The Effect of Performance Optimizations on Soft Error Reliability for Machine Learning Applications

Eda Nur Azın, Işıl Öz

Izmir Institute of Technology

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Outline

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GPUs: Accelerators for Machine Learning

- Developing ML applications starts with training models with large datasets
- GPUs offer throughput-optimized fast parallel processing
- Architectures powered by tensor cores provide faster training and greater performance (especially for neural networks)

GPU Reliability

- With many execution cores and complex memory structures, GPUs show high vulnerability to soft errors
- GPGPU applications do not tolerate errors like graphics applications

Performance/Reliability Tradeoff

- With many execution cores and low-latency memory structures, GPUs offer different performance optimizations
- How do the performance optimizations affect the reliability of the applications?

Outline

CUDA Performance Optimization Principles [1]

- Leverage zero-overhead thread scheduling to hide memory latency
- Optimize use of on-chip memory to reduce bandwidth usage and redundant execution
- Group threads to avoid SIMD penalties and memory port/bank conflicts
- Threads within a thread block can communicate via synchronization, but there is no built-in global communication mechanism for all threads

[1] *"Optimization Principles and Application Performance Evaluation of a Multithreaded GPU Using CUDA"*, S. Ryoo et al., *PPoPP*, 2008.

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Reliability Evaluation on GPUs

- Fault injection experiments
- SASSIFI [2]
  - Does not work for our target platform since NVIDIA has removed the support in the modern architectures (after Maxwell)
- GPU-Qin [3]
  - Too slow due to assembly-level fault injection
- CAROL-FI [4]
  - Software-level open source fault injector tool based on GDB

[2] *"SASSIFI: An architecture-level fault injection tool for GPU application resilience evaluation"*, Hari et al., *ISPASS*, 2017.

[3] *"GPU-Qin: A methodology for evaluating the error resilience of GPGPU applications"*, Fang et al., *ISPASS*, 2014.

[4] *"Reliability Evaluation of Mixed-Precision Architectures"*, Fernandes dos Santos et al., *HPCA*, 2019.

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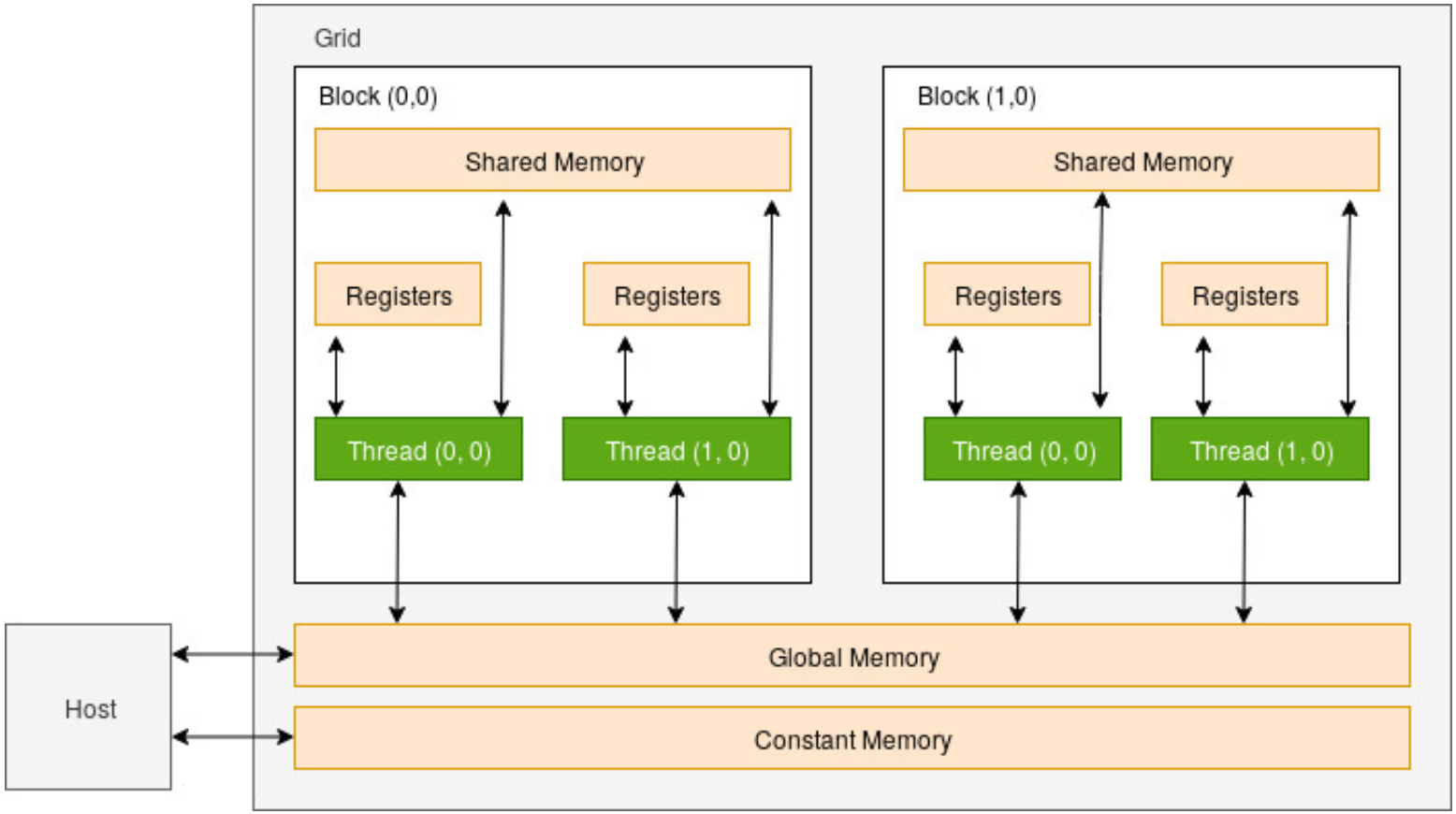
K-means

