Gamma-Ray Imaging in 3D, Pixelated CdZnTe Using Stochastic Origin Ensembles

David Goodman
University of Michigan
Zhong He, hezhong@umich.edu
Consortium for Verification Technology (CVT)

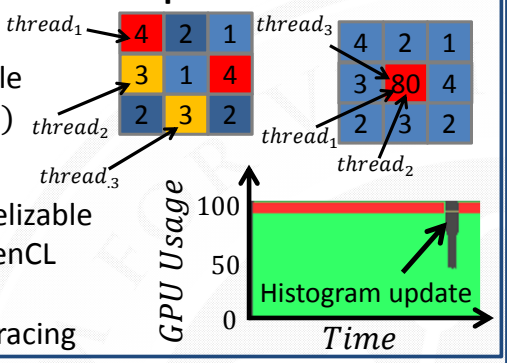
Abstract

The high energy, high position resolution of 3-D, pixelated CdZnTe detectors enables a wide variety of imaging modalities. Higher energy gamma-ray sources can be reconstructed via Compton imaging (CI) while lower energy sources are imagable via coded aperture (CA). Stochastic Origins Ensembles (SOE), a Bayesian technique relying on Markov Chain Monte Carlo (MCMC), can be used to improve reconstructed image quality over traditional simple back-projection (SBP). SOE successfully deconvolves detector response while returning comparable image quality to MLEM on measured point sources.

Parallelization Capabilities:

Histogram update:
- Highly parallelizable
- Source dep. $\mathrm{I}(\theta, \phi)$

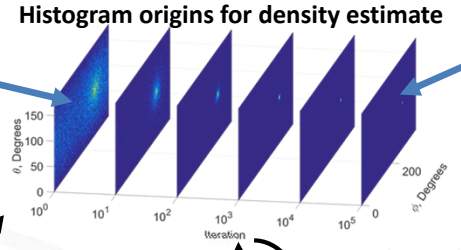
Point Picking:
- Completely parallelizable
- GTX 970 GPU: OpenCL
- Rings: random #
- Attenuation: ray-tracing



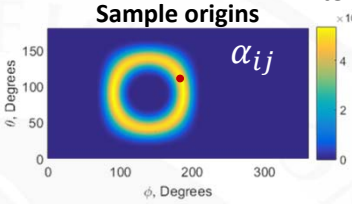
Algorithm Description:

Histogram origins for density estimate

$\hat{f}_{SBP}$ (biased) $\hat{f}_{SOE}$ (unbiased)

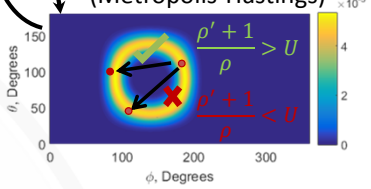


Sample origins

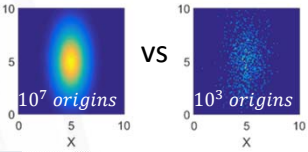


Iterate

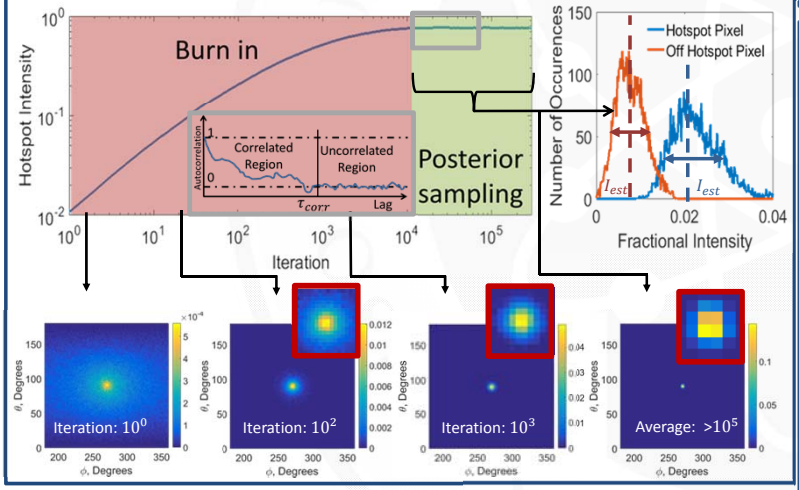
Resample, update estimates (Metropolis-Hastings)



