High Performance Computing for Neutron Tomography Reconstruction
A Parallel Approach to Filtered Backprojection (FBP)

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August 3, 2017

Outline

1. Background
   - What is Laminography?
   - Filtered Backprojection Algorithm
   - MATLAB Data
2. Objectives
3. Methods
   - Filter
   - Serial Program
   - Parallel Program
4. Future Work

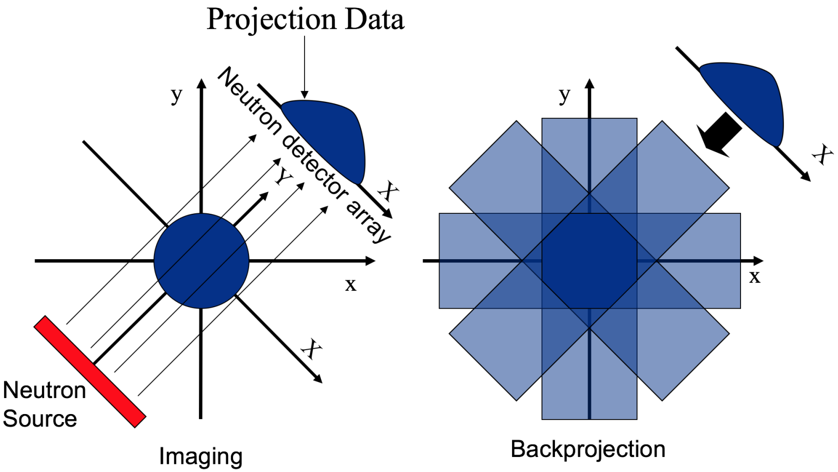
Outline

Laminography & Tomography

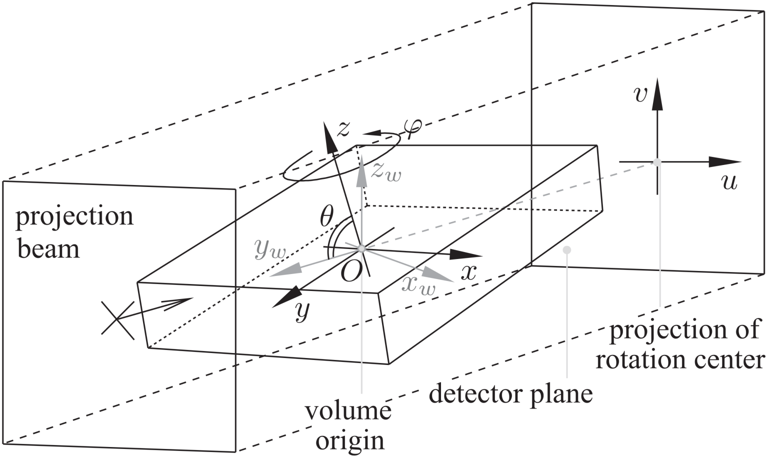
- Image Processing
- Reconstruction of 3D volume from 2D projections (sinograms)
- Fourier/harmonic analysis (specifically Radon transform)

Tomography is special case of laminography (tilt angle $= 0^\circ$)

2D Tomography



3D Laminography



Outline

Filtered Backprojection (FBP) Algorithm

Inverse Radon Transform

$$f(x, y) = \int_0^{\pi} p_f(x \cdot \cos\theta + y \cdot \sin\theta) d\theta$$

projections & orientation information $\rightarrow$ volume

For each projection...

- clean it up (filter)
- "smear" it through the volume (backproject & interpolate)

