An Improved Angle-based Crossover Tabu Search for the Larger-Scale Traveling Salesman Problem[1]

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Abstract

An angle-based crossover tabu search (CTS) has been presented by author of this paper in [1]. In this paper, an improved CTS is presented using the tabu-recorder, which record the tabu times of tabu-active attributes, to confirm new initial resolutions except the first cycle, and enlarge the global search, which is applied for the larger-scale traveling salesman problem (TSP). The key strategies of the improved CTS are intensification strategy, diversification strategy and tabu-recorder. The CTS implement the crossover operator of the genetic algorithm (GA) as the diversification strategy, and the strategy of selecting elite solutions as the intensification strategy. The tabu-recorder is another way of the diversification strategy, and used to confirm the initial routes with some constrains except in the first cycle. the improved CTS with the angel-based idea of sweep heuristic are used to solve twelve same TSP problems from VLSI TSP. The results showed the improved CTS have better performances than other algorithms.

1. Introduction

Almost all metaheuristic have the same problem that how to improve and balance local search and global search. With some strategies, these metaheuristic maybe get good results, but the better results can be got, if combine those strategies appropriately.

TS was proposed and developed by Glover and Glover et al [2,3], which had been used to solve a wide range of tough optimization problems such as job shop scheduling and the Traveling Salesman Problem (TSP) [4,5]. For TS, some intensification strategies and diversification strategies were proposed for this problem. Intensification strategies are used to enhance the efficiency of local search, which are based on modifying choice rules to encourage move combinations [3]. Diversification strategies are designed to drive the search into new regions to enhance the global search.

A CTS has been proposed by author of this paper [1]. The crossover operator of the genetic algorithms is adopted as the diversification strategy of the CTS, and the selecting elite solutions is adopted as the intensification strategies. The good performance of CTS was proved to resolve the small-scale traveling salesman problem (TSP) [1], and the result was not good in the larger-scale TSP. In this research, the *tabu-recorder* and other extra constraints are use to confirm the initial resolution except in the first cycle, and enlarge the global search, which is applied for the larger-scale and got better results than before.

TSP is a NP-Hard, and the larger-scale TSP is more difficult to get better result. Its goal is to find the shortest Hamiltonian cycle in a graph [6]. The solution quality of the TSP is depends on good meta-heuristic, the initial resolution of every cycles and appropriate neighborhood. The solution quality and resolution speed are influenced by neighbors. An angle-based idea of the Sweep heuristic is used to confirm neighborhood in this research. The larger-scale TSP is difficult problem in The TSP instances. The instances adopted in this research are from VLSI TSP. [7]

The paper is organized as the followings. We will discuss the main idea in section 1, the CTS and how use the *tabu-recorder* and some constraint to confirm the initial resolution except the first cycle will be

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introduced in section 2, the compared results analyses of two algorithms will be presented in section 3, followed by conclusion in the final section 4.

2. Angle-based CTS

2.1. Crossover tabu search

In some sense, TS originates from the local search [3], and uses the character of tabu to simulate the way of human thinking. The standard TS includes neighborhood function ϕ , move, *tabu list* T , tabu tenure and aspiration strategy. The standard TS is described in [1,3,8]. The crossover operator of the genetic algorithms is adopted as the diversification strategy of the CTS, and the selecting elite solutions is adopted as the intensification strategies, which is also described in [1].

Fig.1 described the program of the CTS. First, two initial routes ($s1$, $s2$) are randomly generated. Using the standard TS with intensification strategy to search until the elite list is null and the new route ($s1'$, $s2'$) is obtained. The crossover function will generate new route ($s1'$, $s2'$), and $lasts1$ and $lasts2$ will represent $s1'$ and $s2'$ of the last iteration. Speaking in an algorithmic language, the update of ($s1$, $s2$) is as $(s1, s2) = if(\min(lasts1, lasts2) < \min(s1'',$ $s2''), (lasts1, lasts2), (s1'', s2''))$ and then take the ($s1$, $s2$) to standard TS again.

2.2. The angle-based idea of the sweep heuristic

As the city number increase, especially for the large-scale TSP, it is important that how to confirm the neighborhood for the TSP. The scale of the neighborhood influences the resolution speed and quality. In this research, the angle-based idea of the sweep heuristic is used. The sweep heuristic has been applied for VRP (Vehicle Routing problem) [9].

