Medical Image Processing for Interventional Applications

Learning of Material Decomposition

Online Course – Unit 19

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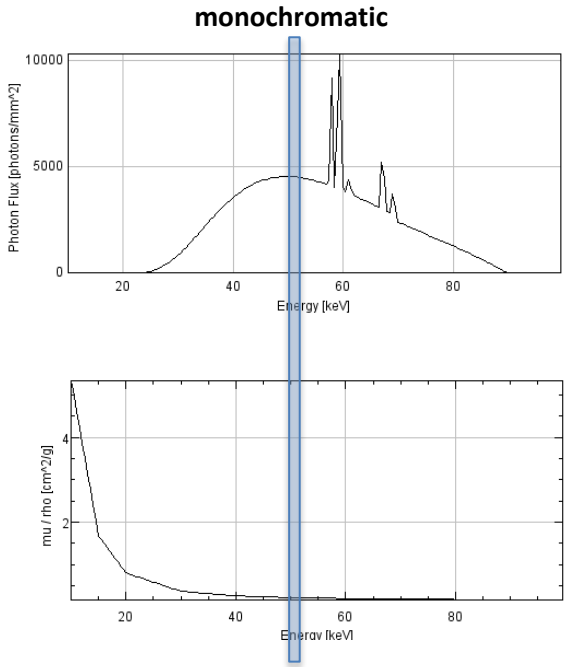
Topics

Polychromatic Material Decomposition (Maaß et al., 2011)

So far we have not considered the polychromatic nature of X-ray radiation:

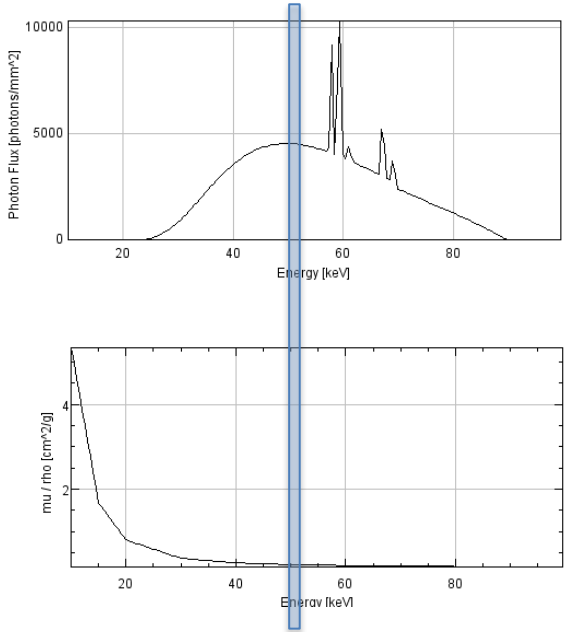


$$I_{0b} e^{-\int \mu(b,j) l_j \mathrm{d}j} = I_b$$

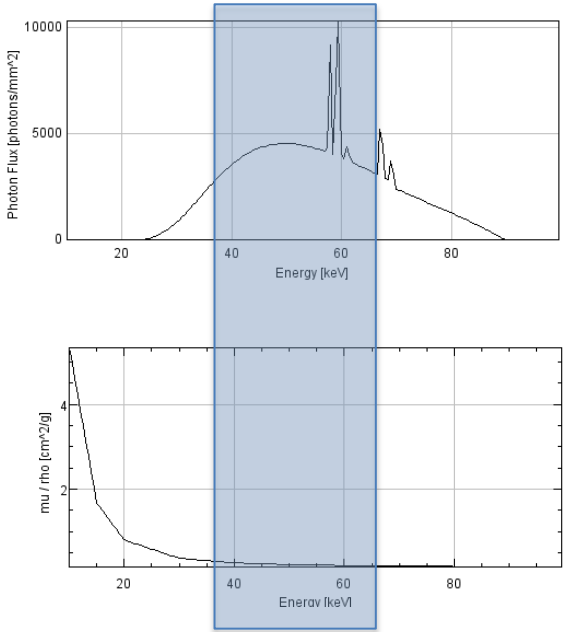
Polychromatic Material Decomposition (Maaß et al., 2011)

