Medical Image Processing for Diagnostic Applications

Fan Beam – Truncation Correction

Online Course – Unit 42

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Topics

Truncation Correction Algorithms

- Defect Pixel Extrapolation
- Heuristic Extrapolation
- Water Cylinder Assumption
- Use of Prior Knowledge
- Use of a Semi-transparent Filter
- ATRACT Filtering

Summary

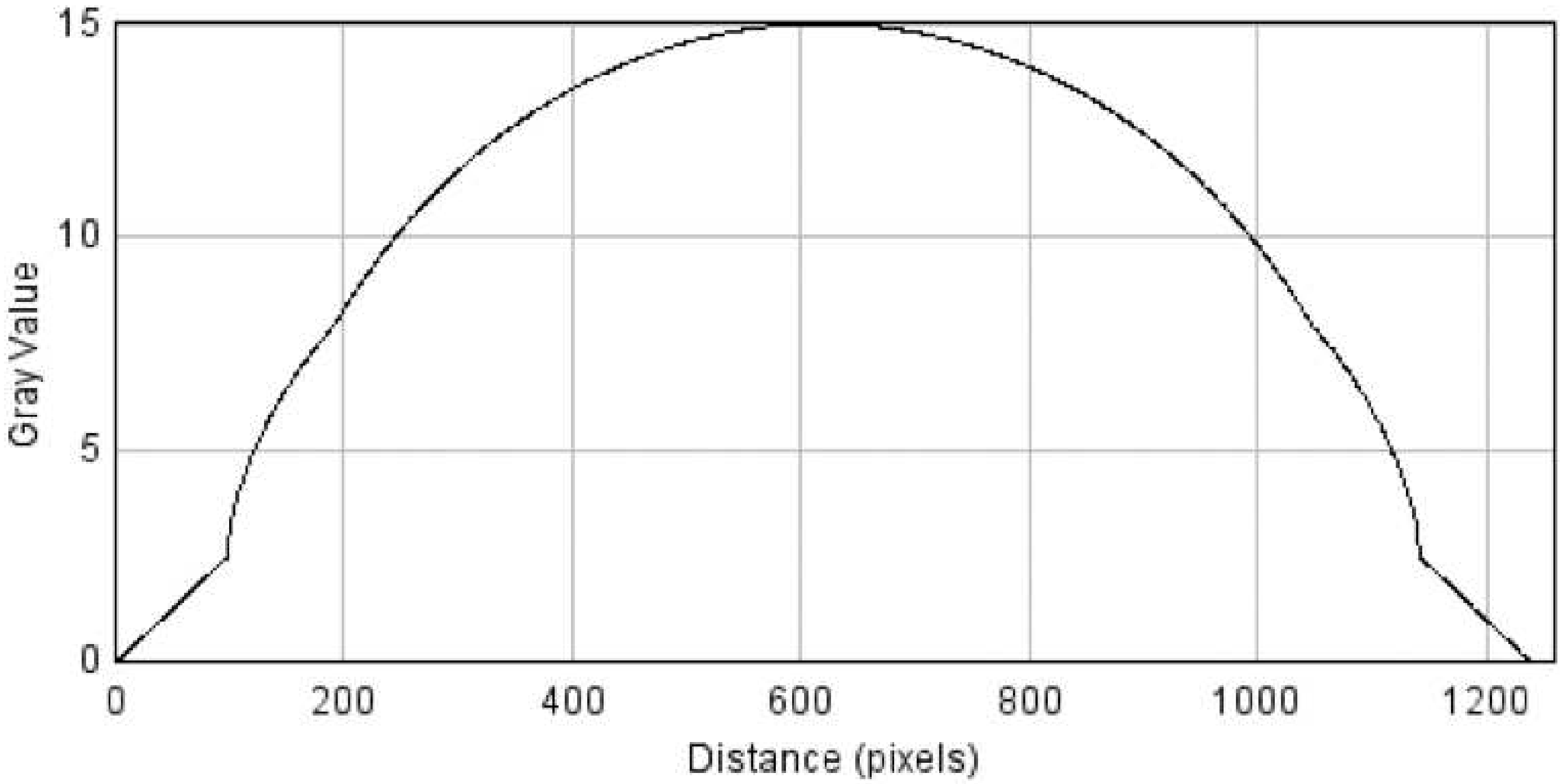
- Take Home Messages
- Further Readings

Truncation Correction via Extrapolation

- Solution 1: Defect pixel extrapolation
- Solution 2: Heuristic extrapolation
- Solution 3: Water cylinder assumption
- Solution 4: Use of prior knowledge
- Solution 5: Use of a semi-transparent filter
- Solution 6: ATRACT filtering

Defect Pixel Extrapolation

- Model extrapolation as deconvolution.
- Use a defect pixel interpolation algorithm.



