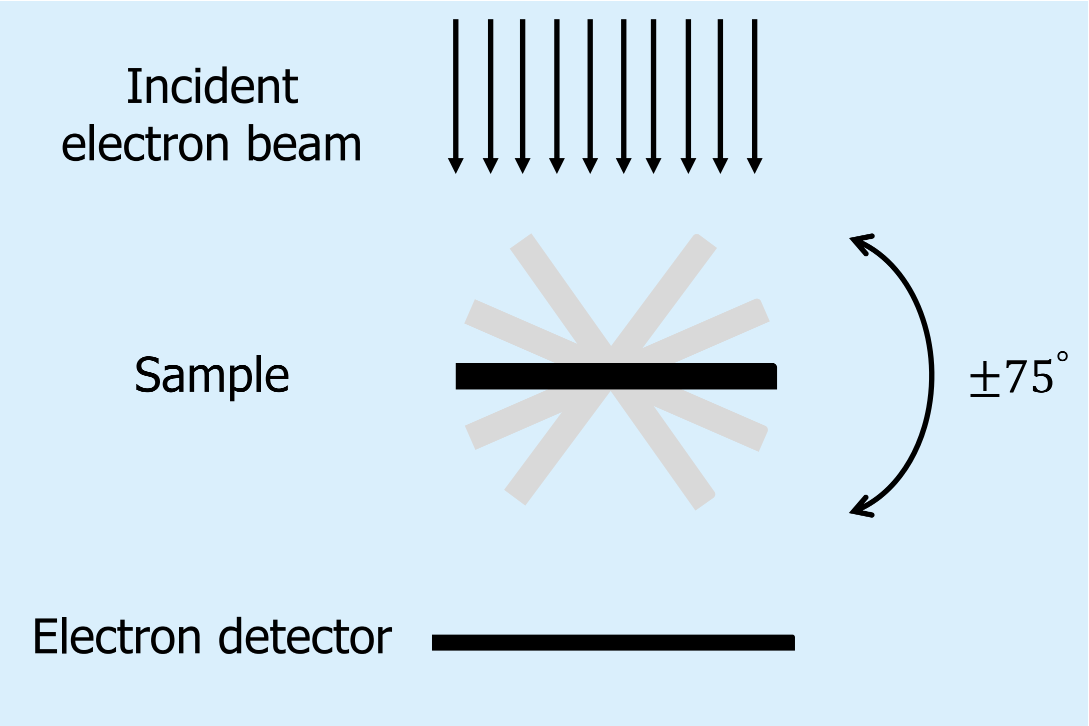
Image Fusion of X-ray and Electron Tomograms

Yan Guo

Delft University of Technology

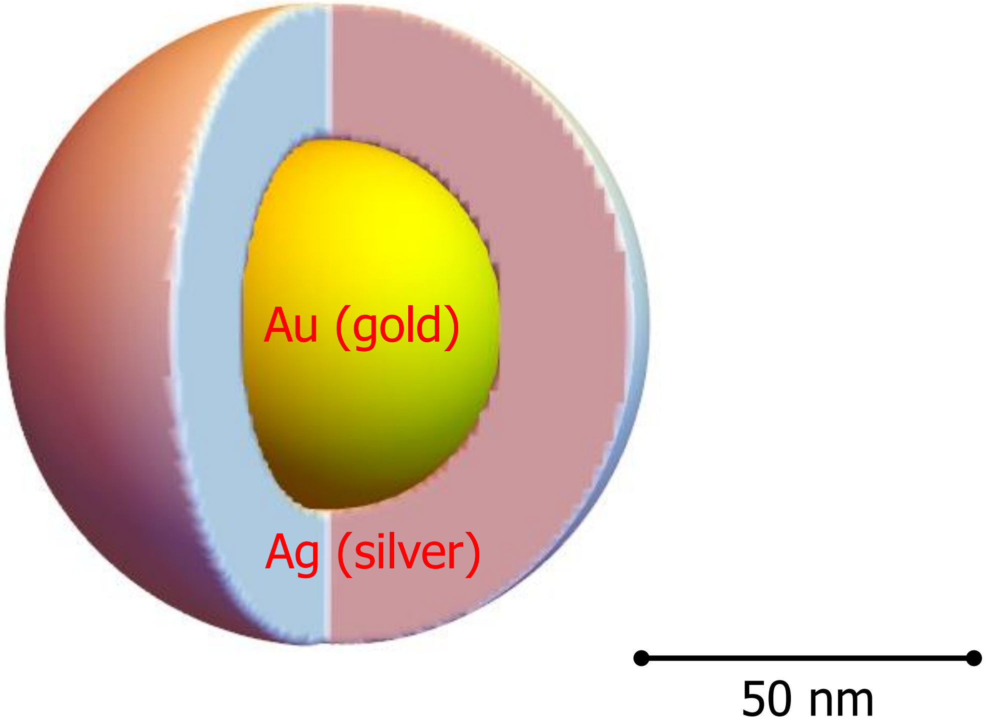
Electron tomography reveals the 3D structure of an object