- Commonly-used clustering algorithm
- Initializing the centroid points for the given cluster
- Until convergence
  - Calculate the distance from each point to each cluster centroid
  - Assign each point to the cluster which is the closest
  - Recalculate each centroid point such that the mean of all points assigned to it

CUDA Memory Model



Application Versions

Simple K-means

The assignment of the points, the computation of the distance, and the update of the centroid points are distributed into CUDA threads

K-means with Thrust Library

Thrust data structures

K-means with SM

Loading data from global memory to shared memory once for all computation without separate references to the global memory for repeating accesses

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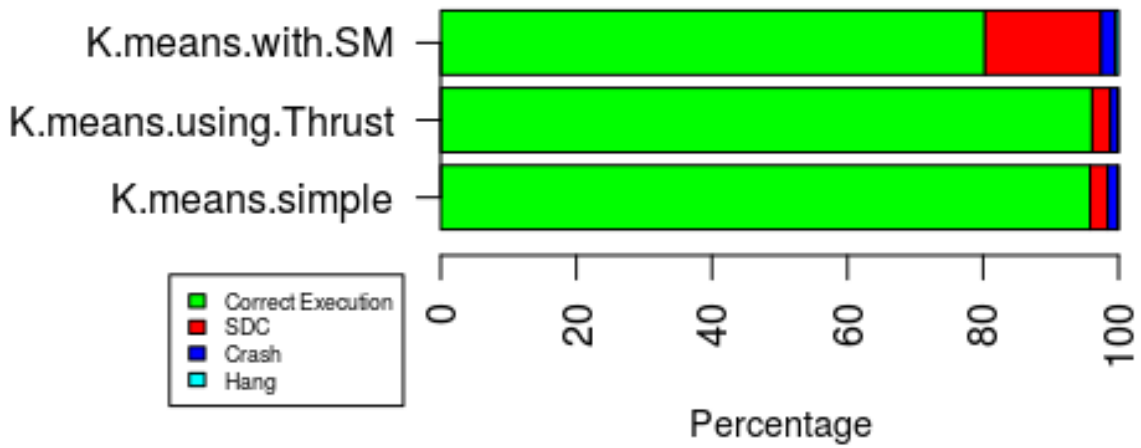
Performance Results

	CPU	GPU	CPU + GPU
Simple approach	4.484s	2.777s	7.034s
Using Thrust	8.664s	2.771s	11.342s
With shared memory	4.440s	2.652s	6.916s

Fault Injection Results



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Research Questions

- Do all performance optimizations impact the ML applications' soft error reliability?
- Do performance optimizations applied for ML applications impact soft error reliability for all hardware structures?
- What kind of performance optimizations do impact the ML applications' soft error reliability?
- Can we generalize the effect of the optimizations?
- Is there a tradeoff between performance and reliability for different versions of ML applications?
- What are the possible suggestions for the software developers aiming faster code to develop also more reliable software?
- What kind of fault tolerance techniques can be developed by considering fast but reliable GPU computation?

Conclusion

- Conduct more systematic and complete work for the analysis of soft error reliability for ML applications
- Extend the analysis for neural network applications

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