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A Review: Local Search Metaheuristic Algorithm using GPGPU

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Abstract: Local search meta-heuristic algorithm (LSM) is the meta-heuristic approximate problems solving method used to solve real world complex problems and those problems, which come in under NP-Hard category. The drawback of using the exact algorithm (e.g., Branch and Bound) is that its computation time increases exponentially when input size is increased. Therefore, meta-heuristic algorithm significantly reduces the search space size to be explored and also the time required to search it. Although LSM finds near- optimal solution in very optimum time compared to the exact algorithm, its computation time increases when the size of input increased beyond some limit. Therefore, General Purpose Graphics Processing Units (GPGPU) based parallel computing is the best alternate way to speed up the search task. Moreover, GPGPU based computing for LSM is rarely investigated and analyzed. This paper gives detailed information about local searching strategy to solve optimization problem on GPU based computing.

Keywords: Exact algorithm, Local search meta-heuristic, GPGPU computing.

1. INTRODUCTION

Looking for the optimal solutions is a tedious task for many optimization problems of science and industrial importance. In practice, approximation methods give satisfactory results in reasonable amount of time i.e. heuristic or meta-heuristic algorithms. F. Glover introduced the term meta-heuristic. Meta-heuristic search techniques can be defined as the upper- level general methodology that can be used as guiding strategies in designing underlying heuristics to solve specific optimization problems. This searching strategy, which is used to efficiently explore the search space in order to find near–optimal solution in very efficient time. Meta-heuristic is among the most promising and successful techniques. It provides good solutions in a reasonable time for solving hard and complex problems in science and engineering. This shows the significant growth of interest in the meta-heuristic domain [1].

Implements using more problem instances are often stopped without any good solution being obtained. Therefore, it is necessary for the design of the meta-heuristic algorithm, there is often a trade-off to be found between the size of the problem instance and the computational complexity to explore it. As a result, only the use of parallelism allows designing new methods to tackle large problems. Even though the meta-heuristic searching strategy fails to handle large problem instances satisfactorily, GPGPU computing has recently been revealed the effective and efficient way to deal large problem instances of difficult optimization problems. Now a day, GPGPU can be used for multipurpose computation [2]. Therefore, GPGPU based parallel computing is the best alternate way to speed up the search task.

One of the major issues for metaheuristics is to rethink over existing parallel models and programming paradigms to allow their deployment on accelerators i.e.GPGPU. In short, the main challenge is to study the different parallel models and paradigms to efficiently take into account the characteristics of GPUs.

However, the exploitation of parallel models is not trivial, and many issues related to the GPGPU memory hierarchical management of this architecture have to be considered.

The major issue using GPGPU has to deal with are the distribution of data transfer between a host (CPU) and device (GPGPU), the thread synchronization, the optimization of data transfer between the different memory hierarchy, the memory capacity constraints, etc.

Meta-heuristics fall into two categories:

1. Single-solution based meta-heuristics (S-meta-heuristics)
2. Population-based meta-heuristics (P-meta-heuristics).

S-meta-heuristics considers the single solution to manipulate for search, whereas in P-meta-heuristics, a whole population of solutions is involved. These two categories have complementary characteristics: S-meta-heuristics are exploitation oriented; they have the ability to intensify the search in local regions (e.g., Hill climbing, tabu search, simulated annealing). P-meta-heuristics are exploration oriented; they provide a better diversification in the entire search space (e.g., Evolutionary algorithm). In this paper, the focus is on single solution meta-heuristic also called as local search meta-heuristic to solve combinatorial optimization problem [3].

Local search meta-heuristic obtains the good solution by doing iterative improvements on their neighborhood solutions. In short, it generates the neighborhood structure of candidate solution using solution-encoding technique and evaluates its cost with candidate solution, if generated solutions are best then keeps it as the good solution, or else try more improvement on it.

2. LITERATURE REVIEW

Until now, there are rarely investigations on single solution based meta-heuristic i.e. local search meta-heuristic. E.D. Taillard [4] published the paper in 1991. Authors used tabu search as local search strategy to solve the quadratic assignment combinatorial optimization problem. The idea of quadratic assignment problem is to assign facility to each location such that assignment cost should be minimized. The Author suggested that the heuristic method gives the better result than the exact algorithm; exact algorithm cannot be solved when problem instance size goes beyond 20. In addition, designed method solved the quadratic assignment problem size up to the 100. Author has also mentioned about parallelizing tabu search (Algorithm 1), where neighborhood solutions should be distributed among multiple processors to reduce the overall computational time, but the idea presented for parallelism is to assign each neighborhood solution to every processor. Therefore, the disadvantage of using this parallelism is, more number of processors are needed when problem instances increase.

Algorithm 1: Tabu Search

1. Generate initial solution S.
2. Initialize Tabu list as empty.
3. While termination criteria not met do
   S = Choose Best of (Neighbor(S)/ Tabu list)
   Update Tabu list
4. End while

M. Dorigo and L.M. Gambardella [5] did solve the traveling salesperson problem using ant colony system method (algorithm 2). This is the population of solution based meta-heuristic. Here, the author compared the ant colony system with other heuristic approaches such as simulated annealing, elastic net, the self-organizing map with respect to 5 randomly generated 50-city problem set with 2500 iterations and 25 trails upon which average time was found. Author has tried to prove ant colony is the best method. In addition to a randomly generated problem, the author also has considered three geometric problems of between 50 to 100 cities namely Eil50, Eil75, KroA100 and compared its performance with the genetic algorithm, simulated annealing, evolutionary programming. Here, author proved how ACS gives a better result than another heuristic approach. But, the author did not mention about applying parallelism to ACS algorithm, now day's parallel mechanism is used to get good solutions with reduced computation time.