So far we have not considered the polychromatic nature of X-ray radiation:

monochromatic



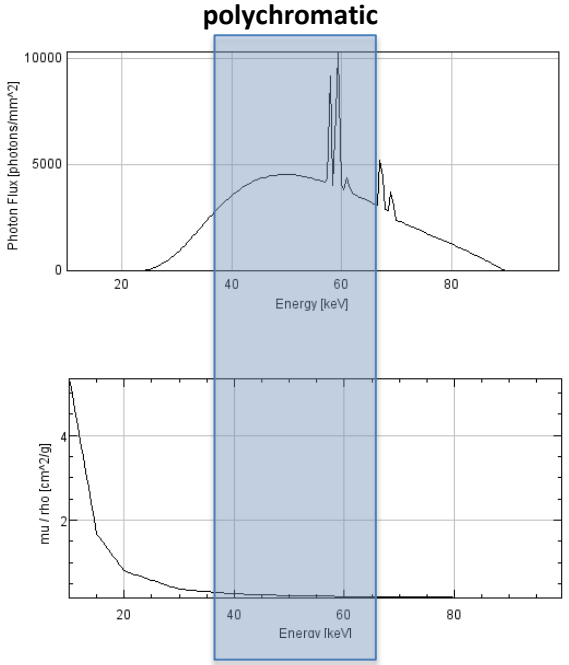
polychromatic



Polychromatic Material Decomposition (Maaß et al., 2011)

So far we have not considered the polychromatic nature of X-ray radiation:

$$\int I_{0b'} e^{-\int \mu(b',j) l_j \mathrm{d}j} \mathrm{d}b' = I_b$$



Polychromatic Material Decomposition (Maaß et al., 2011)

The polychromatic absorption outcome in bin b is given by:

$$\int I_{0b'} e^{-\int \mu(b',j) l_j \mathrm{d}j} \mathrm{d}b' = I_b.$$

The inversion of this problem is quite difficult.

→ Inversion can be approximated by a polynomial of degree K:

$$l(q_1, q_2, \dots, q_B) = \sum_{k_1,k_2,\dots,k_B=0}^{K-1} c_{k_1,k_2,\dots,k_B} q_1^{k_1} q_2^{k_2} \dots q_B^{k_B}.$$

Topics

Material Decomposition with Pattern Recognition (Lu et al., 2015)

- Inversion can be formulated as a general problem of function estimation:

$$l(\boldsymbol{q}) = f_{ML}(\boldsymbol{q}).$$

- Typical models from machine learning can be used:
  - random forests,
  - multilayer perceptrons (MLP),
  - support vector machines.

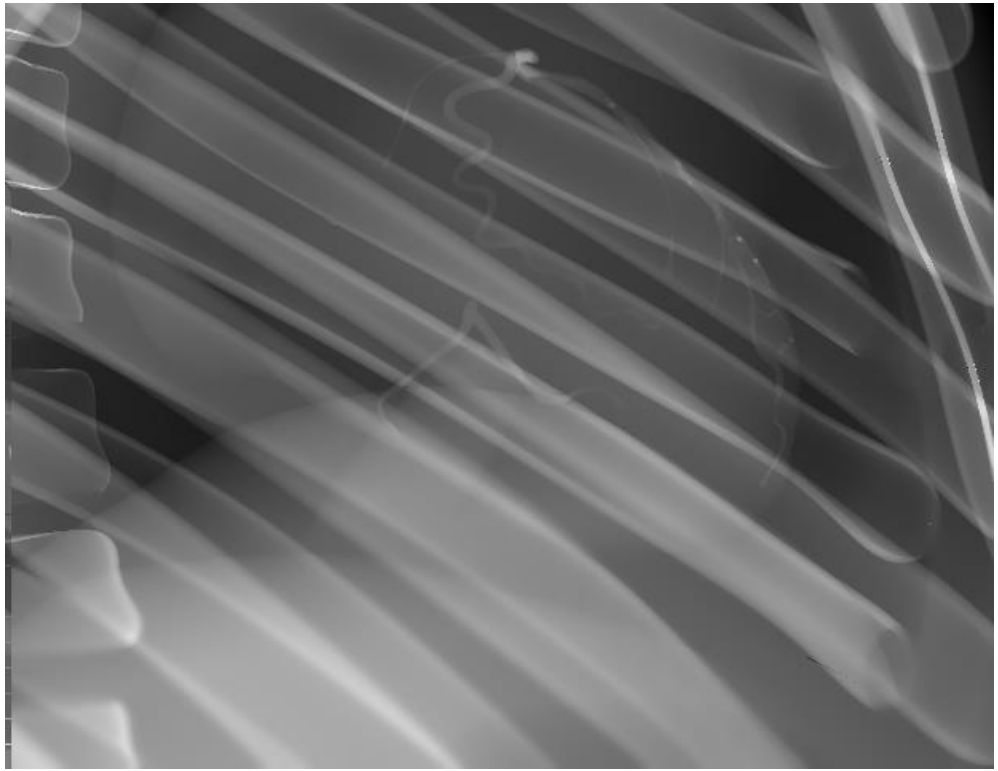
Material Decomposition with Pattern Recognition (Lu et al., 2015)