→ Unfortunately, the algorithm works not as well as expected.

Heuristic Extrapolation

- Use mirroring for extrapolation.
- In order to enforce a limited size of the object, a cosine-like weighting is added.

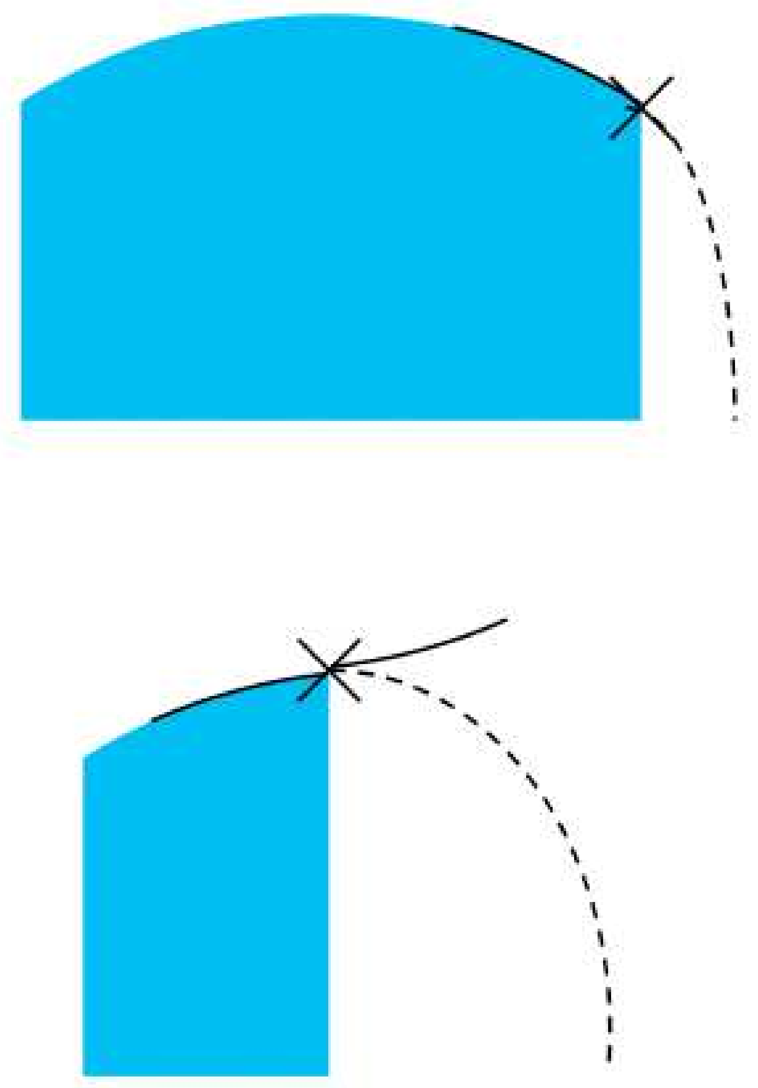


Figure 1: Heuristic extrapolation scheme

B. Ohnesorge et al. "Efficient Correction for CT Image Artifacts Caused by Objects Extending Outside the Scan Field of View". In: *Medical Physics* 27.1 (Oct. 2000), pp. 39–46. DOI: 10.1118/1.598855