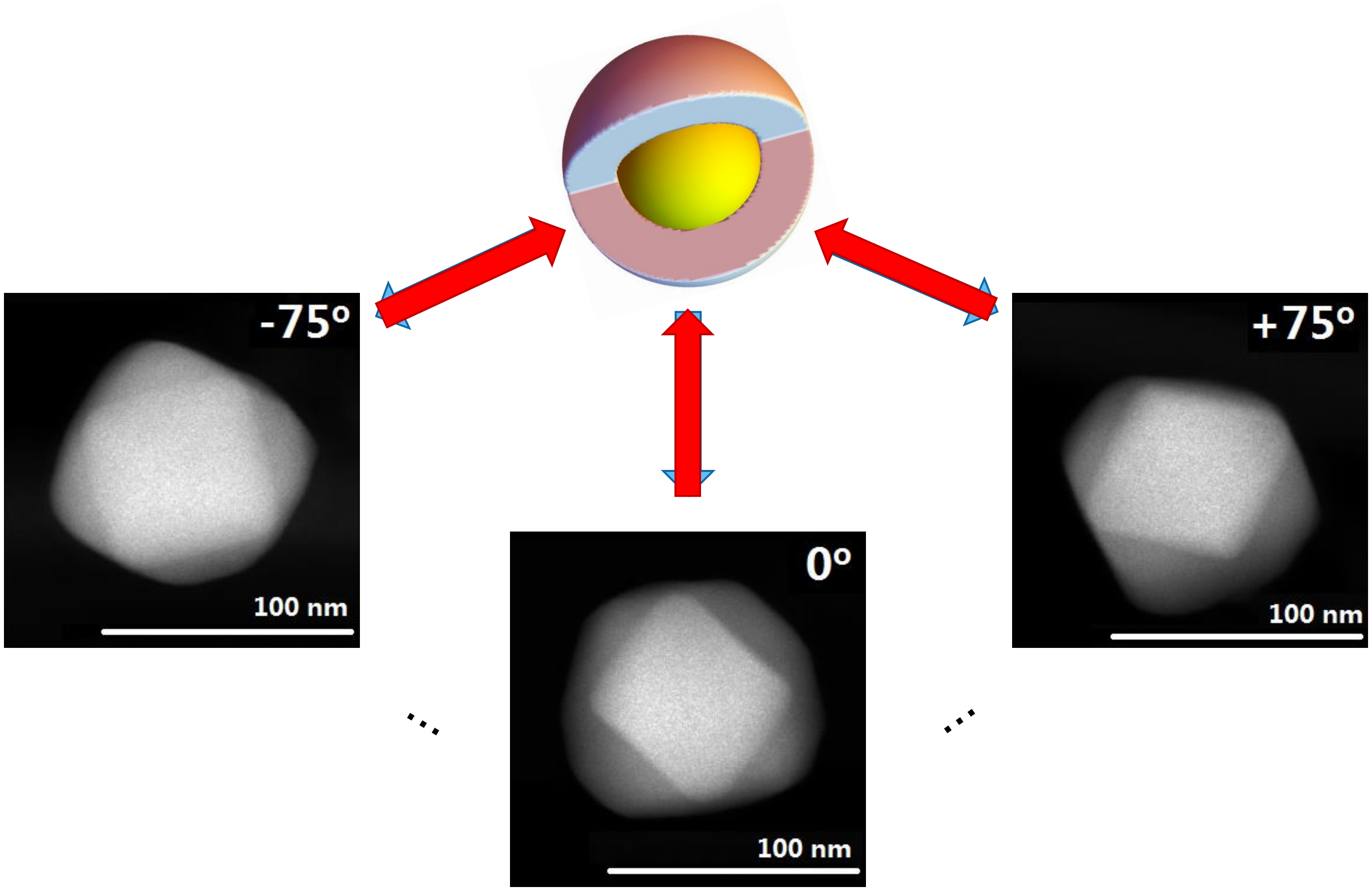
Schematic of tomography

Electron tomography reveals the 3D structure of an object

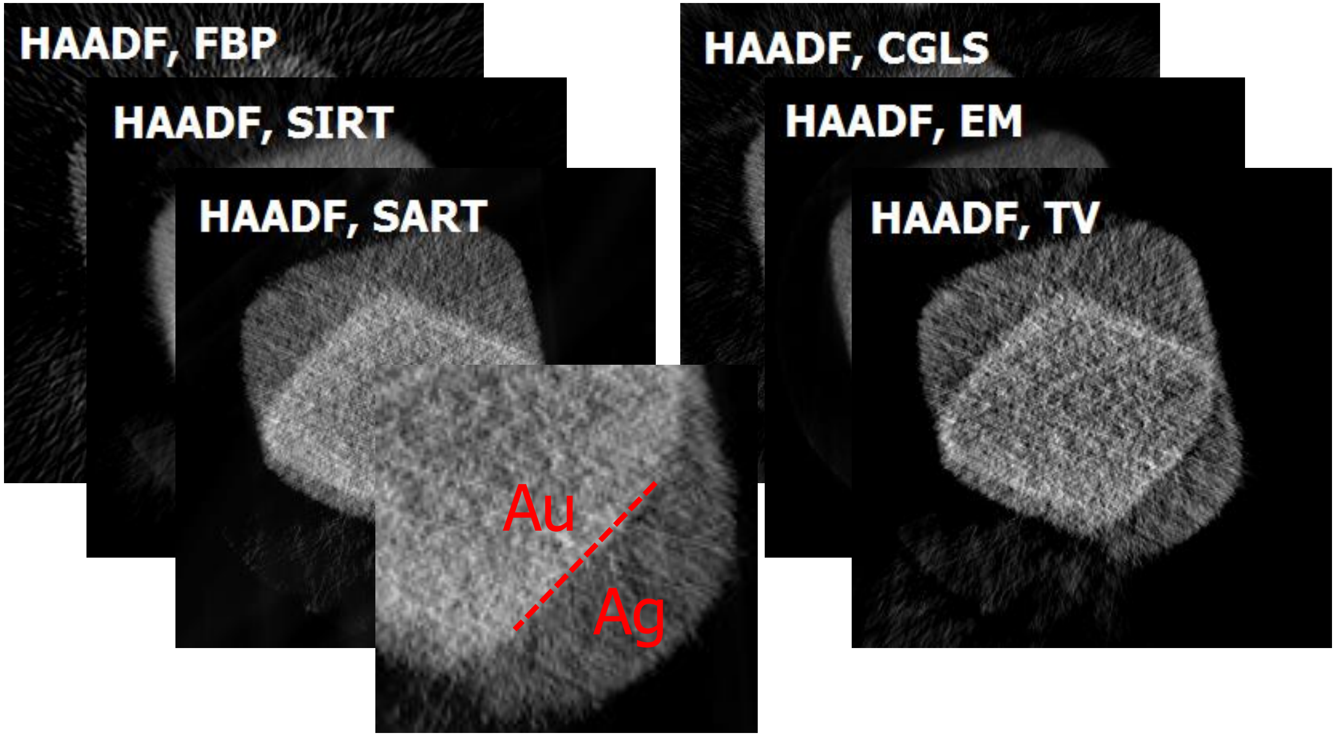
Core-shell nanoparticle



Projection images from the electron detection have high SNR