All cities can be positioned on a plan. In the sweep heuristic, cities have geographic positions. Without loss of generality, suppose an point in the plan as zero point and is given Cartesian coordinates (0,0), and suppose each cities i has polar coordinates (r_i, θ_i) relative to the that the zeros point. Here, suppose $0 \le \theta_i \le 2\pi$ is measured clockwise from the positive x-axis and the angle difference of each two cities can be calculate. So the neighborhood of the city i can be confirmed by the angle difference of the city i and other cities. If the angle difference of the city j and the city i is smaller than some angle threshold designed, the city j is one member of the neighborhood of the city i

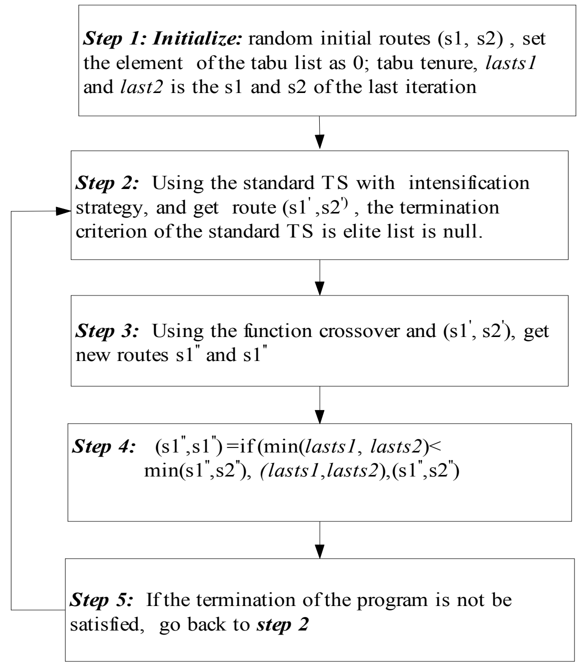

Fig.1 The flow of the CTS

2.3 Using *tabu-recorder* to confirm initial routes of every cycles except the first cycle

Ordinary, the tabu search is used to resolve the TSP problems several times separately, and get the best result, which is not good for larger-scale instance. In this article, the *tabu-recorder* and some constrain to improve this performance. The *tabu lists* record the tabu-active attributes and implicitly or explicitly identify their current status, and prevent cycling back to previously visited solutions. The function of *tabu list* is to enlarge the global search.

During the all process, *the tabu-recorder* is set to record the tabu times of the tabu-active attributes in the *tabu list*. According to the tabu times of the tabu-active attributes, the attributes with larger tabu times would be not appearing in the initial routes of every cycle. So, the conjoint two cities should have the smallest tabu times. Fig.2 describes how confirm the initial routes. Choosing the first city randomly, and all first cities are different; the second city have the smallest tabu times with the first city in *tabu-recorder*.

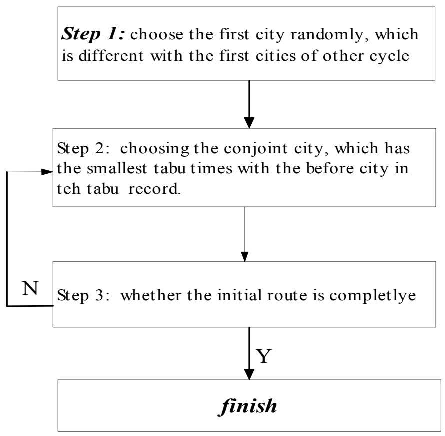

Fig.2 how to confirm the initial routes except the first cycle

So, the improved CTS can be described as Fig.3.

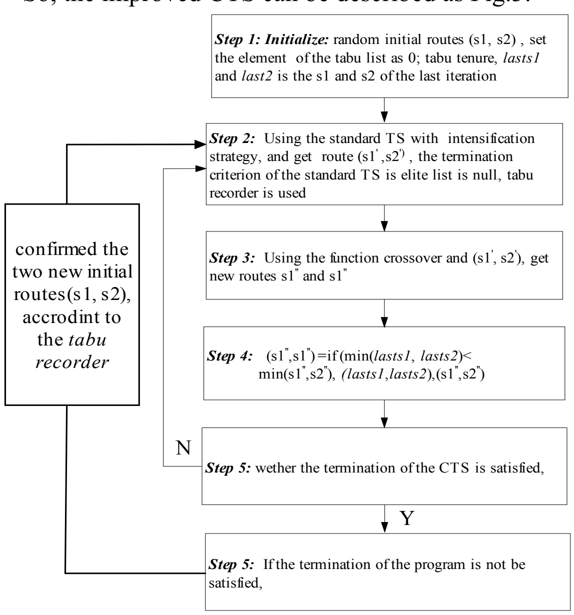

Fig.3 the improved CTS

3. Resolution of Larger-Scale TSP Instances

There are twelve TSP instances, which were adopted to evaluate the efficiency of the improved CTS, and taken from the VLSI TSP instances [7]. The algorithms used in the experimentation are as follows:

1) The crossover tabu search (CTS) algorithm with the angle-based idea of sweep heuristic.
2) The improved CTS with the angle-based idea of sweep heuristic.

