (2018).
Chasing quantitative biases in neutron imaging with scintillator-camera detectors: a practical method with black body grids.
Optics Express, 26(12):15769.

Hassanein, R. (2006).
Correction methods for the quantitative evaluation of thermal neutron tomography.
Diss. eth no. 16809, Swiss Federal Institute of Technology.

Kaestner, A., Münch, B., Trtik, P., and Butler, L. (2011).
Spatio-temporal computed tomography of dynamic processes.
Optical Engineering, 50(12):123201.

Köhler, T. (2004).
A projection access scheme for iterative reconstruction based on the golden section.
In *Nuclear Science Symposium Conference Record*, volume 6, pages 3961–3965. IEEE.