Speedup and accuracy of parallel simulated annealing algorithms

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Abstract **This work presents two parallel simulated annealing algorithms to solve the vehicle routing problem with time windows (VRPTW). The aim is to explore speedups and investigate how the shorter annealing chains (ISR algotithm) and the shorter number of cooling stages (ISC algorithm) influence the accuracy of solutions to the problem.**

Keywords **Simulated annealing, vehicle routing problem with time windows, parallel computing.**

I. Introduction

The vehicle routing problem with time windows can be formulated as follows. There is a central depot of cargo and n customers (nodes) located at some distances from the depot. The locations of the depot $(i = 0)$ and the customers $(i = 1, 2, \ldots, n)$, the shortest distances $d_{i,j}$ and the corresponding travel times $t_{i,j}$ between any two locations i and j are given. The cargo have to be delivered to each customer i according to the delivery demand q_i by a fleet of K vehicles. The vehicles have the same capacity Q. For each customer a service time window $[a_i, b_i]$ and a service time s_i are defined. The objective is to find the set of routes which guarantees the delivery of cargo to all customers and satisfies the time window and vehicle capacity constraints. Furthermore, the size of the set equal to the number of vehicles needed and the total travel distance should be minimized.

II. Parallel simulated annealing

A. Searches with reduced length of the cooling stage

Let us assume that p processes, $p = 4, 8, 16, 20$ and 32 can be executed. In the algorithm with reduced length of the cooling stage (ISR) processes P_j, $j = 1, 2, \ldots, p$ carry out the independent annealing searches. As the final result the best solution among the solutions found by the processes is chosen. At each temperature process P_j executes $L = E/p$ annealing steps.

B. Searches with constant length of the cooling stage

In the algorithm (ISC) the cooling schedule and the number of cooling stages are modified. Each process P_j starts with a different initial temperature $T_0^* = \beta^j T_0$, $j \in \{0, 1, 2, \ldots, p-1\}$ and then the temperature of annealing falls according to the formula $T_{i+1}^* = \beta^p T_i^*$. Processes execute a_f/p cooling stages, each cooling stage consists of E annealing steps.

III. Experimental results

The parallel algorithms of independent searches were implemented using C language and MPI library (computing grant G47-18, Interdisciplinary Centre for Mathematical and Computational Modelling, Warsaw University). The experiments were carried out on the rc2_2_1 and rc2_2_2 test instances of Gehring and Homberger's extended VRPTW benchmark. 100 experiments were performed for each test instance, each algorithm and a given number of processes, p. The mean value of total travel distances of routes, $\bar{y}$, the total execution time, T and the speedup, S, were calculated. The results of experiments are shown in Tab. I.

Table I
Results for tests rc2_2_1 and rc2_2_2

	ISR algorithm			ISC algorithm		
Test	p	$\bar{y}$	S	p	$\bar{y}$	S
rc2_2_1	1	3127,44	1			
	4	3122,69	3,37	4	3123,46	3,74
	8	3129,14	7,40	8	3118,14	6,60
	16	3138,53	15,22	16	3119,16	14,90
	20	3139,69	18,10	20	3118,34	18,20
	32	3144,97	28,70	32	3115,59	27,70
rc2_2_2	1	2846,91	1			
	4	2838,07	3,56	4	2839,93	3,95
	8	2842,41	7,79	8	2835,85	7,73
	16	2845,40	15,22	16	2833,63	14,94
	20	2847,53	17,05	20	2832,27	18,89
	32	2852,11	30,30	32	2831,39	28,81

IV. Conclusion

It is considered as the main result of this work that ISR and ISC parallel algorithms give satisfactory speedup while solving the VRPTW. It turned out that solving Gehring and Homberger benchmark tests in parallel by ISC algorithm can improve the results as the algorithm yields solutions of better accuracy to the problem as compared to the sequential and ISR algorithm.

References

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