Multi-GPU Island-Based Genetic Algorithm for Solving the Knapsack Problem

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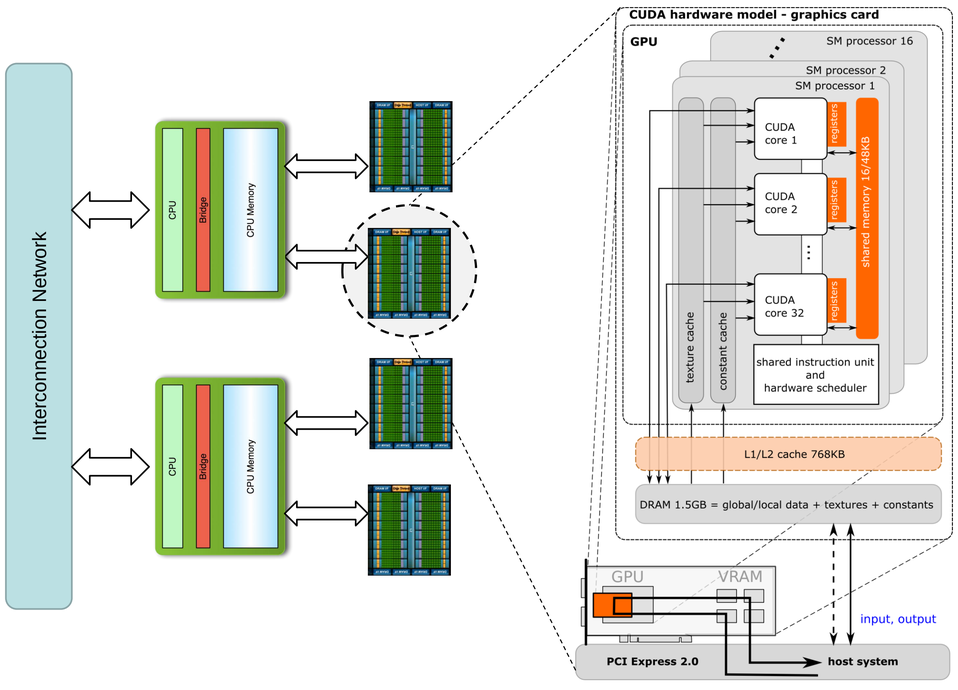
1 Overview

The Genetic Algorithms (GAs) have become widely applied optimization tools since their development by Holland in 1975 [1]. One of the famous NP-hard problems successfully solved by GAs is the knapsack. However, millions of candidate solutions have to be created and evaluated for large problem instances rising the execution time up to hours and days [2]. The latest GPUs are about 15 times faster than six-core Intel CPUs which opens new possibilities for massive acceleration of GAs [3].

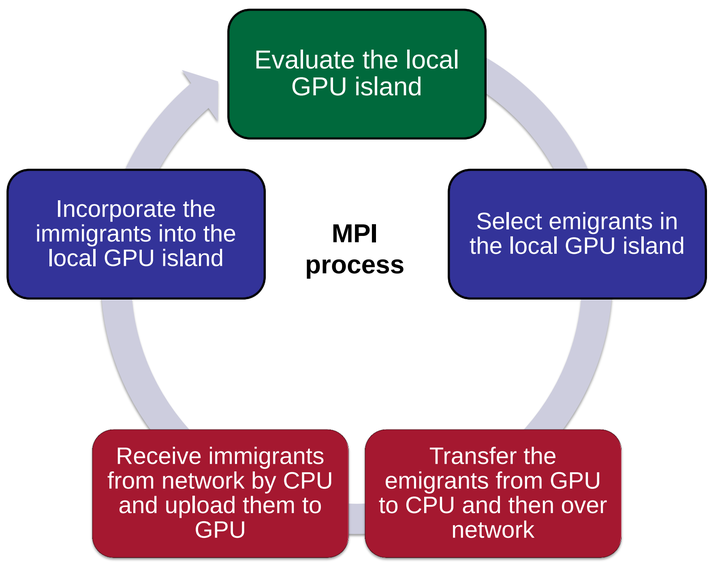
2 Multi-GPU Cluster Systems

The availability of multiple PCI-Express buses, even on very low cost commodity computers, means that it is possible to construct cluster nodes with multiple GPUs. Inter-node communications are done via MPI over a high speed network while intra-node communications exploit CPU shared memory.