...then sum all smeared projections

Result: reconstructed 3D volume

Filtered Backprojection (FBP) Algorithm

initialize

↓

filter projections

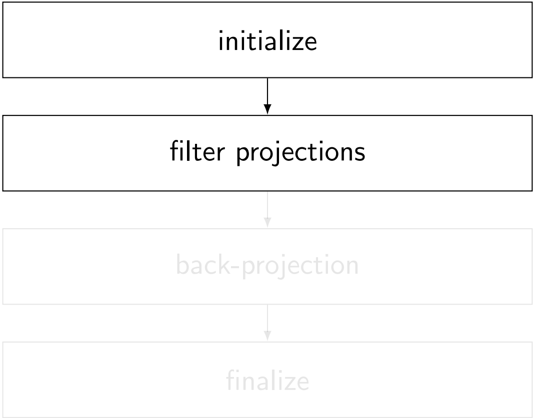
↓

back-projection

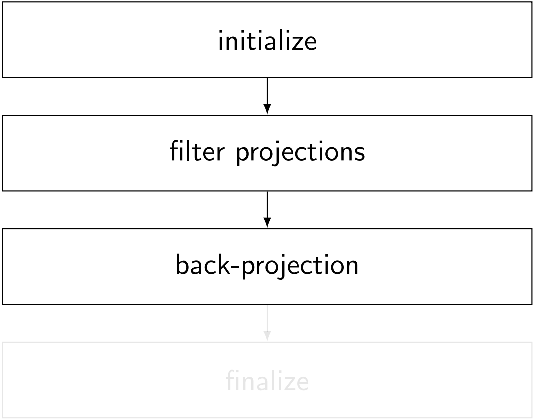
↓

finalize

Filtered Backprojection (FBP) Algorithm



Filtered Backprojection (FBP) Algorithm



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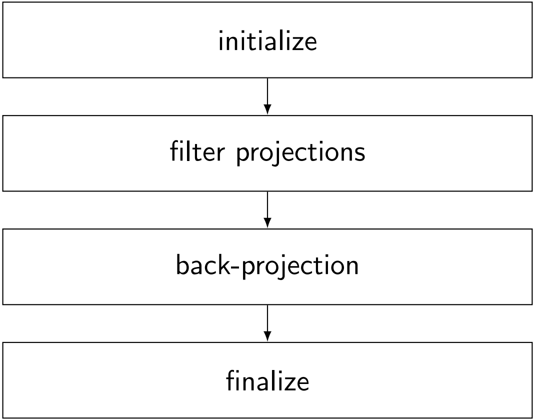

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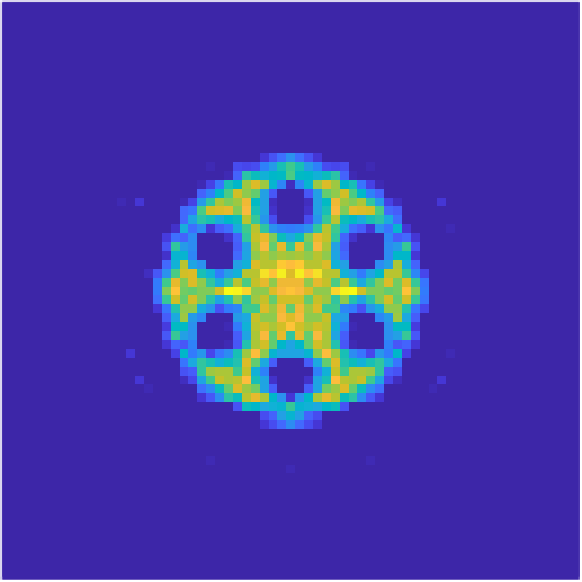
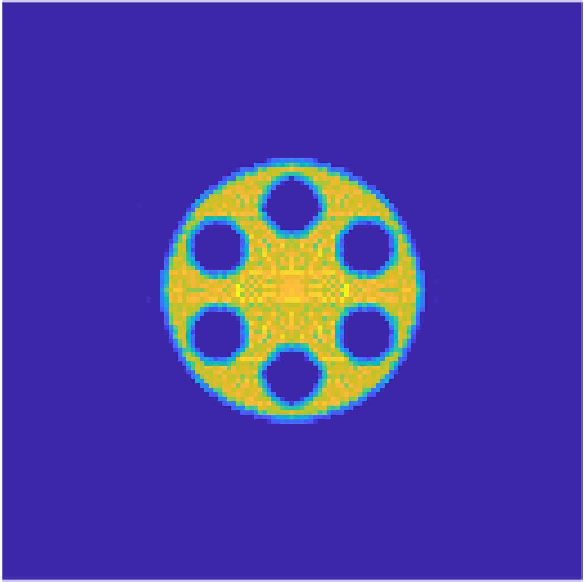
Simulation