Heuristic Extrapolation

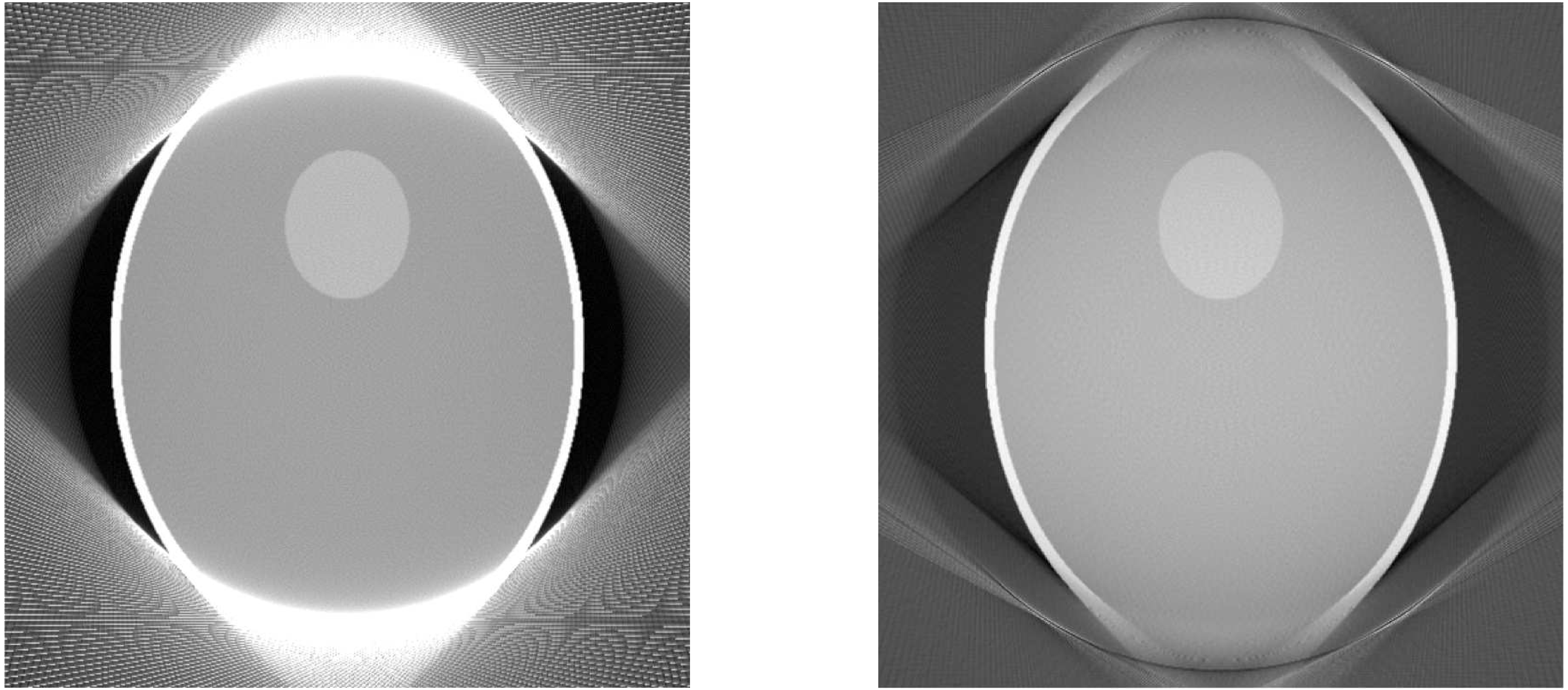


Figure 2: Heuristic extrapolation applied on a phantom

B. Ohnesorge et al. "Efficient Correction for CT Image Artifacts Caused by Objects Extending Outside the Scan Field of View". In: *Medical Physics* 27.1 (Oct. 2000), pp. 39–46. DOI: 10.1118/1.598855

Water Cylinder Assumption

- Assume that the imaged object consists of water ($\rho = \rho_{H_2O}$).
- Fit water cylinder model to observed data

$$g(\gamma) = 2\rho_{H_2O}\sqrt{R^2 - D^2 \sin^2 \gamma}.$$

- Use model to extrapolate.

