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Unsupervised Subspace Decomposition for Fast Hyperspectral Neutron Tomography

Mohammad Samin Nur Chowdhury1, *Diyu Yang2, Shimin Tang3, Singanallur V. Venkatakrishnan2, Hassina Z. Bilheux3, Gregery T. Buzzard1, and Charles A. Bouman1*
1Purdue University, IN 47907, US
2Apple Inc., Cupertino, CA, USA
*3Oak Ridge National Laboratory, TN 37830, USA*chowdh31@purdue.edu

Hyperspectral Neutron Computed Tomography (HSnCT) is an advanced imaging technique in which thousands of wavelength-resolved neutron radiographs are acquired for each tomographic view. Traditionally, hyperspectral reconstruction is performed by reconstructing each neutron wavelength bin separately, which is extremely time-consuming and often produces low-quality reconstructions due to low signal-to-noise ratios. Consequently, material decomposition based on these reconstructions tends to produce erroneous volumetric material separation and inaccurate estimates of the material spectra.
To address these challenges, we introduce two novel algorithms: Fast Hyperspectral Reconstruction (FHR) and Fast Material Decomposition (FMD).
• FHR is a method for fast tomographic reconstruction of hyperspectral data that also visibly and quantitatively reduces noise and improves reconstruction quality.
• FMD is a related method to perform material decomposition, producing 3D reconstructions of component materials and the associated linear attenuation coefficient spectra.
Figure 1 illustrates the core components of FHR and FMD. Both algorithms are based on an unsupervised subspace decomposition procedure that represents the high-dimensional hyperspectral views within a low-dimensional intermediate subspace. The subspace components are then reconstructed using model-based iterative reconstruction (MBIR). The FHR algorithm then directly expands the subspace reconstructions to obtain the hyperspectral reconstructions. Alternatively, the FMD algorithm then volumetrically decomposes the object's materials from the subspace reconstructions and produces the 3D reconstructions of individual materials and their associated spectra. The use of subspace decomposition in our algorithms serves three purposes:
• Eliminates significant spectral noise from data while fitting into low-dimensional subspace.
• Enables over 10x faster computation due to the reduced number of tomographic reconstructions.
• Allows the use of (MBIR) that produces high-quality reconstructions from sparse view data.
We apply our algorithms to simulated and measured neutron data and demonstrate that they are substantially faster and yield more accurate results than traditional HSnCT methods. A comprehensive description of this work is provided in our recent publication [1].
References
[1] M. S. N. Chowdhury et al., "Fast Hyperspectral Neutron Tomography," in IEEE Transactions on Computational Imaging, vol. 11, pp. 663-677, 2025, doi: 10.1109/TCI.2025.3567854.

Topical Area

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Author: CHOWDHURY, Samin (Purdue University)

Presenter: CHOWDHURY, Samin (Purdue University)