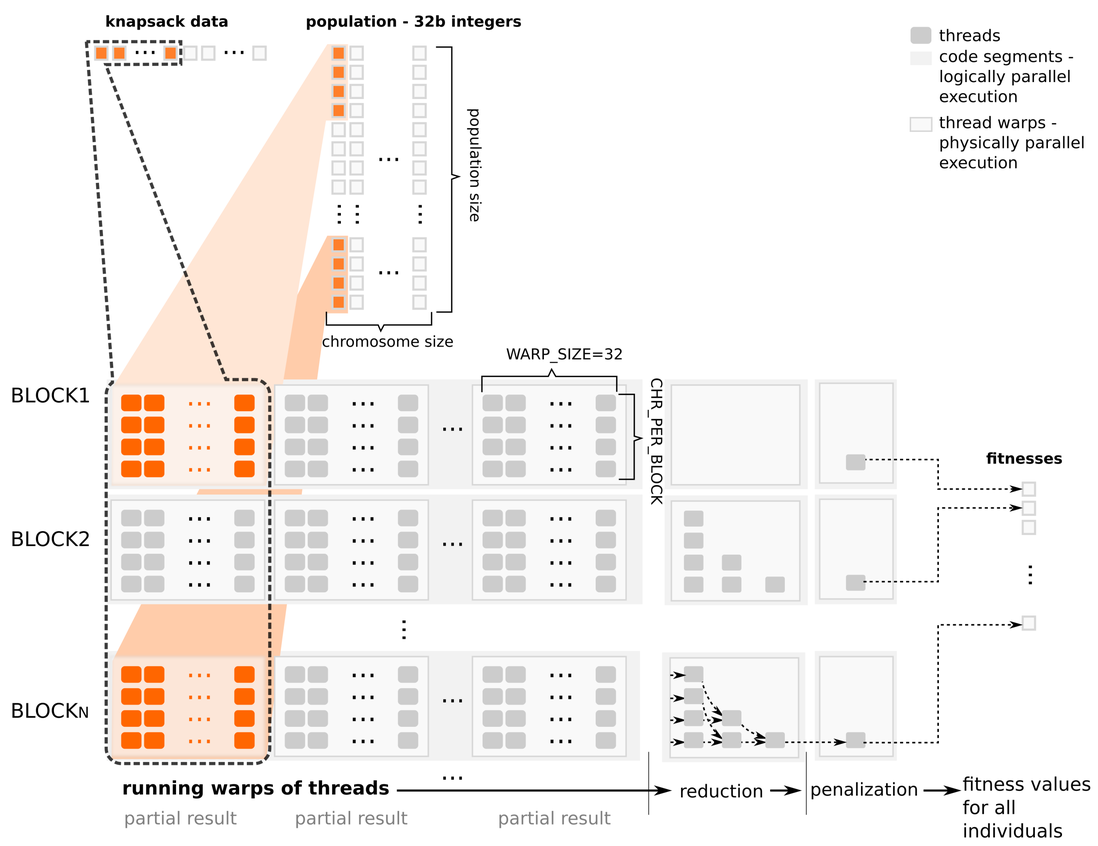
3 Multi-GPU Island-Based Genetic Algorithm

The population of the GA is distributed over multiple GPUs. Every GPU, controlled by a single MPI process, entirely evolves a single island. Migration of individuals occurs after a predefined number of generations exchanging the best local solution and an optional number of randomly selected individuals over a ring topology.



