AN EFFICIENT CUDA IMPLEMENTATION OF THE TREE-BASED BARNES HUT *N*-BODY ALGORITHM

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The Barnes Hut force-calculation algorithm [1] is widely used in n-body simulations such as modeling the motion of galaxies. It hierarchically decomposes the space around the bodies into successively smaller boxes, called cells, and computes summary information for the bodies contained in each cell, allowing the algorithm to quickly approximate the forces (e.g., gravitational, electric, or magnetic) that the n bodies induce upon each other. The hierarchical decomposition is recorded in an octree, which is the three-dimensional equivalent of a binary tree. With n bodies, the precise force calculation needs to evaluate O(n2) interactions. The Barnes Hut algorithm reduces this complexity to O (n log n) and thus makes interesting problem sizes computationally tractable.

The Barnes Hut algorithm is challenging to implement efficiently in CUDA because (1) it repeatedly builds and traverses an irregular tree-based data structure, (2) it performs a lot of pointer-chasing memory operations, and (3) it is typically expressed recursively. Recursion is not supported by current GPUs, so we have to use iteration. Pointer-chasing codes execute many slow uncoalesced memory accesses. Our implementation combines load instructions, uses caching, and throttles threads to drastically reduce the number of main memory accesses; it also employs array-based techniques to enable some coalescing. Because traversing irregular data structures often results in thread divergence (i.e., detrimental loss of parallelism), we group similar work together to minimize divergence.

1. J. Barnes, P. Hut, A hierarchical O(*n* log *n*) force-calculation algorithm, *Nature*, **324** (4) 446 (1986).

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