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An Improved Process to Colorize Visualizations of Noisy X-Ray Hyperspectral Computed Tomography Scans of Similar Materials

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Introduction

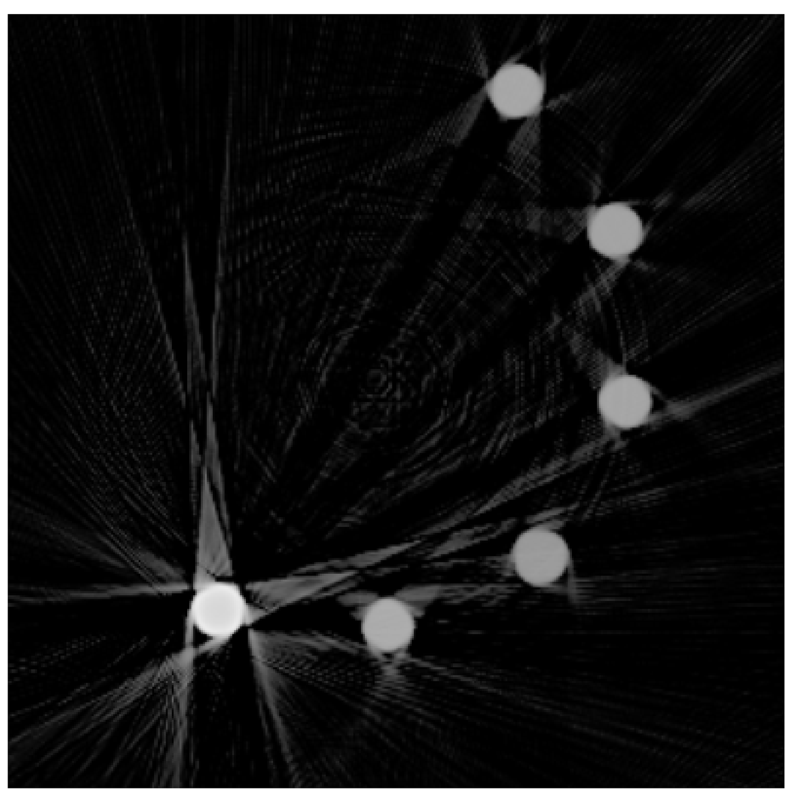
Previous work [1] demonstrated effective preprocessing and dimension reduction pipelines for representing hyperspectral computed tomography (HCT) data of similar materials in a single colorized image using simulated data. This work improves robustness of those methods (most notably by improved reconstruction) and tests them on experimental (non-simulated) data of ceramic cylinders with highly similar compositions and material properties.

