GPU Implementation of Ant Colony Optimization for TSP

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Ant Colony Optimization

- Combinatorial (discrete and finite) optimization method
  - Traveling Salesman Problem (TSP)
  - Vehicle Routing Problem
  - Nurse Scheduling Problem
  - Job Shop Scheduling
- Simulates how ants release pheromones when traversing a graph
- Massively parallelizable: each ant is independent of all other ants

$$\tau(i,j)^{(k+1)} = (1-\rho)\tau(i,j)^{(k)} + \sum_{a=1}^{m} \frac{1}{w^{(a)}}, \quad \forall (i,j) \in \mathcal{V}^{(a)}$$

Our Work

- CPU impl
  - The pheromone matrix is serially updated, so there are no race conditions. Every ant in every iteration gets the current best pheromone matrix for recomputation of attractiveness.
- GPU impl
  - We implement coarse grained parallelism by deploying one ant on every thread, as opposed to fine grained, where every block deploys a single ant [1].
  - There are no race conditions since we synchronize all ants before a maximized update is made to a single memory location.
- OpenMP Impl on CPU
  - We simply introduce a parallel for directive over the serial iterator. This should cause race conditions, since the update is not atomized.

Runtime Comparison

The runs are linear on number of ants.

CPU runtimes on 11 nodes:

Ants	Time (s)	Optimality
1028	5.169134	0.9539
2048	9.848466	0.9626
4096	20	0.9696
8192	39.167262	0.9852
16384	78.566860	0.9852

GPU improvements:

Test	Nodes	CPU Time (s)	GPU Time (s)
1	11	339.893231	0.275187
2	38	1244.983243	2.026859

Hardware Information

- CPU implementation: Cycle computers.
- GPU implementation: GPU nodes at the cycle computers

Future Work

- Reduction
- Atomics for OpenMP
- Fine-grained ants
- Micro-optimizations: storing inverse distances

References

[1] B. A. M. Menezes, H. Kuchen, H. A. Amorim Neto, and F. B. de Lima Neto, “Parallelization strategies for GPU-based ant colony optimization solving the traveling salesman problem,” in *2019 IEEE Congress on Evolutionary Computation (CEC)*, 2019, pp. 3094–3101.

[2] A. Uchida, Y. Ito, and K. Nakano, “An efficient GPU implementation of ant colony optimization for the traveling salesman problem,” in *2012 Third International Conference on Networking and Computing*, 2012, pp. 94–102.