Algorithm 2: Ant Colony System

1. Initialize Pheromone values.
2. While termination conditions not met do

A. Schedule activities
1. Ant Based Solution Construction ()
2. Pheromone Update()
3. Daemon Update()

B. End schedule activities
3. End while

B.-L. Garcia, J.-Y, Potvin, and J.-M. Rousseau [6] used tabu search method for solving vehicle routing problem. The objective of vehicle routing problem is to provide customer demands such that vehicle route cost from its originating depot to customer place and come back to depot should be minimized. This VRP was solved using tabu search. Author has considered different variations in VRP in order to reduce its total cost. They considered time window and split delivery to improve the overall computation cost. For this VRP variation, the author has shown its effectiveness using tabu search. They have given experimental analysis result on this problem using 100 customers. However, authors have not given any procedure to parallelize this algorithm to get optimum performance.

Bevilacqua [7] makes parallel implementation of simulated annealing (Algorithm 3) on Symmetric Multiprocessor (SMP) to gain performance improvement. They designed parallel simulated annealing (Algorithm 3) and tried to check the efficiency of the algorithm using traveling salesperson combinatorial optimization problem. For this purpose, the researcher has applied parallel simulated annealing on 299-city TSP instance from TSPLIB with 15 trials. Based on this implementation, Author proved parallel simulated annealing would be the better way to reduce the search space and search time. This approach has experimented with dual processor system having configuration 800 MHz Pentium III with a 256 KB L2 cache, it could give better result on the cluster of computers.

Algorithm 3: Simulated Annealing

1. Generate Initial solution S.
2. Initialize temperature value T.
3. While termination criteria not met do

1. Pick random solution S' from neighbors (S)
2. Compares S and S' if S' less than S
3. Accept S'
4. Otherwise, S' as new solution with probability p (T, S, S').
5. Update T

4. End while.

T. James, C. Rego, and F. Glover [8] has designed parallel tabu search for solving quadratic assignment problem. Here, Author examines the computational results by allowing the processor to exchange information throughout the run of algorithm instead of collecting data at the end of execution. Designed parallel tabu search has analyzed over 41 test instances taken from QAPLIB. It has implemented using OpenMP; it can be implemented in another programming language to evaluate effectiveness, efficiency and portability of this algorithm with different platforms.

The´ Van Luong, Nouredine Melab, and El-Ghazali Talbi [1] suggest the local search meta-heuristic algorithm gives better result over exact algorithm when problem instances increases. They examine whenever problem instances increase, the computational time also get increases. The

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researcher suggested that parallelize the local search meta-heuristic algorithm on GPU to reduce search time to be explored. To show the effectiveness of designed method, parallel LSM is experimented using tabu search on four different combinatorial optimization problem.i.e. quadratic assignment problem, permuted Perceptron problem, the traveling salesman problem, and the continuous Weierstrass function. These optimization problems are evaluated on GPU; it gives X80 accelerations as compared to CPU-based execution for large combinatorial optimization problems. This method also gives better result while comparing with cluster and grid based parallel architecture.

Here, the comparison can be done with the proposed parallel LSM method and different local search meta-heuristic algorithm i.e. simulated annealing on same GPU parallel architecture for solving the different optimization problem to know about its computational time and efficiency..

3. COMPUTATIONAL RESULTS

In paper [6], Author has used traveling salesman problem as a combinatorial optimization problem. The objective of traveling salesman problem is to look the shortest possible path that visits each city exactly ones and returns to an originating city such that traveling distance should be minimized. Author experimented their proposed algorithm with different data sets like Eil50, Eil75 and KroA100 and analyzed its efficiency with different metaheuristics approaches such as ant colony system (ACS) genetic algorithm (GA) and simulated annealing (SA).

Table 1 shows the result analysis of different metaheuristics approaches with travelling salesman problem. However, a number of tours required to reach optimal solutions are large. It can be obtained with less number of tours and it can also be parallelized. Therefore, minimum cost would get in the reasonable amount of time. Nowadays LSM can be applied to a large number of data instances than used in this paper.

Dataset	ACS	GA	SA
Eil50 (425)	425 (427.96) [1830]	428 (N/A) [25000]	428 (N/A) [25000]
Eil75 (535)	535 (427.96) [3480]	545 (N/A) [80000]	580 (N/A) [173250]
KroA100 (21282)	21282 (21285.44) [4820]	21761 (N/A) [103,000].	NA (N/A) [N/A]

Table 1. Comparisons with different metaheuristics approaches, integer values with each approach shows good optimal distance found, the values in bracket shows optimal distance in fraction, values in square bracket shows number of tours required to obtain best integer solution and N/A means solution not obtained

4. CONCLUSION

This study reveals the effectiveness of meta-heuristic approach over exact algorithm solutions for solving the optimization problem. For combinatorial optimization problems, many of the sequential meta-heuristic approaches have shown the ability to obtain good results. Recently, many researchers build parallel meta-heuristic approaches to gain more improvement in obtaining solutions over sequential meta-heuristic approaches in order to handle large problem instances. Based on experimental results of the above papers, GPU-based computing provides high-quality results than other parallel architectures.

Parallel implementation of local search meta-heuristic using tabu search for different optimization problems like traveling salesperson problem, quadratic assignment problem gives better result on GPU platform. The problem with tabu search implementation is memory overhead. This method needs to keep track of visited nodes. There are different local search metaheuristic approaches are available i.e. hill climbing, simulated annealing method which can be used as LSM approach to compare its efficiency.

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