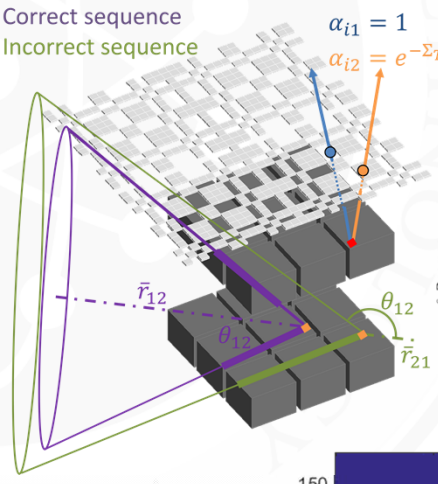
Limiting assumptions:
- Not true MCMC
  - Estimate true density via histogram
  - Low statistics performance?
- Model mismatch in α_{ij}



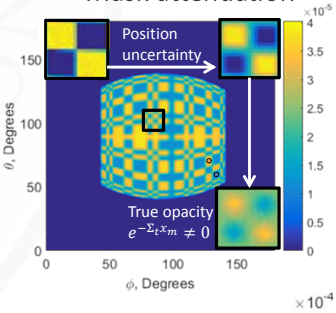
MCMC Chain Behavior:



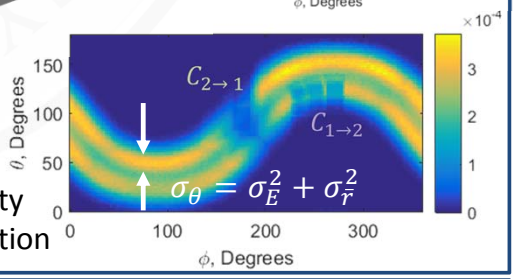
Sampling α_{ij}:



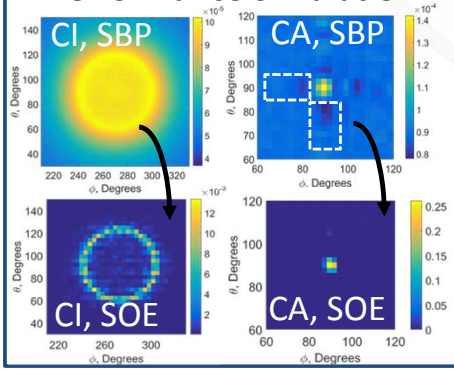
Coded Aperture:
- Position uncertainty
- Detector attenuation
- Mask attenuation



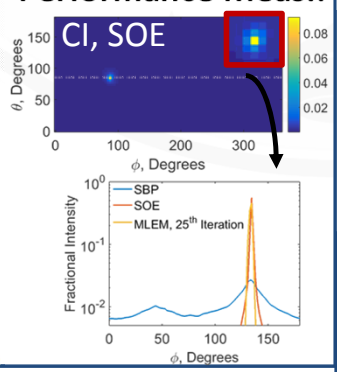
Compton Imaging:
- Sequencing
- Scatter uncertainty
- Detector attenuation



Performance Simulation:



Performance Meas.:



References:

1. A. Sitek, "Representation of Photon Limited Data in Emission Tomography using Origin Ensembles," vol. 72, no. 2, pp. 181–204, 2008.
2. D. Mackin, S. Peterson, S. Beddar, and J. Polf, "Evaluation of a stochastic reconstruction algorithm for use in Compton camera imaging and beam range verification from secondary gamma emission during proton therapy," Phys. Med. Biol., vol. 57, no. 11, pp. 3537–3553, 2012.
3. A. Sitek, Statistical computing in nuclear imaging, 2014.

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