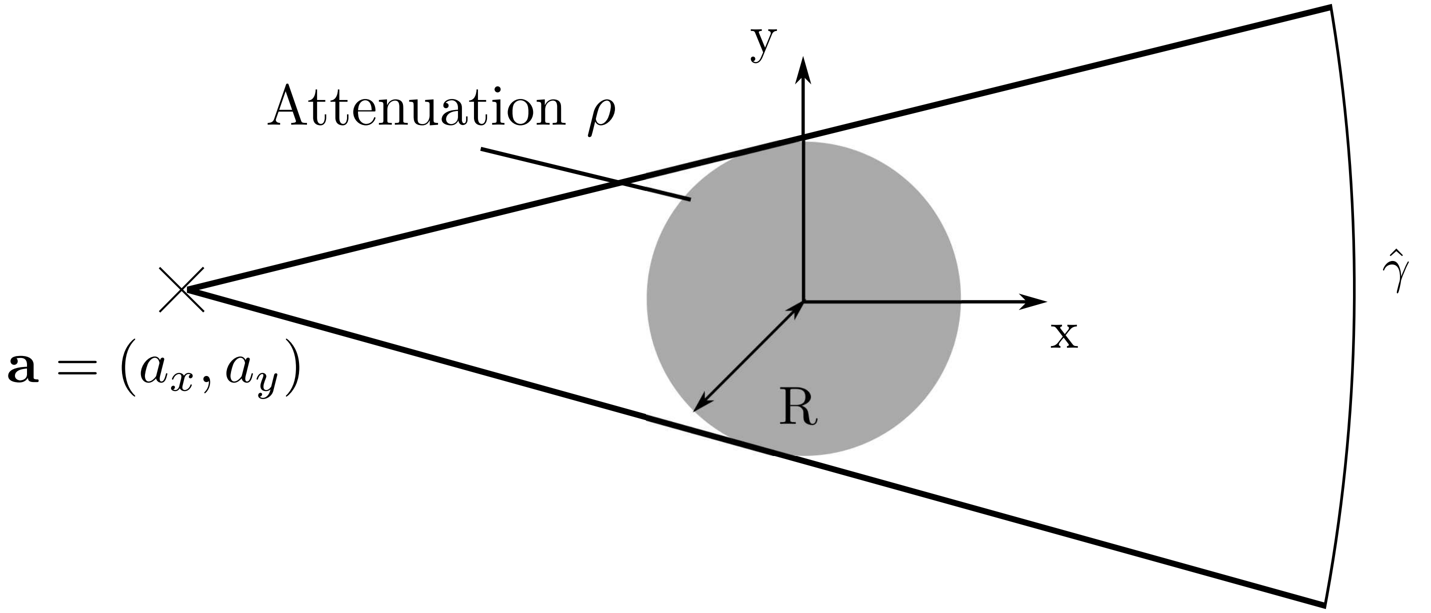


Figure 3: Assume the object to have a shape very similar to a water cylinder.

Water Cylinder Assumption

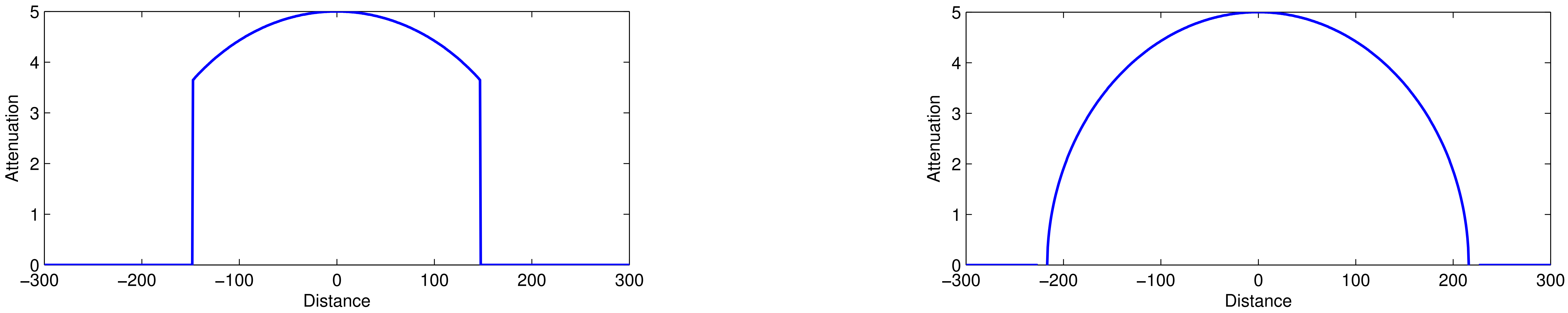


Figure 4: Extrapolate by assuming cylindric shape.

