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The Center for Cyber Defenders
Expanding computer security knowledge

Improving Memory Reuse with FPGAs for Computed Tomography Reconstruction

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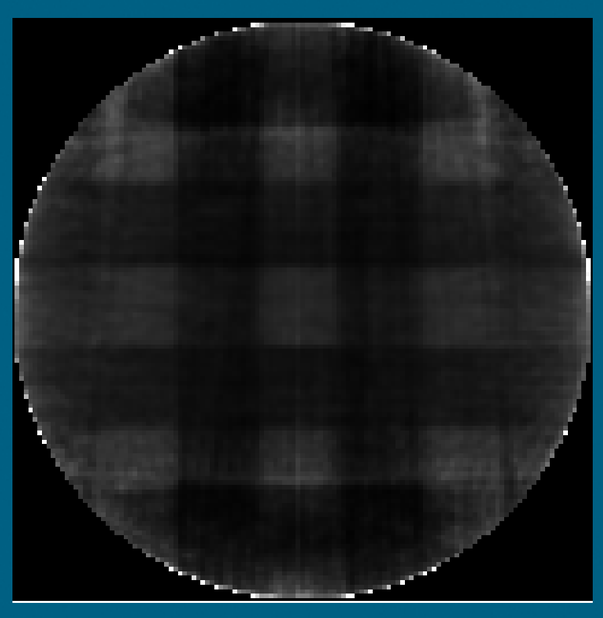
Problem Statement:

- Computed tomography (CT) is a reconstruction of thousands of X-ray images to create a single 3D-image of an object that can be rotated and examined internally.
- A Field Programmable Gate Array (FPGA) is a integrated circuit designed to be configured by the user. Programming FPGAs directly can be difficult.
- Reconstruction of CT images can be expedited with FPGA technology as compared to Graphics Processing Units (GPUs). While GPUs are normally excellent at image reconstruction, FPGAs will increase computational efficiency by decreasing memory bottleneck thus improving performance.

Objectives and Approach:

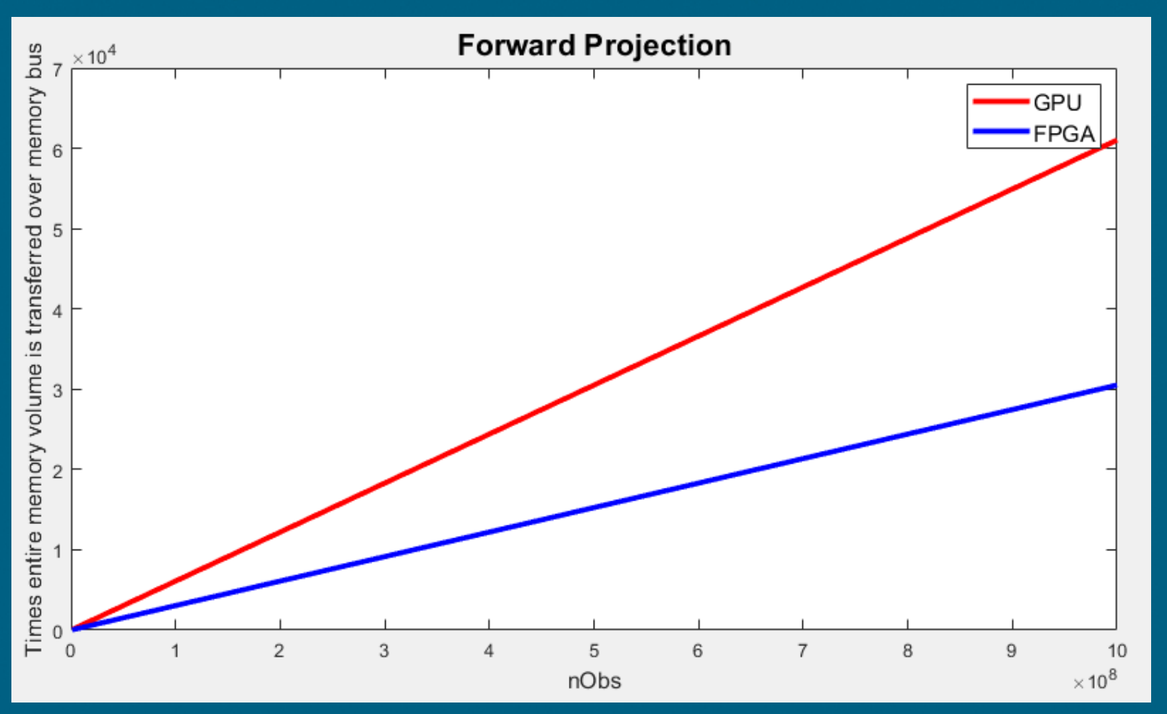
- Objective: Reduce execution time for CT reconstruction by increasing memory efficiency. This can be achieved with FGPAs by improving memory reuse thus reducing total memory traffic and execution time.
- The reconstruction method for the CT follows the maximization-likelihood expectation-maximization (MLEM) algorithm. This iterative algorithm contains forward, backward, and reconciliation steps which are limited by memory traffic constraints and computational expense.
- We are exploring abstract programming approaches and we are initially investigating HLS (high-level synthesis) since directly programming FPGAs is very complex.
- We are using a Xilinx Alveo U200 FPGA.