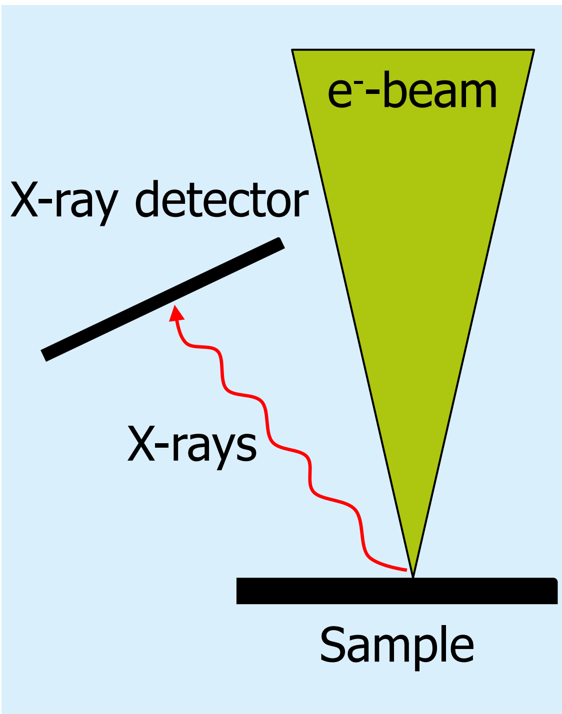


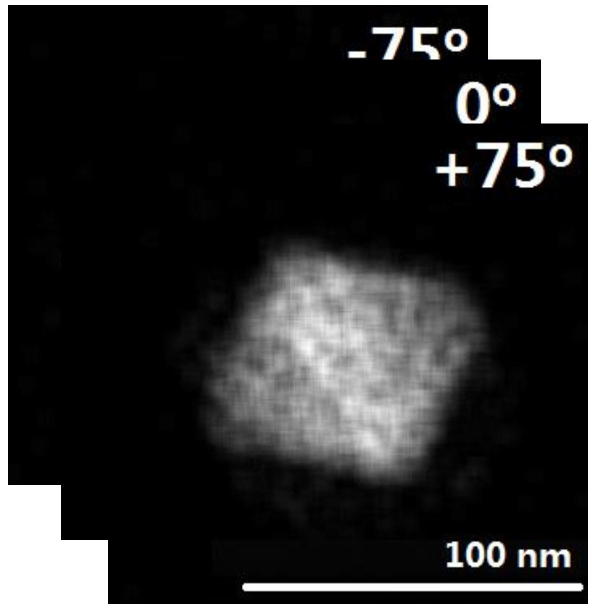
Dozens of reconstruction algorithms have been proposed



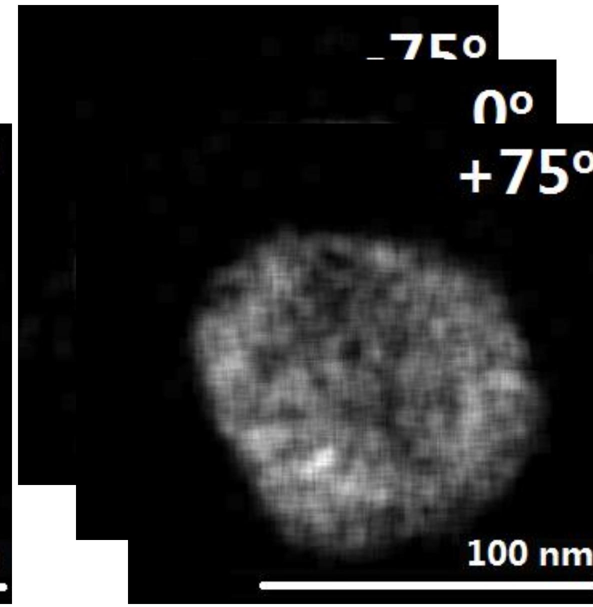
No. 150 out of 300 slices, pixel size is 4 Å