Utilization of additional information becomes possible:

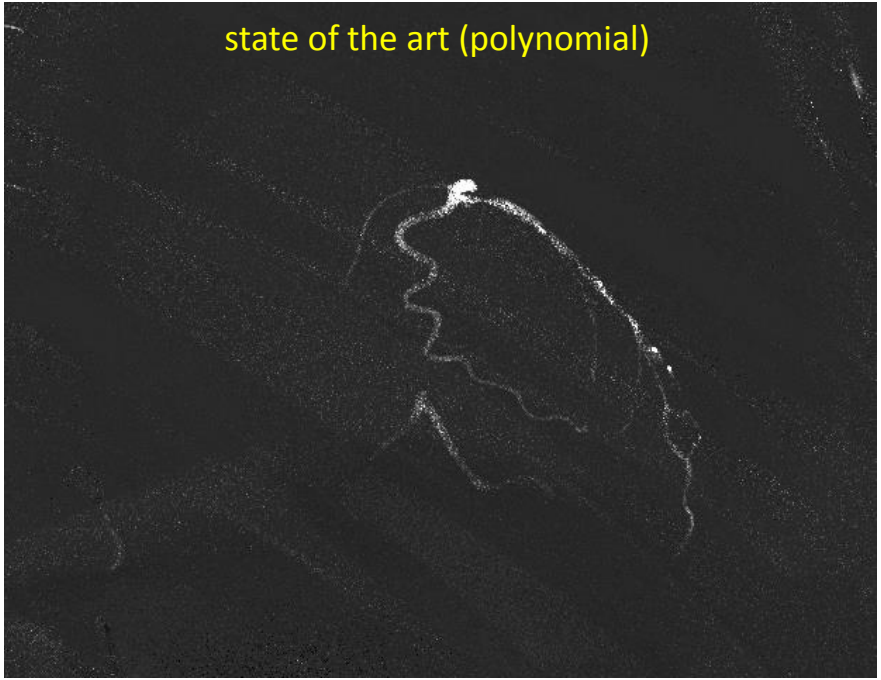
- Structure characteristics can be used to describe shapes.
- Material images should build a basis and should not be correlated.
- Material images must fulfill certain consistency conditions.

→ A decomposition of more material types than bins becomes possible.

Input Image (Bin 1)