Methods

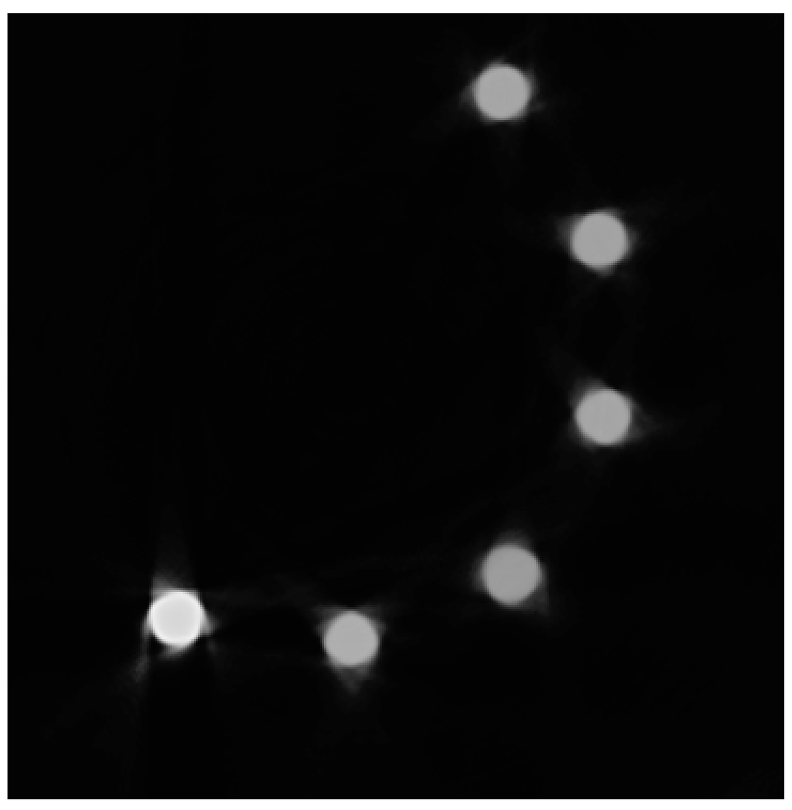
- Colorization accomplished with a 3D representation using uniform manifold approximation and projection (UMAP), polynomial regression [1], or functional principal components analysis (FPCA, a new method for this task).
- Reconstruction used maximum-likelihood expectation-maximization (MLEM) instead of filtered back-projection (FBP).
- Preprocessing included a more robust thresholding and erosion method using mask from full reconstruction. New automated channel selection added (drop >2% difference between channel and full reconstruction mask, included channels 109-128). Finally, applied a 3x3 median filter on each channel.
- HCT system single source detector with 5 Multix ME100 modules providing 640 square pixel array calibrated for 300 keV across 128 channels [2] (source-to-detector distance 2.05 meters, source-to-object distance 1.75 m).
- Scan has 6 ceramic cylinders (made from room-temperature glass mica, high-temperature glass mica, alumina-silicate, alumina-bisque, alumina, and water-resistant zirconia) placed in a circular arrangement, with a second scan including a steel penny and wood block [3].

Results: Reconstruction

- The signal difference-to-noise ratio (SDNR), quantifying contrast of objects against background noise [4], was used to compare reconstruction methods.
- Better SDNR values observed for MLEM (averaged 45% greater than FBP).



(a) FBP Reconstruction



(b) MLEM Reconstruction

Figure 1: Reconstruction comparison (hyperspectral channel 16)

Results: Colorization

- After all preprocessing, UMAP produces distinct colors between all objects.