Energy-dispersive spectrometer (EDS) records element-specific X-rays



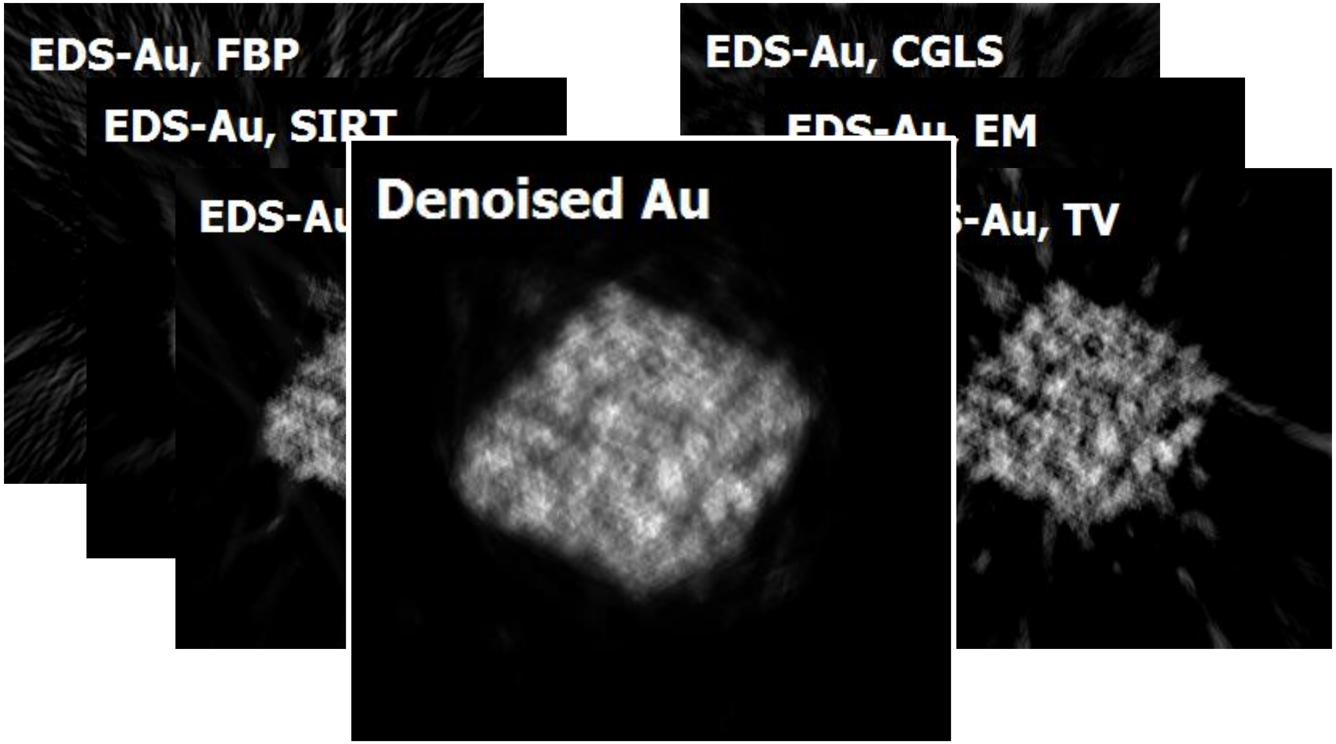


EDS data of Au



EDS data of Ag

EDS reconstructions are noisier at the same spatial resolution



Denoised gold (Au) slice using non-negative matrix factorization

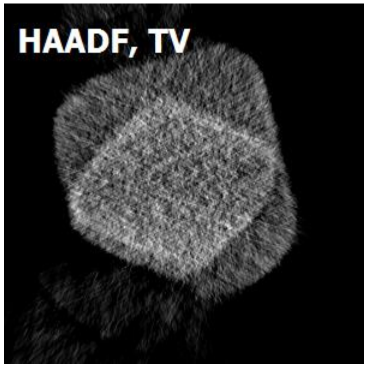
No. 150 out of 300 slices, pixel size is 4 Å