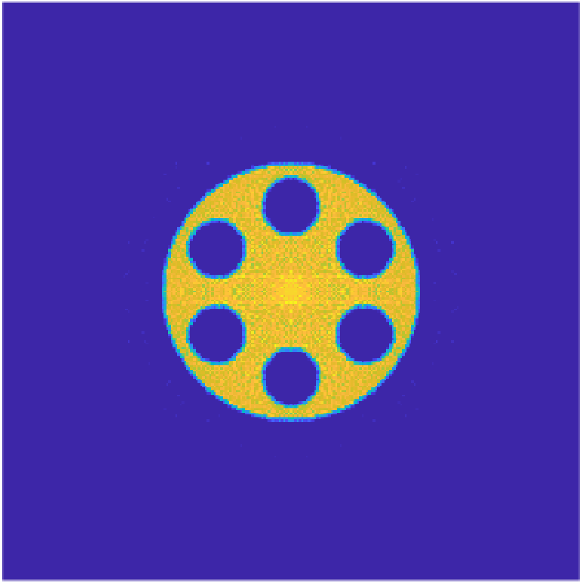
Volume: $65 \times 65 \times 65$

Simulation



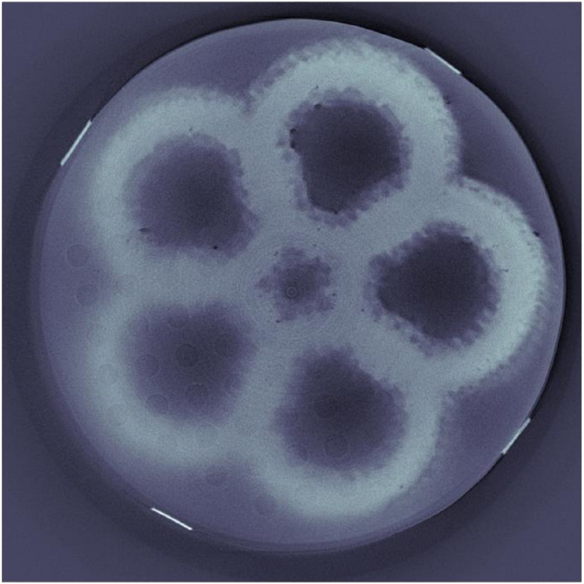
Volume: $129 \times 129 \times 129$

Simulation



Volume: $257 \times 257 \times 257$

ORNL Spallation Neutron Source (SNS) Data



“Volume”: $1501 \times 1501 \times 1$

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Overall reduction in code execution time and memory requirements

- Implement laminography filter

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  - Graphics Processing Unit (GPU) → FFT and filtering

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Filter Selection

Filter necessary to reduce blurring from backprojection

- basic high-pass ramp filter (standard in tomography)
- laminographic ramp filter (scaled depending laminography angle)
- sinc filter (slightly varying frequency response)
- cutoff frequency (dependent upon experiment geometry)

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Using laminographic ramp filter with adjustable cutoff frequency

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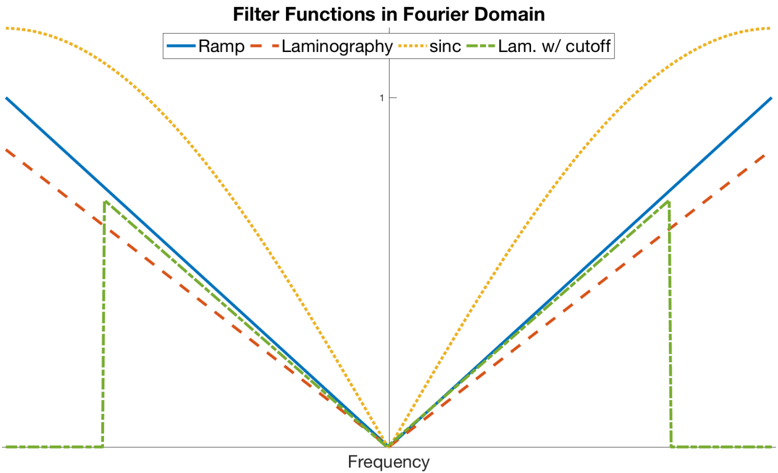

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Reading data formatted for MATLAB:

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Backprojection:

- coordinates before & after rotation
- meshgrid?

