Deep Learning-Based Scatter Correction for Dual Source Dual Energy CT

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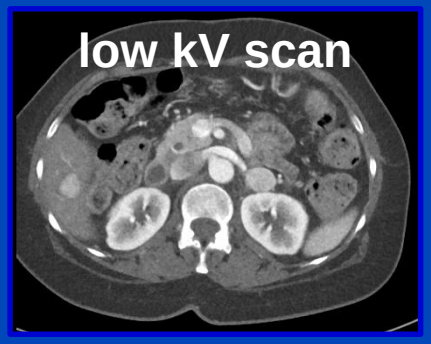
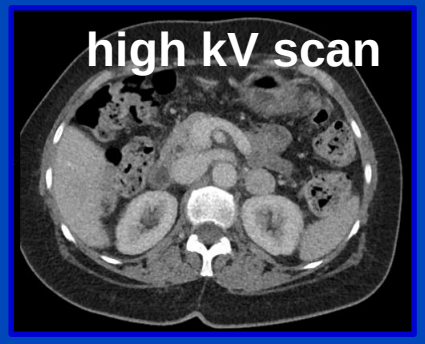
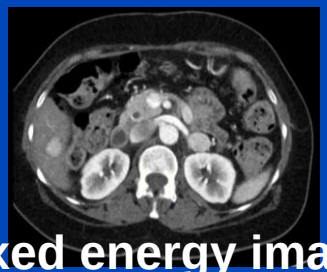
Dual Energy in Dual Source CT (DSCT)

- Dual Source CT (DSCT) uses two measurement systems A and B
- Dual Energy CT (low and high energy image) :
  - Different attenuation (HU) of materials at different energies enable material decomposition and characterization to create different image sets like Virtual Non Contrast (VNC), Iodine Maps or monoenergetic images with additional diagnostic information.

Acquisition of low and high energy image …





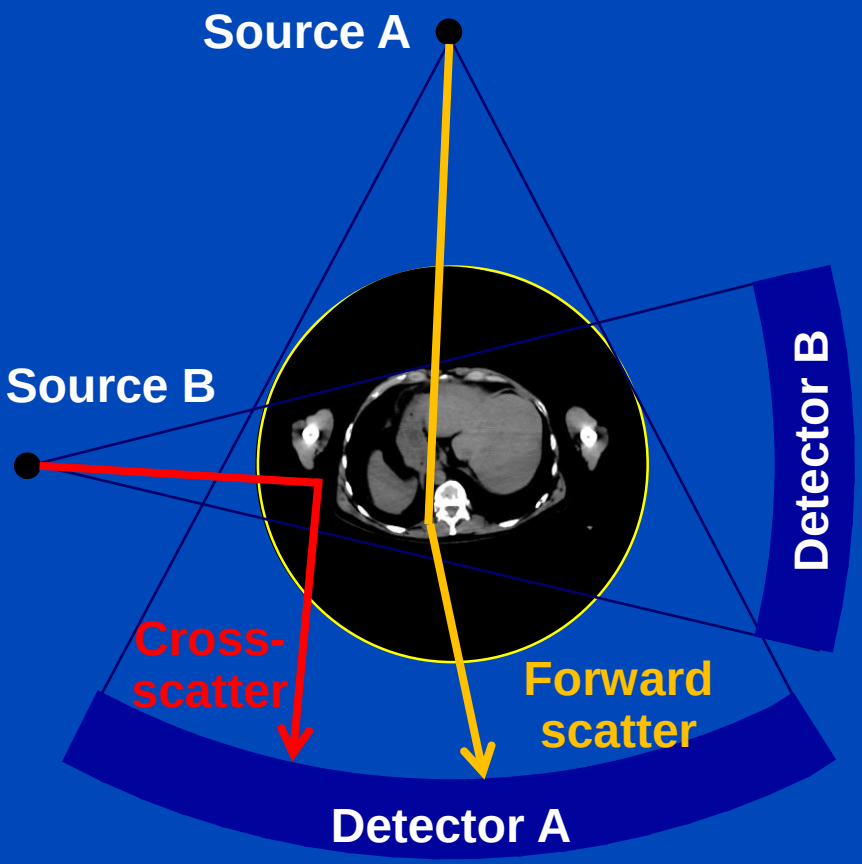

Mixed energy image


VNC

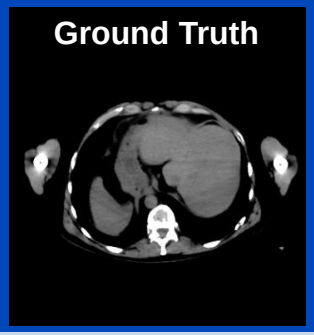

Iodine map overlay

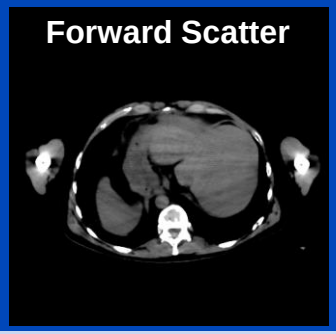
… which can be reconstructed in different ways