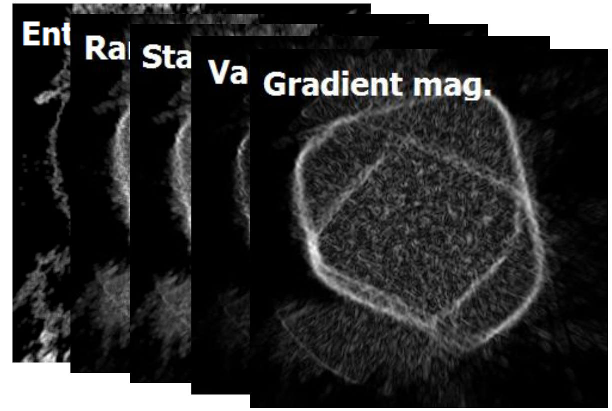
Three-step cross-modal fusion

1. Generate feature images
2. Denoising
3. Build cross-modality model for fusion

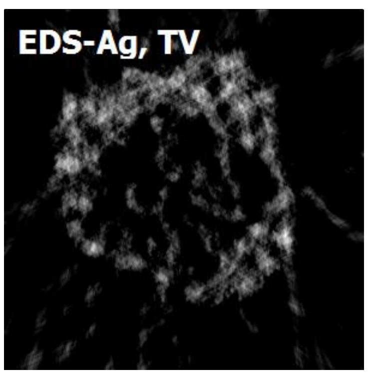
R. van de Plas et al., "Image fusion of mass spectrometry and microscopy: a multimodality paradigm for molecular tissue mapping," *Nature Methods*, vol. 12, pp. 366–374, 2015.

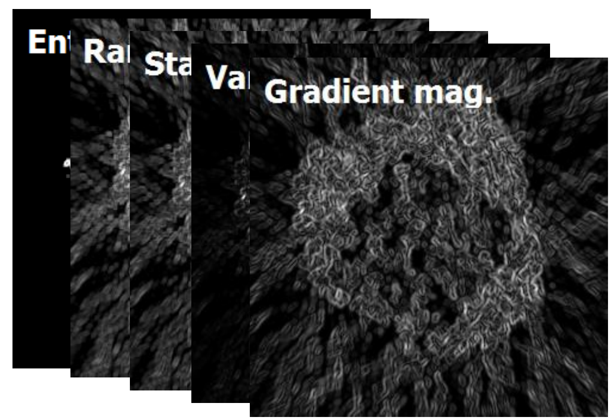
1. Generate feature images for HAADF and EDS-Ag



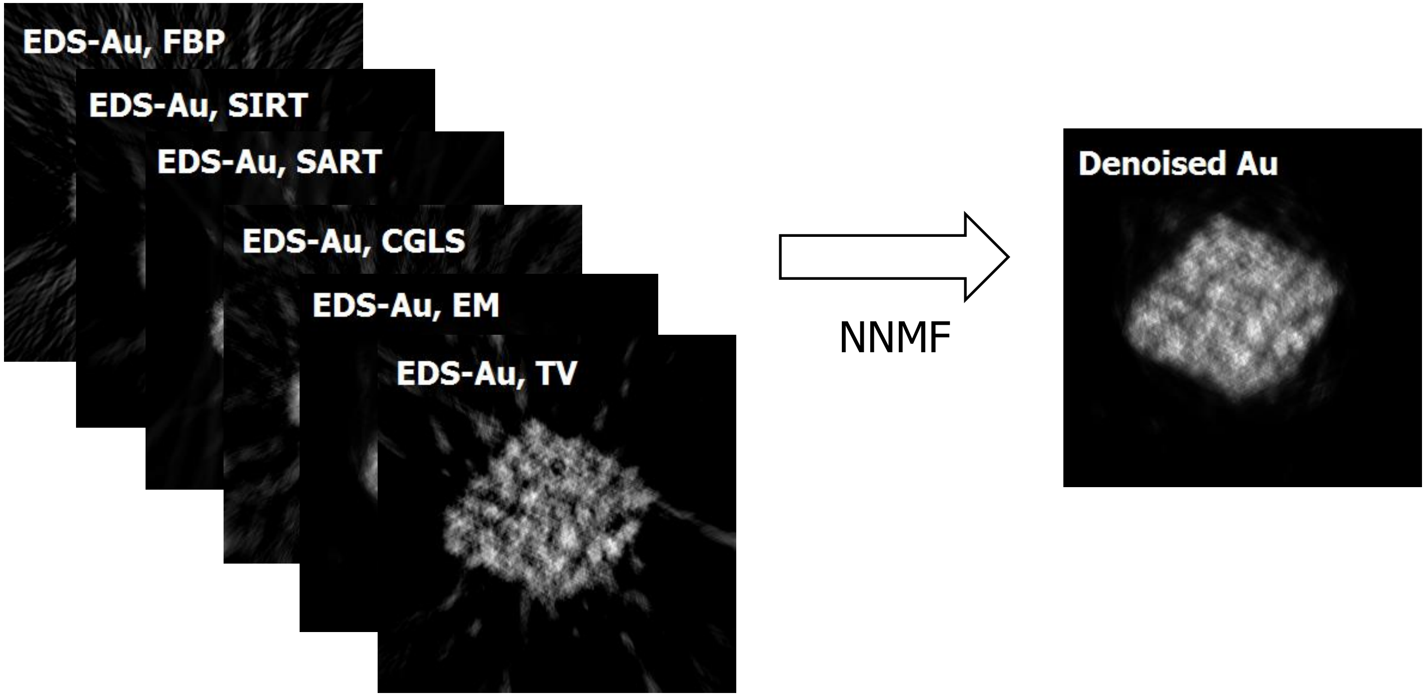


Texture filters, scale spaces, etc.

