Fast Monte Carlo Photon Transport Simulations for Heterogeneous Computing Systems

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Motivation

- Monte Carlo (MC) method is considered as the gold standard for modeling light propagation inside complex media, such as human brains or bones.
- Due to its computational complexity, sequential execution can easily take up to several hours.
- Leveraging Graphics Processing Units (GPUs), we can significantly reduce the simulation time.
- For scalability and portability, we have developed a fast Monte Carlo photon transport simulation framework in OpenCL for heterogeneous computing systems.

Algorithm

Optimizations

- OPT1: Native Math
- OPT2: Balanced Threads
- OPT3: Simplify control flow

Evaluation

Benchmarks

- B1: No reflection
- B2: Reflection with nonatomic operations
- B2a: Reflection with atomic operations

Implementation

Load-partitioning strategies

- S1: Number of stream-processors
- S2: Estimated device throughput
- S3: Linear-programming solution

Results

- GPUs excel in MC simulations with many less powerful cores. The Intel HD 520 GPU reports the highest power efficiency.
- Optimization schemes achieve a 56% performance improvement on average on AMD GPUs, 20% on Intel CPUs/GPUs, and 10% on NVIDIA GPUs.
- Efficient load-partitioning strategies, based on the device throughput and linear-programming models, achieve higher throughput vs. core-based approach.

References

- Source code for MCXCL, http://mcx.space/mcxcl

Acknowledgement

- This research is supported by the National Institutes of Health (NIH) grants # R01-GM114365 and R01-CA204443.