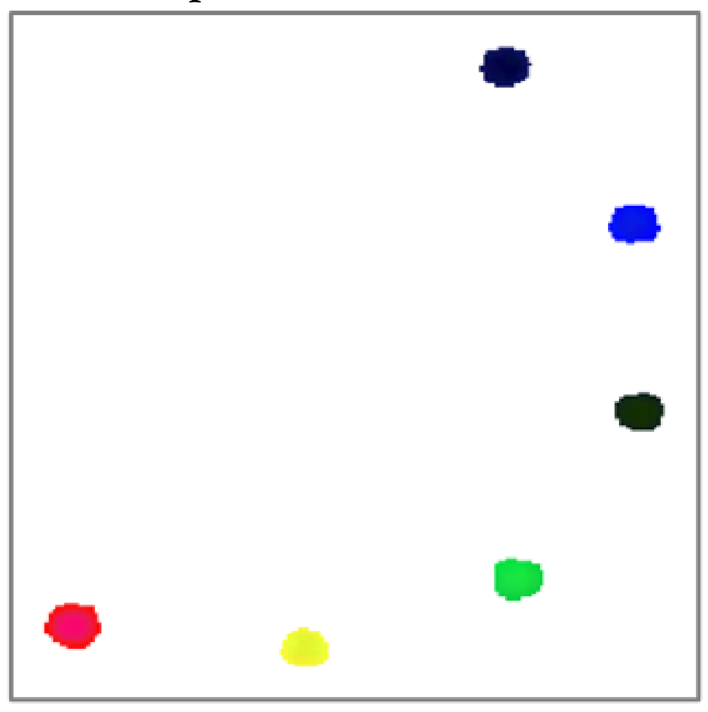
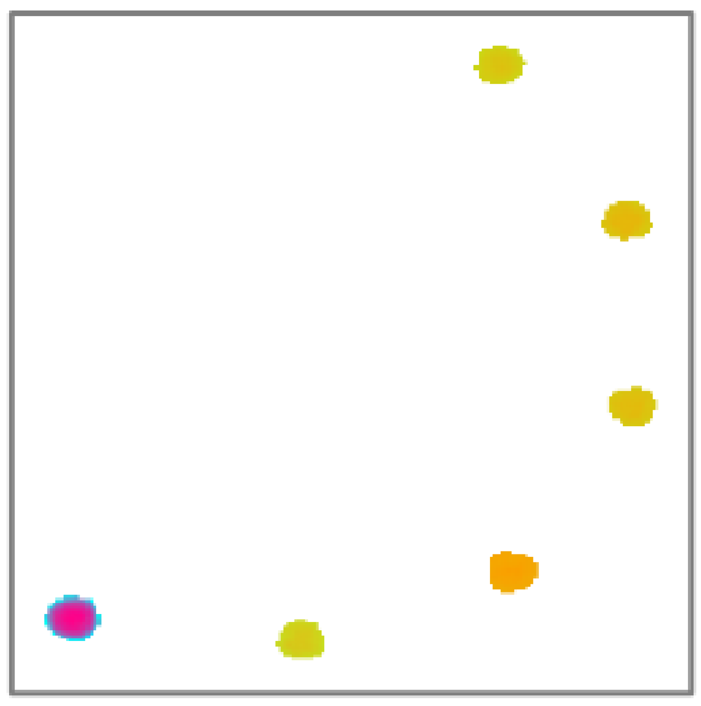
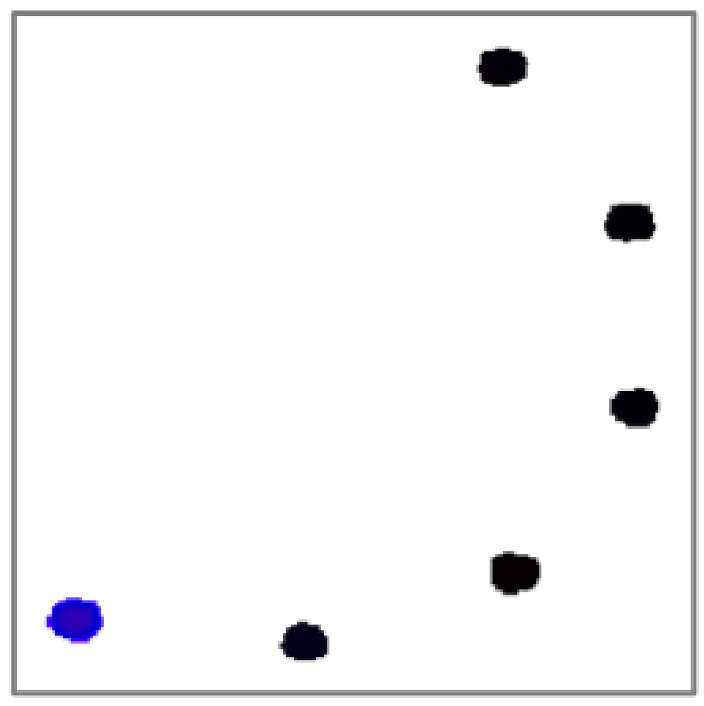


Figure 2: UMAP coloring after channel selection and median filtering

- After preprocessing, polynomial regression and FPCA do not produce distinct colors, which is driven by the large relative magnitude difference in the hyperspectral signature for zirconia (leftmost object) versus other ceramics.



(a) Polynomial Regression Colorization



(b) FPCA Colorization

Figure 3: Alternative colorization method comparison

- The UMAP manifold from the ceramics-only scan successfully replicates colors for ceramic objects on a new scan with additional materials (Figure 4).