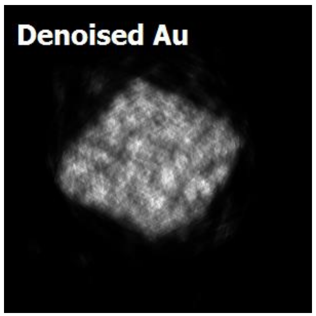




2. Denoise EDS-Au using non-negative matrix factorization



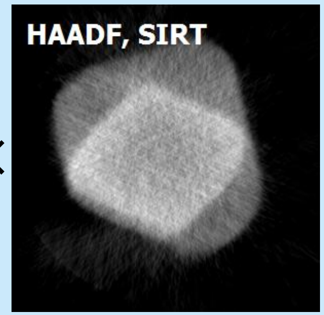
3. Build cross-modality model by partial least squares regression



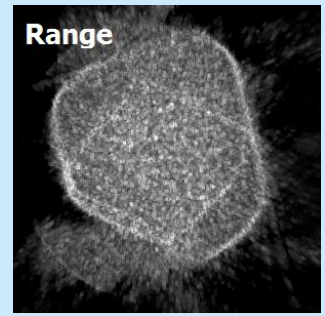
$\approx$

72 feature images from HAADF

$b_1 \times$



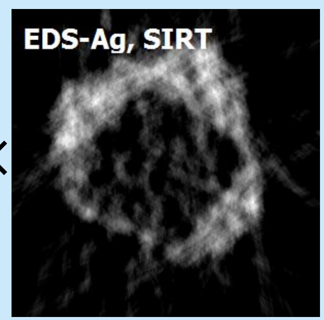
$+ \; b_2 \times$



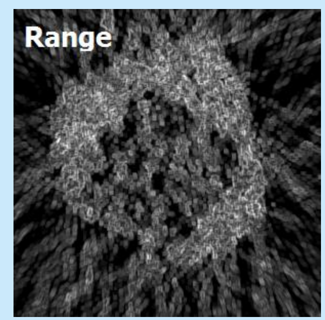
$+ \cdots$

72 feature images from EDS

$+ \; b_p \times$



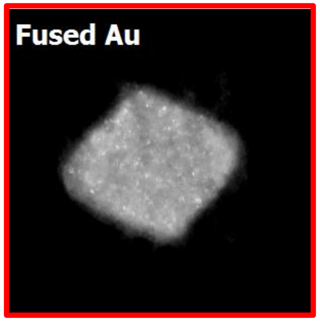
$+ \; b_{p+1} \times$



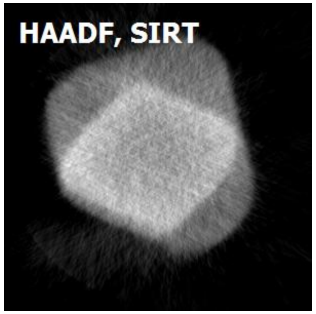
$+ \cdots + b_0$

6 algorithms
$\times$6 feature images
$\times$2-level scale spaces
=72

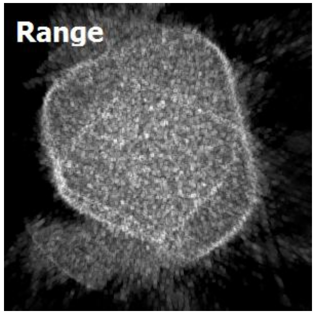
3. Build cross-modality model by partial least squares regression



$= b_1 \times$

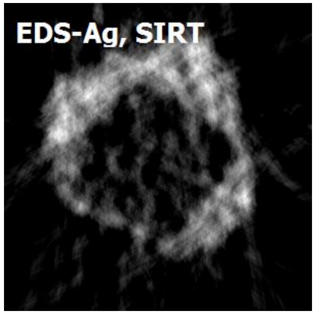


$+ \; b_2 \times$

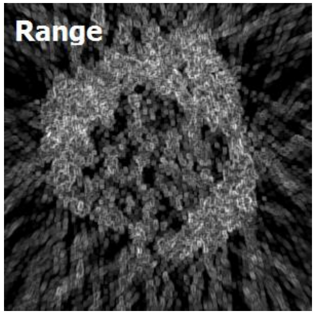


$+ \cdots$

$+ \; b_p \times$



$+ \; b_{p+1} \times$



$+ \cdots + \; b_0$

We compared our algorithm to FBP and SIRT, and a newly proposed bimodal tomography

