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AN EXACT GPU-ACCELERATED ALGORITHM FOR THE SUBSET SUM PROBLEM

The Subset Sum Problem is a well-known NP-complete problem that asks whether there exists a subset of a given set of integers that sums up to a given target value. This problem has many applications in cryptography, combinatorics, and optimization. However, finding an exact solution for large instances of the problem is computationally challenging, as the number of possible subsets grows exponentially with the size of the input set.

An exact algorithm for solving the Subset Sum Problem with acceleration on GPU is proposed in this work. The algorithm is based on backtracking [1, p. 231], a general technique that explores the search space of possible solutions by recursively branching on each element of the input set. Pruning is utilized to restrict the exploration.

When the current partial sum surpasses the target value, the path is deemed infeasible, and the algorithm backtracks to explore alternative branches. Furthermore, if the sum of the current subset and the maximum achievable sum remaining falls below the target, the branch is abandoned to prevent exhaustive exploration of unproductive paths. These pruning rules allow the elimination of large portions of the search space that cannot contain a feasible solution.

The algorithm consists of two phases: a breadth-first search (BFS) phase on CPU and a depth-first search (DFS) phase on GPU. In the BFS phase, the algorithm starts from the empty subset and expands it by adding one element at a time, following the order of the input set. The intermediate subsets and their sums are stored in a queue, and the pruning rules are applied to discard infeasible subsets. The BFS phase stops when a predefined depth limit is reached, or when the queue is empty, or when a solution is found.

In the DFS phase, the data from the queue is transferred to the GPU memory, and a kernel with multiple threads is launched. Each thread performs a DFS on a different subtree of the search space, starting from a different subset in the queue. The DFS phase follows the same logic as the BFS phase, but it uses a stack instead of a queue to store the intermediate subsets. The DFS phase terminates when all the threads finish their work, or when a solution is found.

The proposed algorithm was implemented in C# programming language using the ILGPU library, which provides a high-level abstraction for GPU programming.

The proposed algorithm is an effective method for solving the Subset Sum Problem with acceleration on GPU. The algorithm exploits the parallelism and the memory hierarchy of the GPU architecture, and reduces the search space by applying pruning rules. The algorithm can be extended to solve other NP-complete problems that can be formulated as subset problems, such as the knapsack problem, the set cover problem, and the partition problem.

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