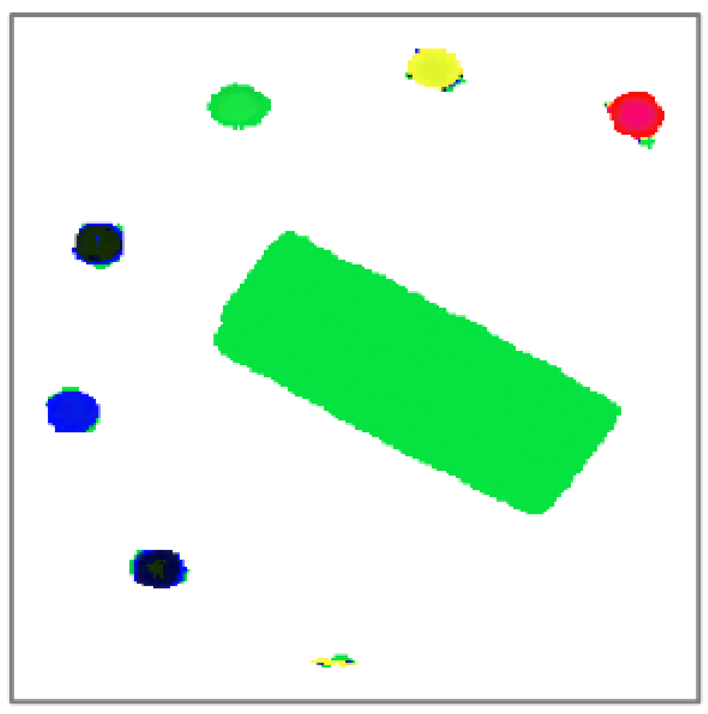


Figure 4: UMAP trained on original data used to color new data

- UMAP results accurately determines the number of materials/objects in the ceramics-only scan (optimum average silhouette width for clustering). Thus, it can inform material classification, e.g., as input for the iterative hierarchical clustering in Gallegos et al. [3].

Future Work

- Validate this approach, testing the methods are indeed more robust, on various HCT systems as well as simulations with different materials, geometries, etc.
- Further investigate the potential for utilizing the colorization methods to inform both human understanding and material classification.

References

[1] J. M. Clifford, E. Kemp, B. Limpanukorn, and E. S. Jimenez, "A process to colorize and assess visualizations of noisy x-ray computed tomography hyperspectral data of materials with similar spectral signatures." in *2021 IEEE Nuclear Science Symposium and Medical Imaging Conference*, 2021. [Online]. Available: https://www.osti.gov/biblio/1866899

[2] E. S. Jimenez, K. R. Thompson, A. Stohn, and R. N. Goodner, "Leveraging multi-channel x-ray detector technology to improve quality metrics for industrial and security applications," in *Radiation Detectors in Medicine, Industry, and National Security XVIII*, G. P. Grim, L. R. Furenlid, and H. B. Barber, Eds., vol. 10393, International Society for Optics and Photonics. SPIE, 2017, pp. 137 – 147. [Online]. Available: https://doi.org/10.1117/12.2275850

[3] I. O. Gallegos, S. Koundinyan, A. N. Suknot, E. S. Jimenez, K. R. Thompson, and R. N. Goodner, "Unsupervised learning methods to perform material identification tasks on spectral computed tomography data," in *Radiation Detectors in Medicine, Industry, and National Security XIX*, G. P. Grim, L. R. Furenlid, H. B. Barber, and J. A. Koch, Eds., vol. 10763, International Society for Optics and Photonics. SPIE, 2018, pp. 91 – 104. [Online]. Available: https://doi.org/10.1117/12.2326394

[4] T. Gomi, "Comparison of different reconstruction algorithms for decreasing the exposure dose during digital breast tomosynthesis: A phantom study," *Journal of Biomedical Science and Engineering*, vol. 08, pp. 471–478, 01 2015.

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