Bimodal tomography incorporates EDS data into HAADF projections

$$\text{HEBT} = \min \alpha^2 \ \text{HAADF}^2 + (1-\alpha)^2 \ \text{EDS}^2$$

High SNR

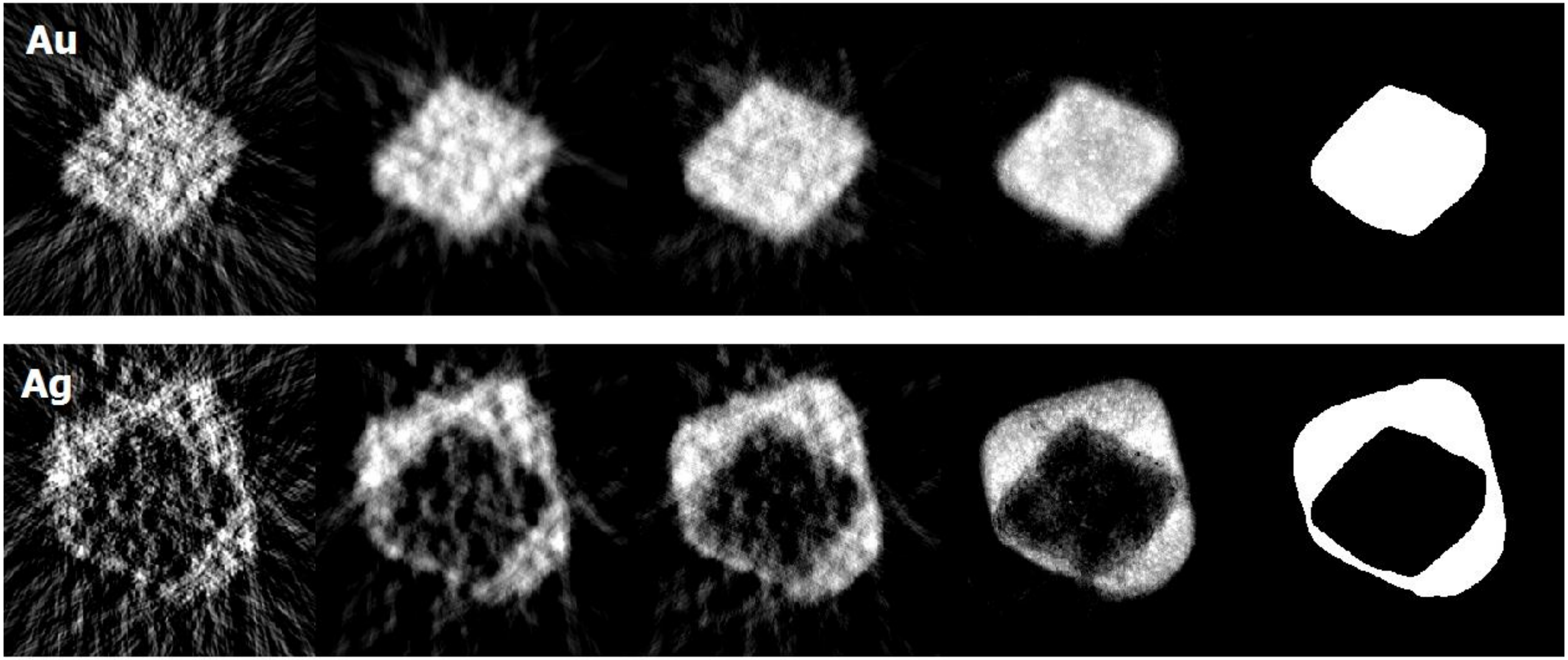
Element specificity

- Weighting factor $\alpha \in (0,1)$
- Number of iterations 3

HEBT: HAADF-EDS bimodal tomography

Z. Zhong et al., “A bimodal tomographic reconstruction technique combining EDS-STEM and HAADF-STEM,” *Ultramicroscopy*, vol. 174, pp. 35-45, 2017.

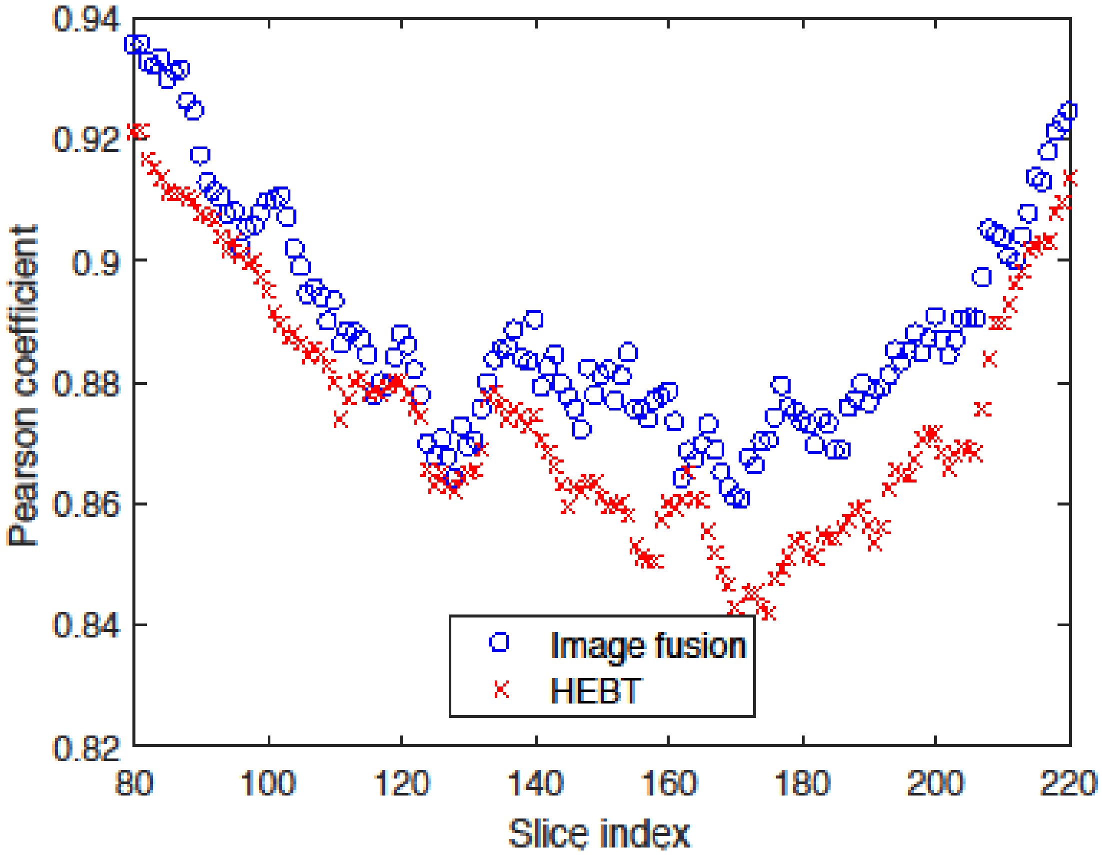
Our algorithm effectively improves reconstruction quality