4 Local GPU Island Implementation Details [4]

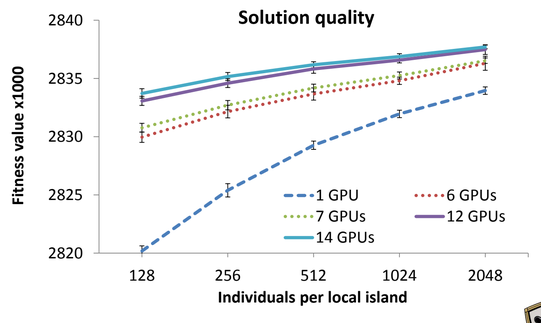
- 32 knapsack items packed into a single integer value
- Individuals processed by CUDA WARPS in multiple rounds
- Most CUDA block barriers removed
- Negligible thread divergence (< 0.5%)
- Blocks of knapsack data shared within the block
- Uniform crossover, bit-flip mutation, binary tournament

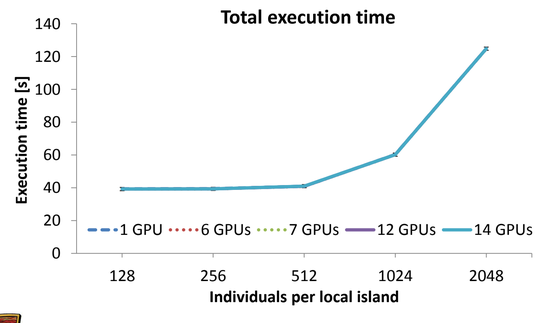


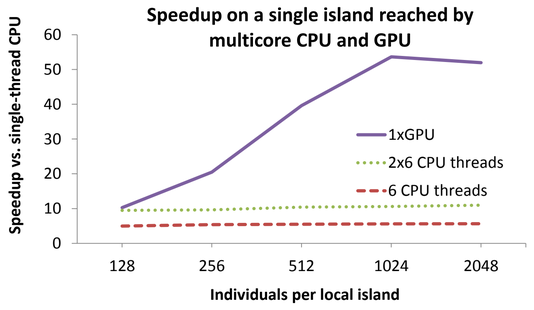
5 Experimental Results

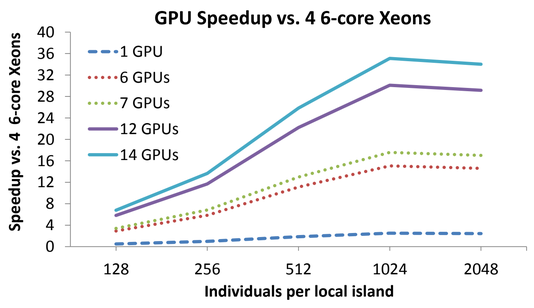
- Highly optimized CPU implementation running on 4 6-core Intel Xeon processors with 40Gb infiniband interconnection
- CUDA implementation running on 14 NVIDIA GTX 580

Knapsack problem with 10,000 items









6 Conclusions

The proposed multi-GPU island-based GA allows the solution of large-scale instances of the knapsack problem.
The significant benefits:

- Speedups up to **35**, **194**, **781** (14 GPUs vs. 24, 6, 1 cores)
- Overall performance of **5.67 TFLOPS** (14 GPUs)
- Overall efficiency of **26%**

The codes will be released as an open-source software (http://www.fit.vutbr.cz/~jarosjir).

[1] J. H. Holland, “Adaptation in Natural and Artificial Systems”, Ann Arbor, no. 53. University of Michigan Press, 1975, p. 211
[2] Z. Michalewicz and J. Arabas, “Genetic algorithms for the 0/1 knapsack problem”, in Lecture Notes in Computer Science, 1994, vol. 869/1994, 134-143
[3] V. W. Lee et al., “Debunking the 100X GPU vs. CPU myth,” in Proceedings of the 37th annual international symposium on Computer architecture - ISCA ’10, 2010, p. 451
[4] J. Jaros and P. Pospichal, “A Fair Comparison of Modern CPUs and GPUs Running the Genetic Algorithm under the Knapsack Benchmark”, in Applications of Evolutionary Computation, Heidelberg, DE, Springer, 2012, p. 426-435

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