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X-ray Diffraction Tomographic Imaging and Reconstruction

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Material discrimination based on conventional or dual energy X-ray computed tomography (CT) imaging can be ambiguous. X-ray diffraction imaging (XDI) can be used to construct diffraction profiles of objects, providing new molecular signature information that can be used to characterize the presence of specific materials. Combining X-ray CT and diffraction imaging can lead to enhanced detection and identification of explosives in luggage screening. In this work we are investigating techniques for joint reconstruction of CT absorption and X-ray diffraction profile images of objects to achieve improved image quality and enhanced material classification. The initial results have been validated via simulation of X-ray absorption and coherent scattering in 2 dimensions.

Abstract

Methodologies

• XDI Imaging Modality

Material discrimination based on conventional or dual energy X-ray computed tomography (CT) imaging can be ambiguous. X-ray diffraction imaging (XDI) can be used to construct diffraction profiles of objects, providing new molecular signature information that can be used to characterize the presence of specific materials. Combining X-ray CT and diffraction imaging can lead to enhanced detection and identification of explosives in luggage screening. In this work we are investigating techniques for joint reconstruction of CT absorption and X-ray diffraction profile images of objects to achieve improved image quality and enhanced material classification. The initial results have been validated via simulation of X-ray absorption and coherent scattering in 2 dimensions.

X-ray Diffraction Imaging

• X-ray scattering types: coherent and incoherent
• XDI makes use of coherently scattered X-ray to reconstruct the coherent-scatter form factor
• XDI identifies material based on their molecular composition
• Form factor $|F(q)|^2$
  • expressed in transferred momentum $q$ that causes the deviation of photon of wavelength $\lambda$ by angle $\theta$: $q = \lambda \sin(\theta/2)$
  • reveal Bragg peaks for material discrimination

XDI State-of-the-Art

• Direct imaging rather than tomographic
• Can be slow
• Probe with polychromatic X-ray radiation
• Measure coherent scattering with energy-resolving detectors
• Require line collimators to localize scattering location under investigation
• Often used as confirmation sensor for ambiguous regions in CT

Experiment and Results

A phantom with size 105×105 mm consisting of 5 materials and air as background was centered at the origin. A mono-energetic X-ray parallel beam of 60KeV was used to probe the phantom. Given form factor priors, diffraction patterns were simulated on a detector of size 100(height)×151(width) mm placed 620 mm away from the origin. 90 projections were collected for reconstruction. Both FBP and ART reconstruction methods were evaluated under various Gaussian noise. Every pixel in the reconstructed fields was assigned to the class that minimizes the Euclidean distance from the reconstructed diffraction profile to the priors.

Discussion

The initial results are encouraging, but are limited by the fidelity of the simulation model, which is similar to the model used in the reconstruction algorithm. We are exploring integration of higher fidelity X-ray models based on Monte Carlo techniques. We also want to explore algorithms that avoid the independence assumption of the scattering paths, requiring algebraic inversion, and perform joint reconstruction and recognition. The resulting algorithms can lead to new generations of X-ray diffraction imaging sensors that have higher photon counts than current systems by capturing additional scattering directions. The approach can be combined with multi-energy illumination and photon counting detectors, as well as advanced inversion techniques.

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