Visualization Contrast Agent



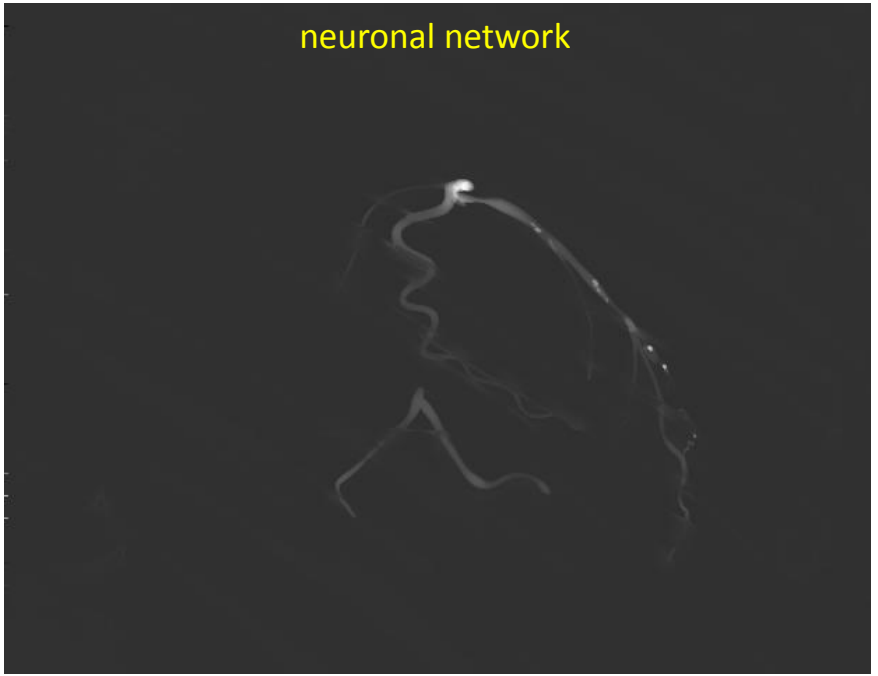
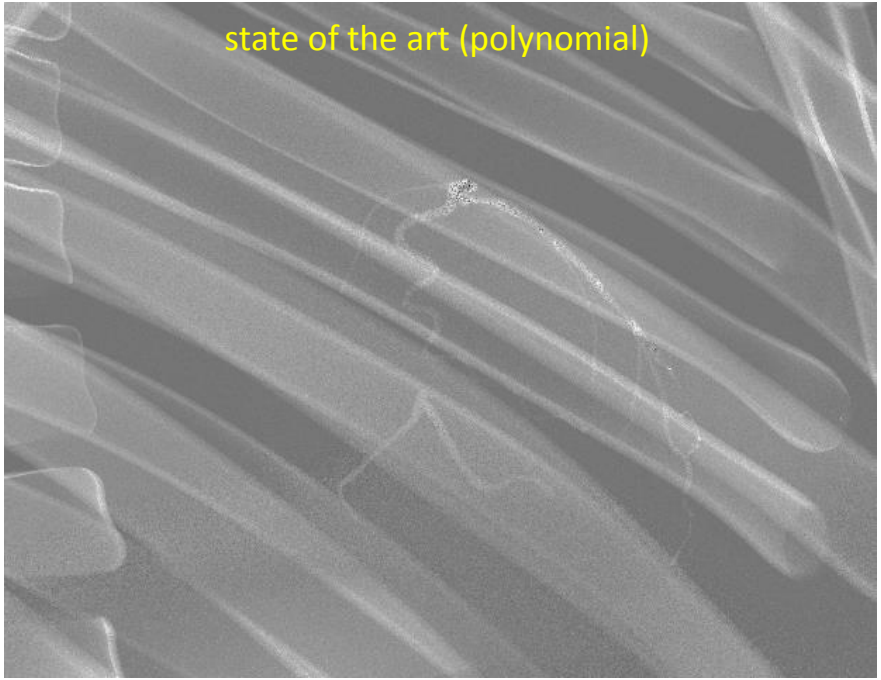


Figure 4: Polynomial fit (left), multilayer perceptron (MLP) (right)