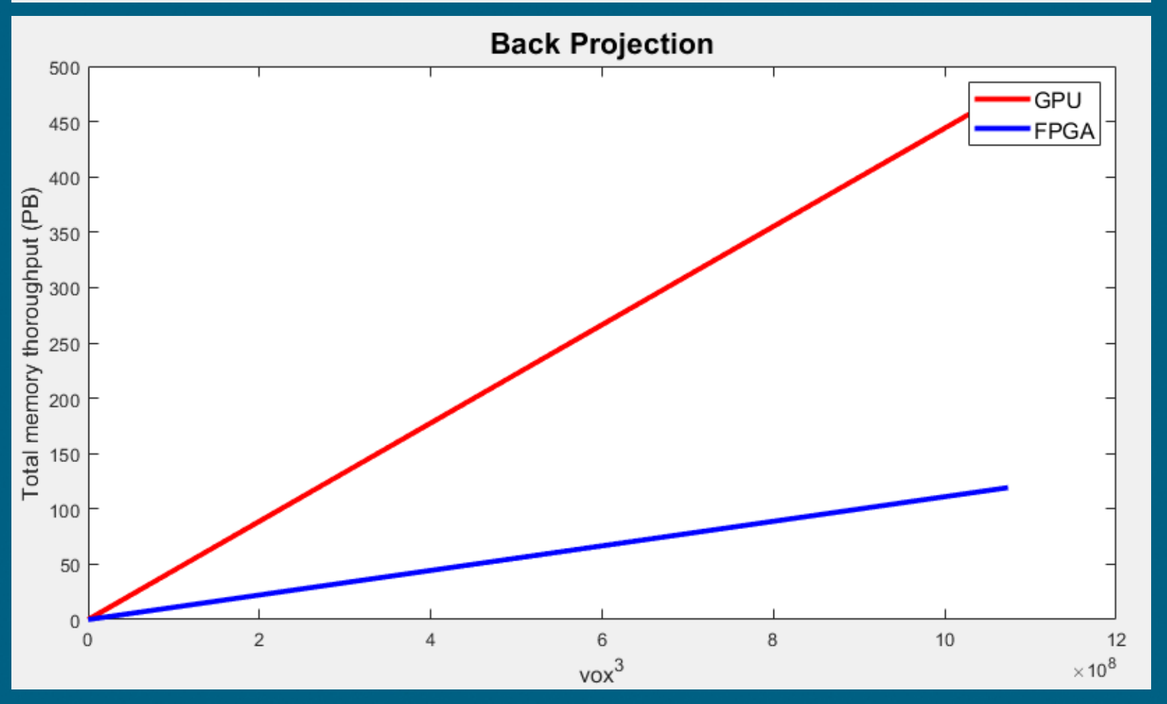


An example reconstruction of 3x3 grid copper bars

Preliminary Results:

- Dataset: Our exemplar data consists of 11,206,656 observations with a total size of 1.1 GB. We process this data in 10 iterations with a runtime of 42.480 min.
- Forward projection: The amount of times entire memory volume is transferred over the memory bus is orders of magnitude lower for FPGAs.
- Back projection: The total memory throughput (PB) over the memory bus is orders of magnitude lower for FPGAs.





Impact and Benefits:

- MLEM allows for more accurate reconstructions but takes orders of magnitude more time than traditional reconstruction algorithms. This work means that MLEM could now be more widely implemented.
- Optimized CT reconstruction has numerous applications:
  - Airport security: CT increases throughput by decreasing manual checks since the 3D image shows an unobstructed view of a bag's contents.
  - Manufacturing: CT allows for quality control of internal components.

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