Sample-sort simulated annealing for parallel optimization

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Introduction

Can you find the minimum value of the two functions plotted below and at what the coordinates they occur (x1, x2)? Many real-world optimization problems such as network design require solving complex functions like the ones below. Either the minimum or maximum value is desired.

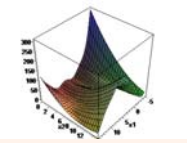

Fig. 1. Branin is a 2-dimension (2-D) function and has three global minima at (-3.14, 12.28), (3.14, 2.28), (9.42, 2.48) with a minimal value of 0.3979.

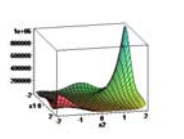

Fig. 2. GoldPrice is a 2-D function and has a global minimum at (0, -1) with a minimum value of 3.

Sample-sort simulated annealing

Simulated annealing accepts higher cost solutions when minimizing functions in a controlled way to climb out of local minima and find a global minimum. It will converge to the optimum solution in the limit.

Sample-sort simulated annealing is a parallel version of simulated annealing. It samples the function in parallel and then sorts them. It is convergent in the limit and is well-suited to take advantage of parallel processing.

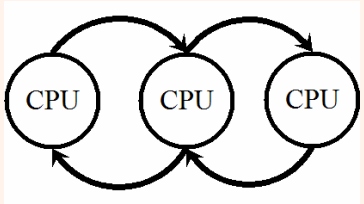

Fig. 3. Illustration of sample-sort simulated annealing optimizing a function on three CPUs

Method

Sample-sort was compared with serial simulated annealing over a set of global optimization problems of varying type and degree of difficulty. The set came from Torn, Ali, and Viitanen.

Complexity categories

- Easy type one (E1)
- Easy type two (E2)
- Moderate type one (M1)
- Moderate type two (M2)
- Difficult type one (D1)
- Difficult type two (D2)

Test problems

- F1 – Branin, 2-D, E1
- F2 – GoldPrice, 2-D, E1
- F3 - Shekel5, 4-D, E1
- F4 - Shekel7, 4-D, E1
- F5 - Hartman3, 3-D, E1
- F6 - Hartman6, 6-D, E1
- F7 - Schubert3, 3-D, E2
- F8 - Griewank2, 2-D, M2
- F9 - Schubert5, 5-D, M2

Note that no problems from the "difficult" category were chosen because the sample space provides no clues to an algorithm. Consider the "golf hole" problem where the optimum solution is like a golf hole in the middle of a flat course. Only a random search is used in such problems.

The method shown in Fig. 4 was applied to sample-sort and simulated annealing using 1,000, 10,000, and 100,000 iterations per dimension.

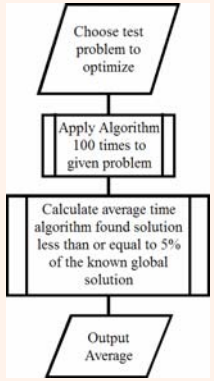

Fig. 4. Method to compare sample-sort and simulated annealing

Results

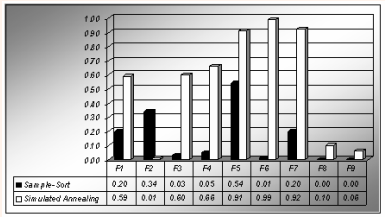

Fig. 5. Probability of finding global minimum when using sample-sort vs. simulated annealing at 1,000 iterations per dimension

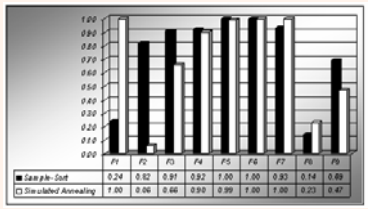

Fig. 6. Probability of finding global minimum when using sample-sort vs. simulated annealing at 10,000 iterations per dimension

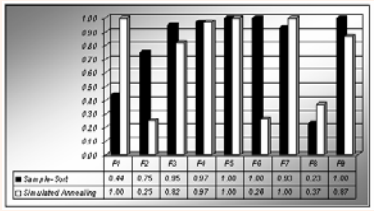

Fig. 7. Probability of finding global minimum when using sample-sort vs. simulated annealing at 100,000 iterations per dimension

Conclusions

Sample-sort is comparable to simulated annealing if each sampler executes a "sufficient" number of iterations. This is analogous to simulated annealing running a "sufficient" number of iterations at one temperature.

More importantly, sample-sort is a parallel simulated annealing algorithm that is provable convergent. If the evaluate phase dominates, efficient parallel optimization can be performed on parallel CPUs.

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Future Work

Sample-sort was applied to global optimization problems constructed by researchers to test optimization algorithms. Future work includes the following.

- Apply sample-sort to a difficult problem such as the routing and wavelength assignment problem in wavelength division multiplexing computer networks.
- The present implementation of sample-sort arranges the samplers, which could be individual CPUs, in a single row and exchanges solutions with neighboring samplers. Different topologies such as rings and meshes should be investigated.
- Sample-sort is implemented in serialized code. The code should be written to use a message-passing library such as MPI.
- Hierarchical arrangements of samplers (CPUs) are possible.
- The hierarchical arrangements of samplers could be used in a distributed routing algorithm for computer networks.

References

D. R. Thompson and G. L. Bilbro, "Sample-sort simulated annealing," *IEEE Transactions on Systems, Man, and Cybernetics – Part B: Cybernetics*, vol. 35, no. 3, pp. 625-632, June 2005.

Acknowledgments

I thank G. Bilbro for allowing me to help develop this new algorithm and his guidance on the proof and presentation.

For further information

Please contact *d.r.thompson@ieee.org*. More information on this and related projects can be obtained at *http://csce.uark.edu/~drt*. An online PDF file of this poster can be found at *http://csce.uark.edu/~drt/pubs.htm*

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