Visualization Bone



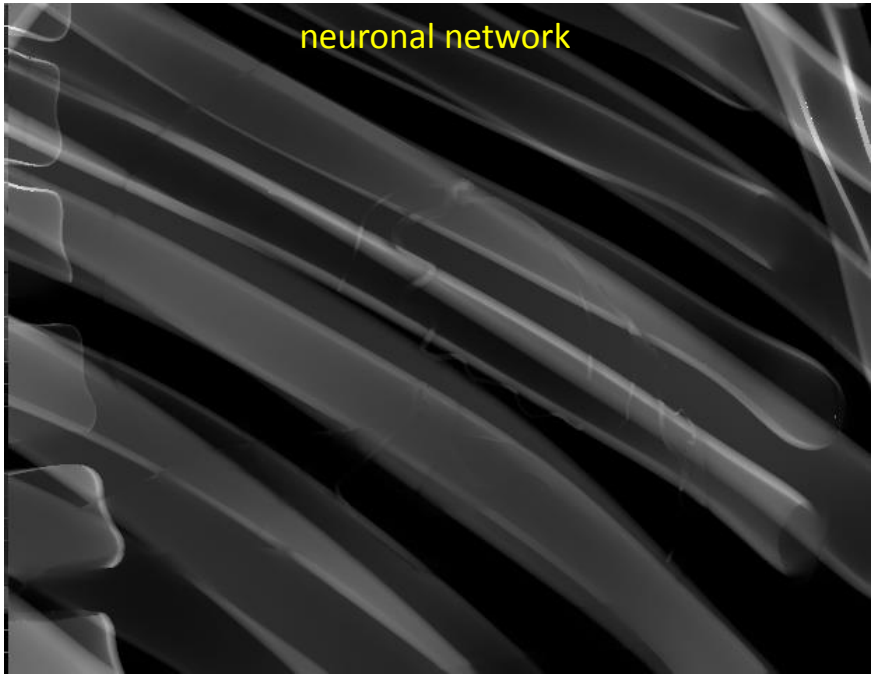


Figure 5: Polynomial fit (left), multilayer perceptron (MLP) (right)

Original Acquisitions

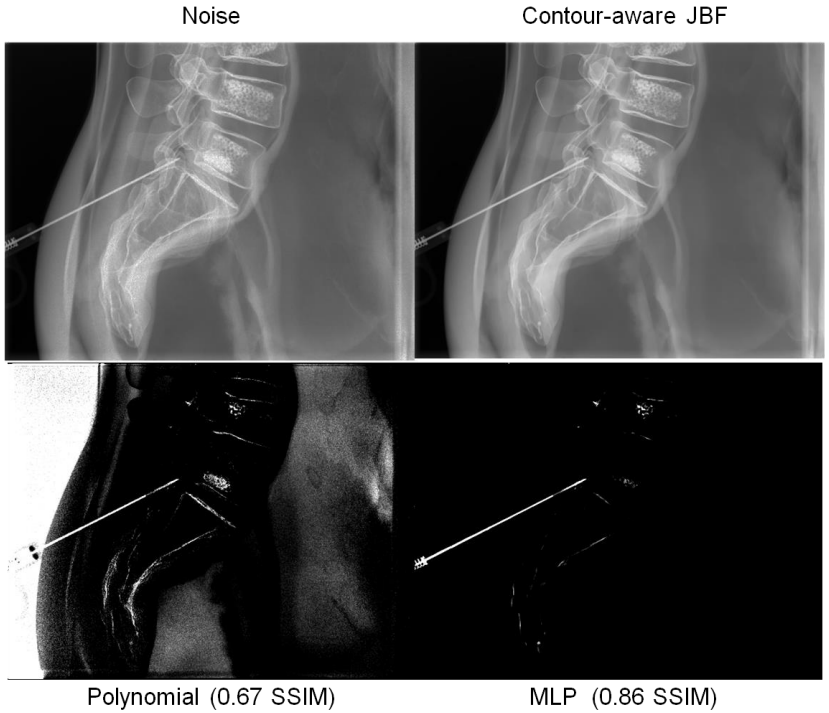


Figure 6: These images were acquired in cooperation with Stanford University.

Topics

Polychromatic Material Decomposition

Material Decomposition with Pattern Recognition

Summary

- Take Home Messages
- Further Readings

Take Home Messages

- The polychromatic model to describe the physical phenomenon of X-ray attenuation for a specific radiation emission system is even closer to physics than the monochromatic model.
- Respectively, material decomposition makes use of either of these models. The monochromatic case can be described by a linear system of equations, while we used methods from machine learning for the polychromatic case.

Further Readings

- Markus Firsching et al. “Material Resolving X-ray Imaging Using Spectrum Reconstruction with Medipix2”. In: *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 591.1 (June 2008), pp. 19–23. DOI: 10.1016/j.nima.2008.03.017
- Nicole Maaß et al. “Empirical Multiple Energy Calibration (EMEC) for Material-Selective CT”. . In: *Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2011 IEEE*. IEEE, Oct. 2011, pp. 4222–4229. DOI: 10.1109/NSSMIC.2011.6153810
- Yanye Lu et al. “Projection-based Material Decomposition by Machine Learning using Image-based Features for Computed Tomography”. In: *The 13th International Meeting on Fully Three-Dimensional Image Reconstruction in Radiology and Nuclear Medicine*. Newport, Rhode Island, USA, 2015, pp. 448–451