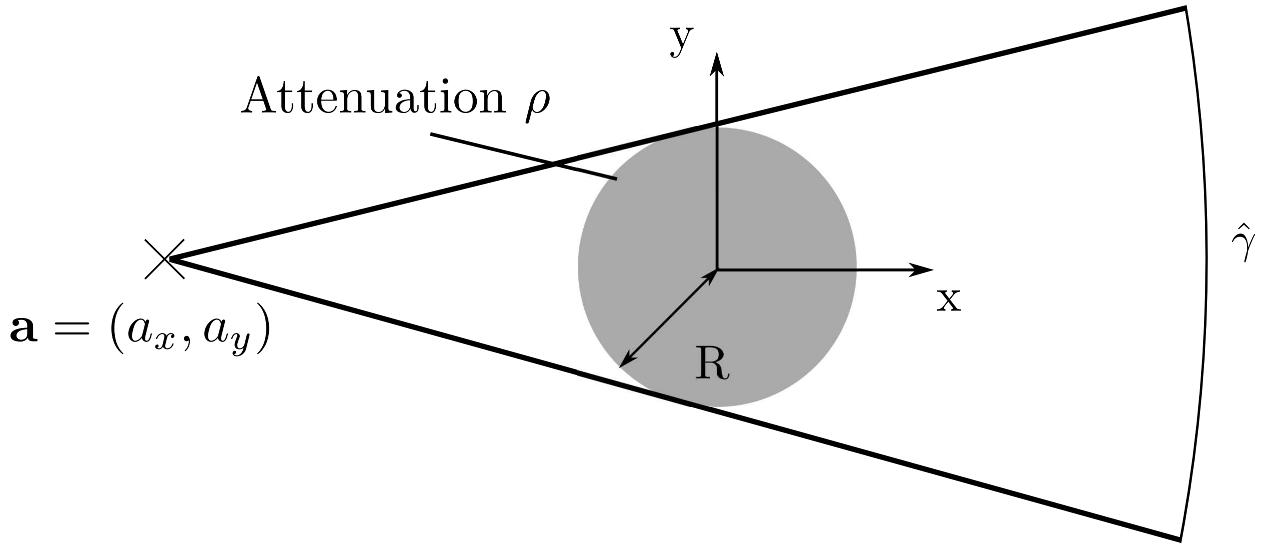
Water Cylinder Assumption

This approach ...

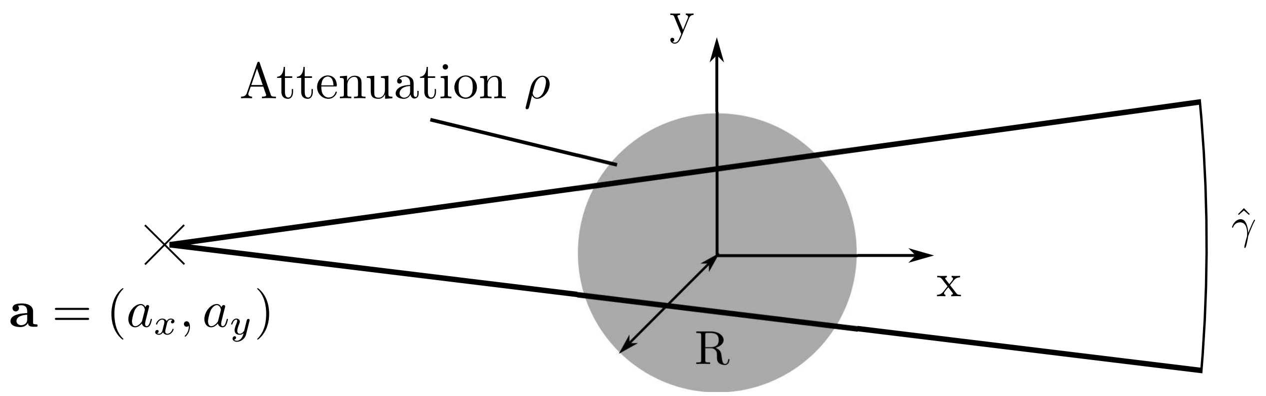
- ... will work perfectly if a water cylinder is imaged.
- ... yields good results for most objects (head, abdomen, etc...).
- ... will yield suboptimal results if the water cylinder assumption is violated (e. g., two cylinders).
- Different versions exist:
  - water ellipsoid assumption,
  - combination with cosine-like roll-off.

Use of Prior Knowledge

Prior scan (low dose)



Volume-of-interest scan (higher dose)



Use of Prior Knowledge

- Use data from a first scan to complete the data from a second scan.
- Correction will be perfect if the object did not change.
- One might also use a lower resolution prior scan.
- Movement and deformation of the object have to be compensated.
- This approach is only applicable if a prior scan exists.