The calibrating performances of the algorithms are The average deviation $\overline{\delta}$ of solutions from a provably optimal solution: $\overline{\delta} = (\overline{Dist} - Dist_{opt}) / Dist_{opt}[100\%]$, where $\overline{Dist}$ is the average tour length of 10 runs for the CTS and a run for the improved CTS, and the $dist_{opt}$ is the provable optimal result of those TSP instances.

The results of the comparison are presented in Table 1. The CTS has been proved have better performances than TS on local search [1]. From this research, the average deviation $\overline{\delta}$ of the improved CTS is better than that of the CTS, which proves *tabu-recorde*r and some constraint improve the global search, and improve the CTS performance in larger-scale TSP. In the same time, the improved CTS don't find the optimal resolution, which means the local search is not good for the larger-scale TSP.

Table 1. Comparison of the algorithm

Instance	n	$Dist_{opt}$	$\overline{Dist}, \overline{\delta}$			
			CTS with angle-base idea of sweep		Improved CTS	
pma343	343	1368	1435	4.7	1379	0.8
pka379	379	1332	1401	5.1	1345	1
pbl395	395	1281	1349	5.3	1298	1.3
pbn423	423	1365	1448	6.1	1389	1.8
EIL439	436	10,7217	1141 86	6.5	1098 97	2.5
xql662	662	2513	2722	8.3	2613	4
rbx711	711	3115	3392	8.9	3246	4.2
rbu737	737	3314	3626	9.4	3461	4.4
dkg813	813	3199	3526	10.2	3379	5.6
lim963	963	2789	3076	10.3	2962	6.2
pbd984	984	3588	3958	10.3	3807	6.1
xit1083	1083	3558	3950	11	3809	7

Run time is not compared as a parameter, because it depends on many factors. In this research, *Matlab* is used to run the program, and the run time will be decreased with C or other language

4. Conclusion

We discussed an improved angle-based crossover tabu search in this paper, in which the selecting elite solutions were used as the intensification strategy, and the crossover operator of the GA was used as the diversification strategy and the angel-based idea of the sweep heuristic to confirm the neighborhood, and the *tabu-recorder* is used to confirm the initial routes with some constrain except the first cycle. Some TSP instances were used to test the improved CTS and were compared with CTS. The improved CTS showed better performances than the CTS,.

Regarding possible extensions of the angle-based CTS, the following further improvement must be reasonable: a) Implementing other more efficient intensification strategy. b) Using other ways to confirm neighborhood. c) Trying to use CTS to resolve other combinatorial optimization problems.

5. References

[1] Yang, Ning ,Li, Ping ,Mei, Baisha, An Angle-based Crossover Tabu Search for the Traveling Salesman Problem, Natural Computation, 2007. ICNC 2007. Third International Conference. Volume: 4, p: 512-516

[2] Glover F. Heuristic for integer programming using surrogate constraints. *Decision Sciences* 8:156-66 1977;

[3] Glover, F., *"Tabu Search Fundamentals and Uses"*, Graduate School of Business, University of Colorado, Boulder, 1995

[4] Y. Peng, B. H. Soong, and L.P. Wang, "Broadcast scheduling in packet radio networks using a mixed tabu-greedy algorithm", *Electronics Letts*., vol.40, no.6, pp.375-376, March, 2004.

[5]Huajin Tang; Tan, K.C.; Zhang Yi: A columnar competitive model for solving combinatorial optimization problems. *IEEE Trans. Neural Networks* 15 (2004) 1568 - 1574

[6] E. L. Lawler, J. K.Lenstra, A. H. G. Rinnooy Kan and D. B. Shmoys, editors. *The Traveling Salesman Problem*. John Wiley & Sons, New York, 1985

[7] http://www.tsp.gatech.edu/vlsi/

[8] Michel Gendreau. *An Introduction to Tabu Search*. Centre de recherche sur les transports and Département d´informatique et de recherche opérationnelle Université de Montréal ase postale 6128, Succursale ”Centre-ville” Montréal, Canada H3C 3J7 July 2002

[9] Jacques Renaud and Fayez F. Boctor. A sweep-based algorithm for the fleet size and mix vehicle routing problem. *European Journal of Operational Research.* Vol140 p618-628, 2002