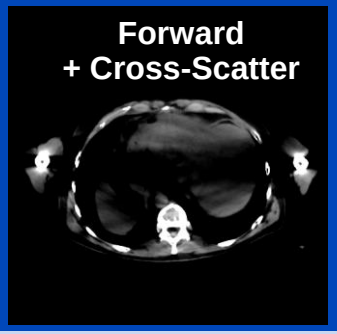
Scatter in DSCT



- Scatter in dual source CT: forward and cross-scatter
- Leads to visible cupping artifacts and dark streaks
- Scatter can not only produce visible artifacts, but can also lead to shift of measured CT values
- Scatter correction is necessary to maintain the accuracy of CT-measurement







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C = 40 HU, *W* = 300 HU, with anti-scatter grid

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Deep Scatter Estimation (DSE) for Dual Source CT

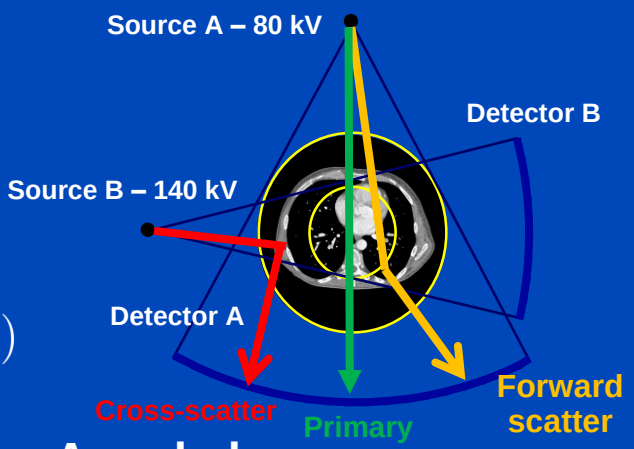
- Neural networks are trained to learn Monte Carlo scatter intensities
- Two separate deep convolutional neural networks (CNN) to correct forward and cross-scatter
- Forward scatter: Deep CNN to predict scatter using a function of the aquired projection data (fDSE[1,2])
- Cross-scatter: Deep CNN with an additional cross-scatter approximation (xDSE xSSE[2]) to maintain high robustness of scatter estimation
- For the cross-scatter approximation an initial non-scatter corrected reconstruction is computed and the interactions of X-rays with matter are simulated through volume raytracing[2]
- Neural networks are trained for the combination A: 80 kV, B: 140 kV

[1] Maier, Kachelrieß et al. Med Phys. 2019 Jan;46(1):238-249. doi: 10.1002/mp.13274. Epub 2018 Nov 26.
[2] Erath, Kachelrieß et al. Deep Scatter Correction in DSCT, CT Meeting August 2020.

Scatter in Dual Energy Mode

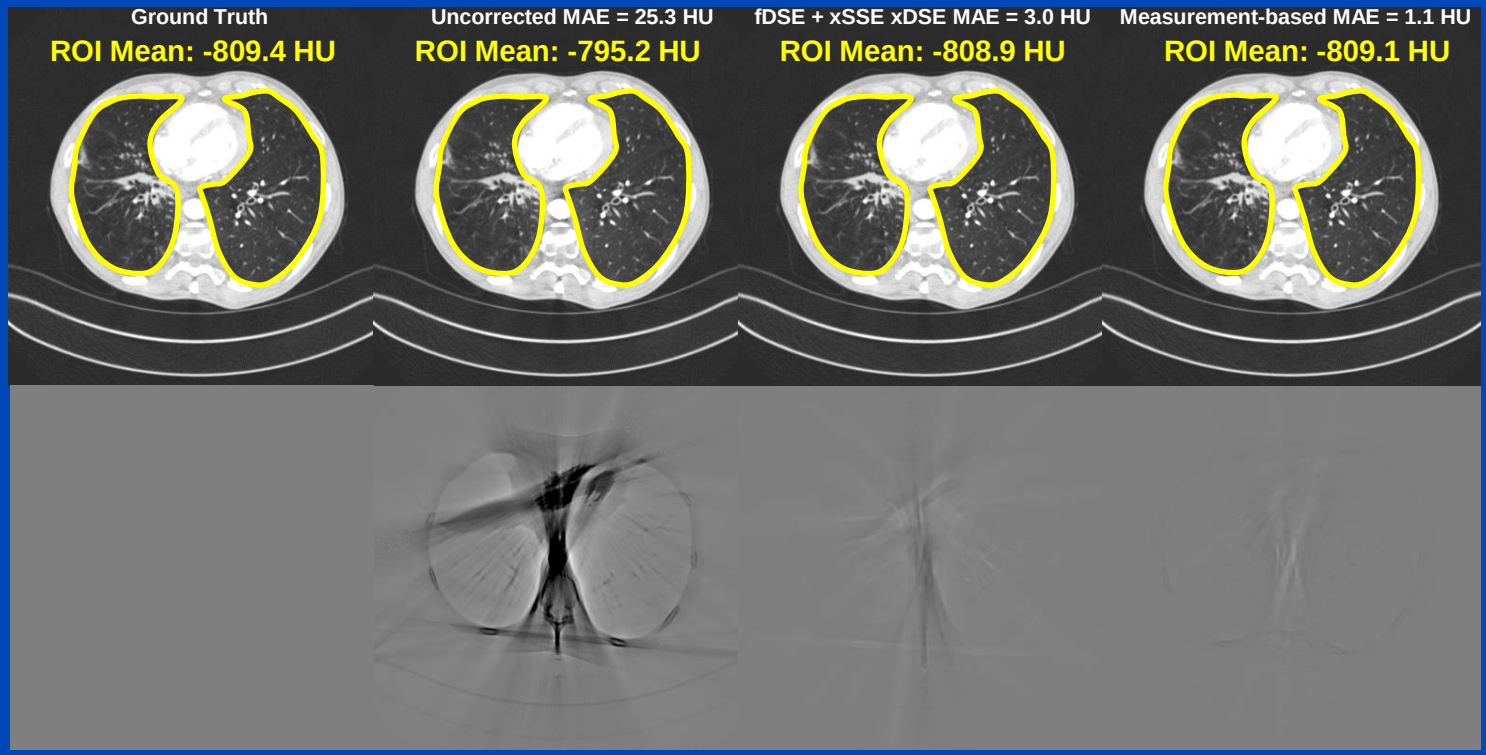
- Combination tube A: 80 kV, tube B: 140 kV
- Measured signal at detector A:

$$p = -\ln\left(\frac{I_{\text{primary}}}{I_0} + \frac{I_{\text{forward-scatter}}}{I_0} + \rho \cdot \frac{I_{\text{cross-scatter}}}{I_0}\right)$$



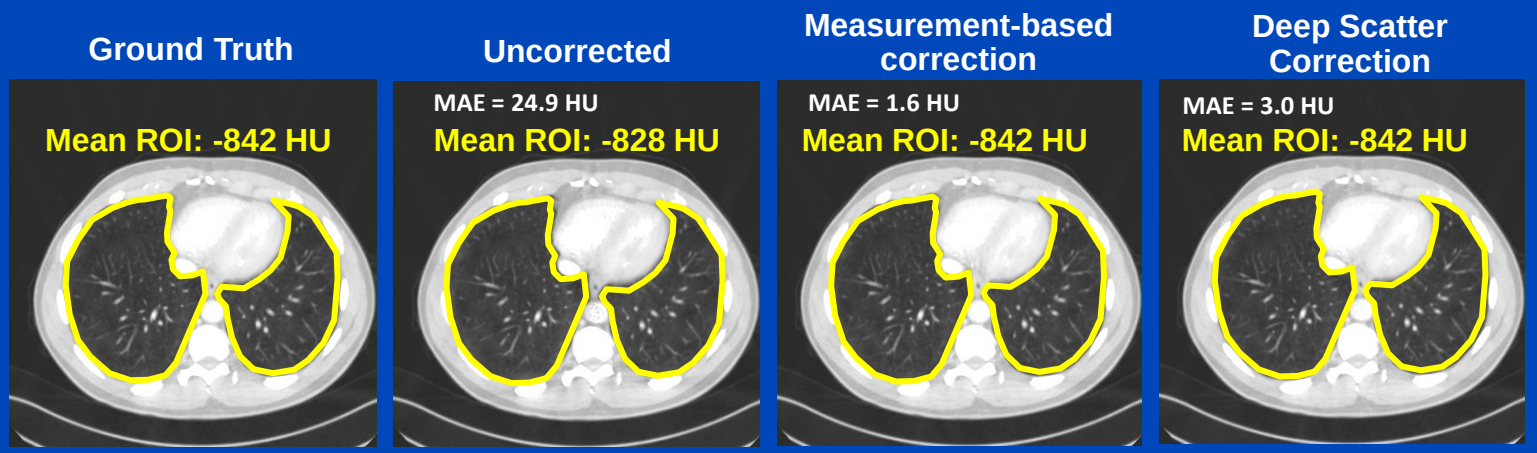
- Detector A will receive primary and forward of tube A and also cross-scatter of tube B → high scatter-to-primary ratio
- ρ ratio between the tube current of the cross tube and the tube current of the forward tube, ρ is known when performing a measurement
- Scatter correction crucial in dual energy mode
- Absolute CT values are of great importance in Quantitative CT
- For example: measuring air trapping and the extent of emphysema-like lung parenchyma
- Variability in intrathoracic air values between different CT scanners makes comparison challenging
- Mean CT value of the lung without scatter correction, with measurement-based correction and DSE correction is compared

Example of Scatter Correction in Dual Energy CT



Discussion

- Scatter correction is crucial in dual energy for DSCT
- DSE is able to remove the scatter artifacts and improves the accuracy of the CT values
- DSE improves the accuracy of CT numbers for quantitive CT imaging
- The accuracy of the corrected CT values is similar to a measurement-based correction technique but does not need additional detector sensors



Thank You!

Questions? julien.erath@dkfz.de

Job opportunities through DKFZ's international Fellowship programs (marc.kachelriess@dkfz.de).
Parts of the reconstruction software were provided by RayConStruct® GmbH, Nürnberg, Germany.

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