

Purpose

To provide a fast and accurate dose calculation solution, a massively parallel version of a Monte Carlo superposition (MCS) method is developed on a computer with a Nvidia GTX260 graphics card.

Method and Materials

Graphics processing units (GPU) can be extremely powerful and economical in accelerating computationally intensive applications. However, the GPU memory structure can be too rigid for certain types of applications to realize its computation potential. The MCS method, by nature, is a memory-intensive application since most of its operations are based on linear interpolation and table-look-up. To leverage the power of GPU, we modified a sequential MC algorithm and implemented a parallel version. The biggest challenge to our implementation is to how to arrange memory access sequences and increase temporal and spatial data locality. We introduced several techniques for handling this challenge, including stage-based processing, photon grouping with respect to kernel index, etc. To match the hierarchy of GPU memory, data were carefully organized to minimize off-chip memory accesses. A parallel thread-safe random number generator was implemented to produce the necessary randomness required by the MC algorithm.

Results

Our GPU-based implementation is based on fully optimized code and demonstrates a speedup of 25~40 times over the CPU-based single-thread implementation. Although the speedup is significant, the research does reveal some inherent limitations on the GPU-based implementation of the particular target MC algorithm. The most critical one is due to the conflicts between the GPU's SIMD (single-instruction-multiple-data) architecture and the stochastic nature of the MC algorithm.

Conclusion

A massively parallel version of a MCS method is implemented on a computer powered by GTX260 GPU and a speedup up to 40X is observed. This indicates that a GPU-based MC approach is viable and cost-efficient for satisfying the increasing demands on computation power and accuracy by advanced radiation therapy technologies.