Development of Fast Reconstruction Techniques for Prompt Gamma Imaging during Proton Radiotherapy

UMBC REU Site: Interdisciplinary Program in High Performance Computing

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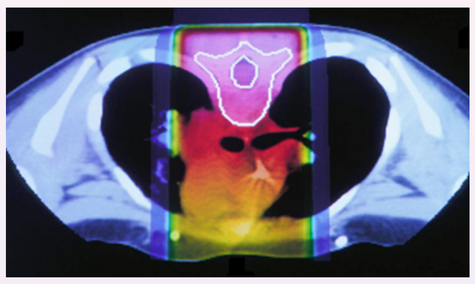
Motivation

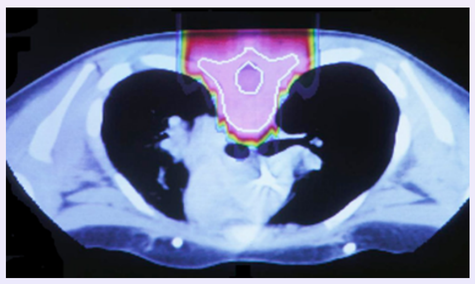
We apply parallel computing to the Stochastic Origin Ensemble (SOE) algorithm for the reconstruction of images of secondary gammas emitted during proton beam therapy. We implement MPI to optimize the C++ implementation of the algorithm to allow the use of multiple compute nodes.

Proton Beam Therapy

The use of proton therapy for treating cancer has greatly increased over the past decade because of the advantageous properties of proton beams.



X-Ray Treatment



Proton Beam Treatment

Because of the uncertainties in the exact position of the distal dose gradient within the patient, a method of verifying the in vivo beam range is critcal.

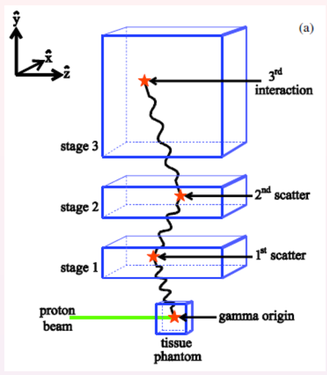
References and Acknowledgments

[1] Mackin, Peterson, Beddar, and Polf, *Phys. Med Biol.*, 2012

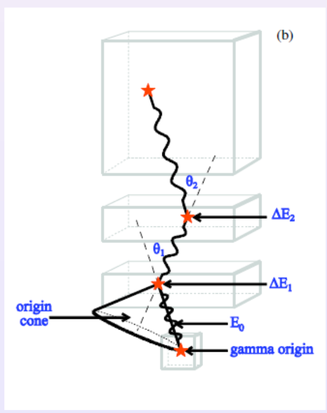
[2] Full technical report: HPCF–2017–16 `hpcf.umbc.edu` > Publications

- REU Site: `hpcreu.umbc.edu`
- NSF, NSA, DOD, UMBC, HPCF, CIRC, NIH, Constellation Energy

SOE Algorithm



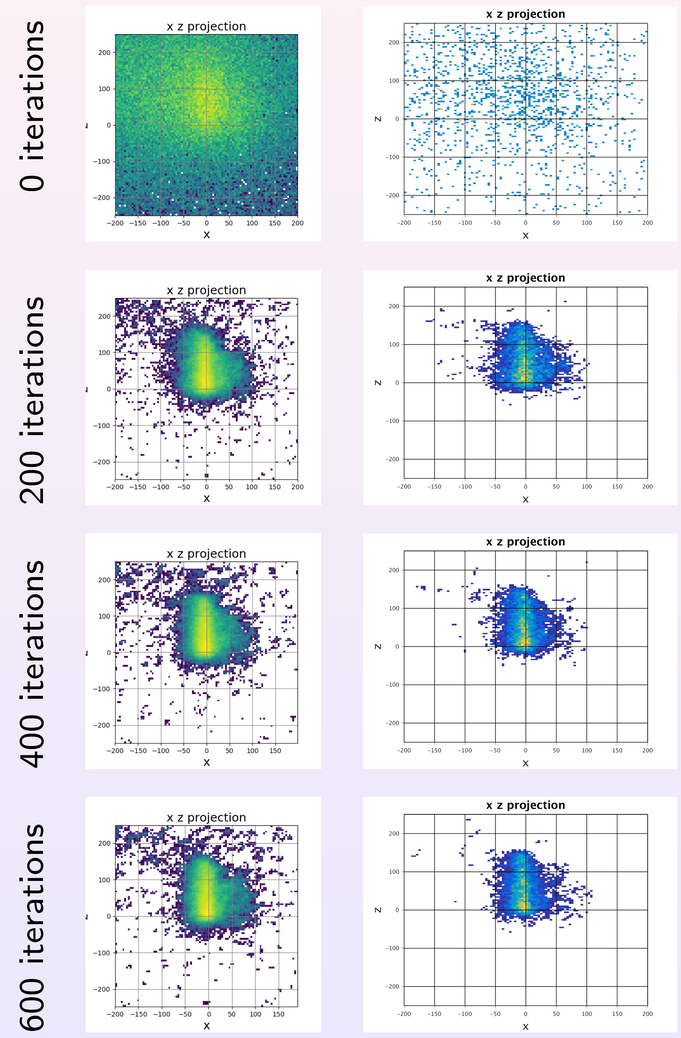
- Gamma rays scatter into the Compton Camera (CC). The CC records the coordinates of each hit.
- The algorithm then constructs the origin cones.



- Random points are chosen within each cone to be a likely origin.
- Each iteration attempts to move each origin to a more probable point.

Convergence of Reconstruction

Convergence of reconstructed image:



- Serial Algorithm plots likely origin. MPI Algorithm plots histogram.
- Both give necessary resolution and correct image

Performance on Maya with 4 Nodes (two 8-core E5-2650v2 CPUs each)

Observed wall clock time in seconds for reconstruction of image from 100,000 cones with $102 \times 102 \times 126$ bins in 3-D histogram using 600 iterations:

Computational cores	1	2	4	8	16	32	64
OpenMP multi-threading	1885	889	344	188	105	N/A	N/A
Original MPI algorithm	1592	546	372	354	511	477	430
Modified MPI algorithm	985	485	277	184	148	392	83

- Multi-threaded algorithm using OpenMP is effective, but limited to one node.
- Initial MPI algorithm computates reconstruction of image to same quality. It did not show good performance, but can scale to multiple nodes.
- Modified MPI algorithm shows better performance. Key potential for additional speedup lies in optimizing the code more and in using hybrid MPI+OpenMP code.