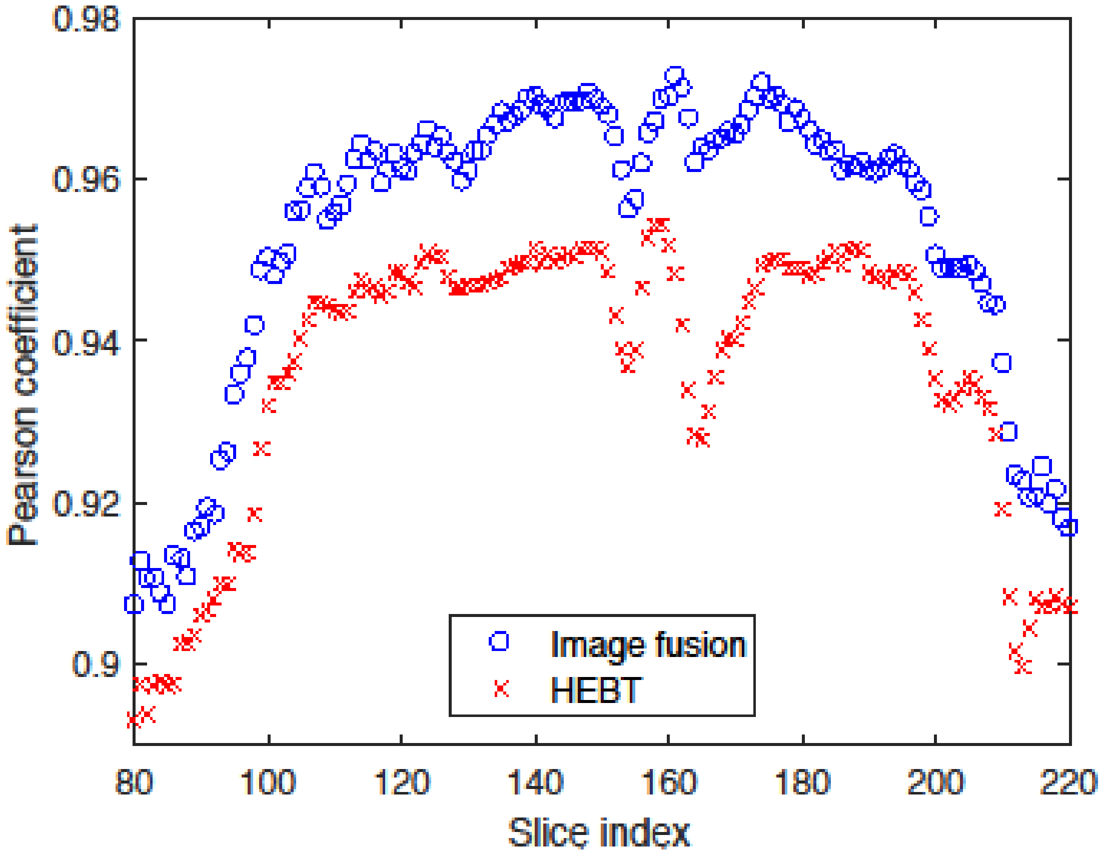
FBP SIRT HEBT Fusion Ground truth

No. 150 out of 300 slices. For better visualization, we performed percentile contrast stretching from 0 to 99%.

Our algorithm outperforms HEBT in Pearson coefficient (Au)



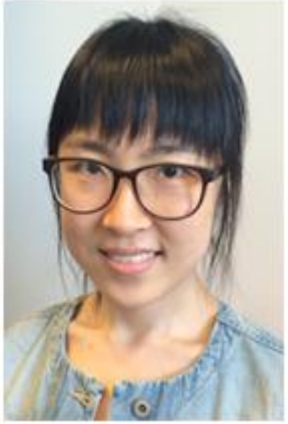
Our algorithm outperforms HEBT in Pearson coefficient (Ag)



Conclusion

- We present a cross-modal framework to fuse X-ray and electron tomograms without a tuning parameter
- Qualitatively, our algorithm can produce sharper edges and smoother fore- and background
- Quantitatively, it achieves higher Pearson coefficients than bimodal tomography

Thank you!
Questions?




Yan Guo and Bernd Rieger
{y.guo-3, b.rieger}@tudelft.nl
Department of Imaging Physics
Delft University of Technology