Semi-transparent Filter

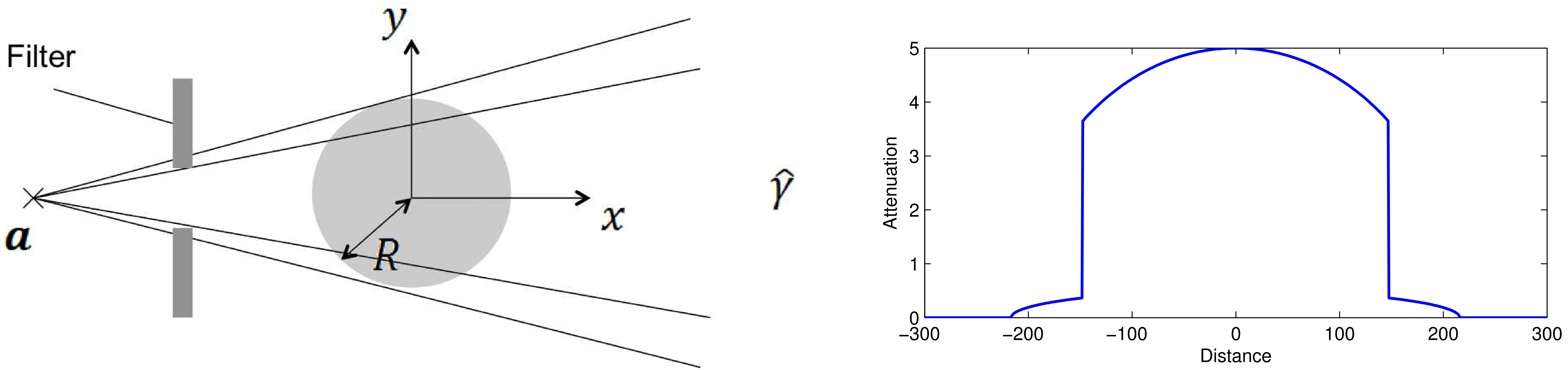


Figure 5: Scheme of a semi-transparent filter: setup (left) and example of a projection result (right)

Semi-transparent Filter

- Locate filter boundary.
- Amplify filtered signal to original amplitude.
- Reduce noise in the amplified signal.

$\rightarrow$ This yields perfect truncation correction.

Semi-transparent Filter

Challenges:

- Filter boundary must be located correctly (which may be influenced by the object).
- Correct amplification factor has to be estimated.
- Method has to be applied carefully in order not to introduce artificial high frequencies.
- Requires additional hardware in the scanner.

ATRACT

Idea:

$$|\omega| = 2\pi i\omega \cdot \left(-\frac{1}{2\pi} i\,\mathrm{sgn}(\omega)\right) = (2\pi i\omega)^2 \cdot \left(-\frac{1}{4\pi^2} i \frac{\mathrm{sgn}(\omega)}{\omega}\right)$$

The first term is the 2nd order derivative (local), and the right is called residual filter (global).
At the truncation boundaries the 2nd derivative produces a sparse signal. The resulting peaks are filled with zero and then the global filter is applied.

Remark: Without further considerations this does not preserve the mean value.

Topics

Take Home Messages

- Truncation artifacts can be dealed with by extrapolating the projection data at the truncation boundaries.
- We have learned about six methods, which basically divide into
  - estimation of the truncated part,
  - incorporating prior knowledge from earlier scans, or
  - a special hardware setup.
  - filtering during reconstruction.

Further Readings

Helpful reads for the current unit:

B. Ohnesorge et al. "Efficient Correction for CT Image Artifacts Caused by Objects Extending Outside the Scan Field of View". In: *Medical Physics* 27.1 (Oct. 2000), pp. 39–46. DOI: 10.1118/1.598855

Frank Dennerlein and Andreas Maier. "Approximate Truncation Robust Computed Tomography–ATRACT". In: *Physics in Medicine and Biology* 58.17 (Aug. 2013), pp. 6133–6148. DOI: 10.1088/0031-9155/58/17/6133

Yan Xia et al. "Scaling Calibration in Region of Interest Reconstruction with the 1D and 2D ATRACT Algorithm". In: *International Journal for Computer Assisted Radiology and Surgery* 9.3 (May 2014), pp. 345–356. DOI: 10.1007/s11548-014-0978-z

L. A. Shepp and Logan B. F. "The Fourier Reconstruction of a Head Section". In: *IEEE Transactions on Nuclear Science* 21.3 (June 1974), pp. 21–43. DOI: 10.1109/TNS.1974.6499235

W. P. Segars et al. "Realistic CT Simulation Using the 4D XCAT Phantom". In: *Medical Physics* 35.8 (Aug. 2008), pp. 3800–3808. DOI: 10.1118/1.2955743