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Pointers and integers...

Outline

Parallel Program

Different Approaches

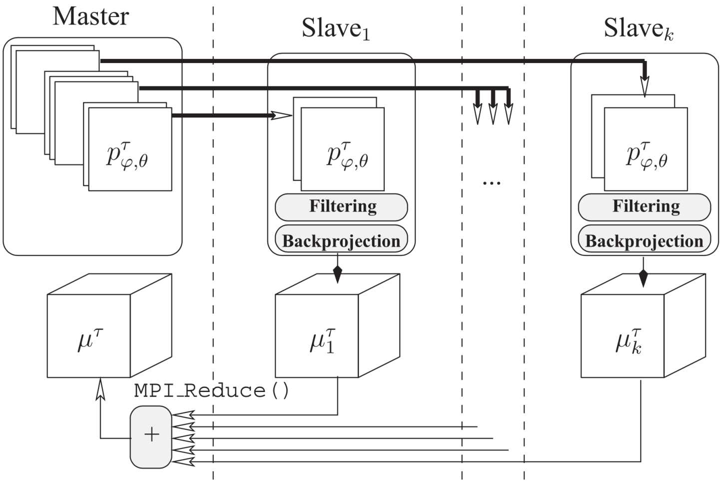
MPI (Myagotin, *et al.*):

- distribute projections (many independent projections)
- decompose reconstructed volume (single volume between all nodes)

GPU acceleration:

- FFT (many 1D transforms)
- applying filter (many multiplication operations)
- interpolation (texture mapping for hardware acceleration)

Data decomposition by projections



Intel MPI Library
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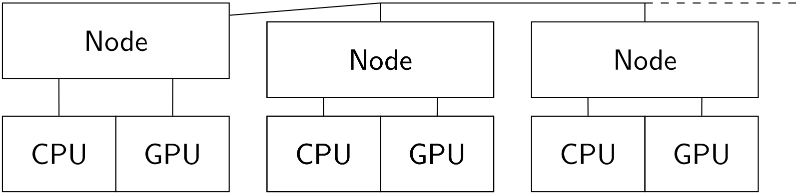
Drawbacks:

- large memory consumption (each node has full memory in volume)
- `MPI_Reduce` operation (more operations to perform)

GPU

Hardware configuration



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Execution time improved over serial code
Testing data sets could be too small to see major improvement?

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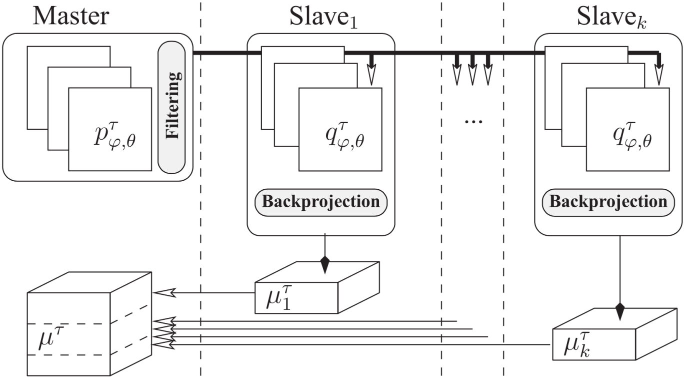
Data decomposition by reconstructed volume



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- MPI: communication improvement via “ring” method
- GPU: hardware interpolation

Acknowledgements

University of Tennessee, Knoxville (UTK)
Oak Ridge National Laboratory (ORNL)
Joint Institute for Computational Sciences (JICS)
National Science Foundation
Extreme Science and Engineering Discovery Environment (XSEDE)
Bridges system, Pittsburgh Supercomputing Center (PSC)

Dr. Rick Archibald (ORNL)
Dr. Kwai Wong (UTK, JICS)

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