Multimodal Optimization of Traveling Salesman Problem: A Niching Ant Colony System

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ABSTRACT

Multimodal optimization (MMO) aims at finding multiple optimal (or close to optimal) solutions, which plays a crucial role in various fields. However, most of the efforts have been devoted to the continuous MMO domain, while little attention has been paid to discrete problems like the traveling salesman problem (TSP). This paper makes a proof of principle study on multimodal TSP. Particularly, we design a test suite for multimodal TSP and then develop an ant colony algorithm to accomplish the optimization task. The traditional ant algorithms such as the ant colony system are unable to maintain multiple solutions because of the global convergence. To deal with this problem, we propose a novel niching ant colony system (NACS). The algorithm employs a niching strategy and multiple pheromone matrices to preserve population diversity and keep the trace of multiple paths. The experimental results are presented to validate the good performance of the proposed algorithm.

CCS CONCEPTS

• **Computing methodologies** → *Optimization algorithms*;

KEYWORDS

Ant Colony Optimization, Multimodal optimization, Traveling Salesman Problem

1 INTRODUCTION

Multimodal optimization (MMO) refers to seeking multiple optimal or close to optimal solutions. Conventionally, most discrete problems aim at finding one single optimal solution. However, in many real-world situations, it is insufficient to provide the user with a single solution to make the decision. For example, in a traveling salesman problem (TSP), the salesman prefers several alternative optimal solutions at hands in case that some solutions become unsuitable for some reasons.

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Ant colony optimization (ACO) [1, 4] is a competitive evolutionary computation paradigm, which is originally developed to solve the TSPs. However, most of these ACO algorithms like the ant colony system (ACS) bias the elite solutions which resulting in the diversity loss. Therefore, ACS is not suitable for solving the MMO-TSP.

To obtain multiple optimal solutions of MMO-TSP, we propose a niching ant colony system (NACS) which shares a similar structure with the ACS. The main differences between the NACS and the ACS lie in the following two aspects. First, the ants are divided into different sub-groups by a niching strategy for diversity preservation and broader searching area. An effective distance measure, the sharing-tour distance, is proposed and incorporated into the niching strategy. Second, multiple pheromone matrices are employed to guide the ant colony to explore different problem subspaces so as to identify and preserve multiple optimal tours.

To test the performance of NACS, we propose a test suit including ten MMO-TSP instances, among which four instances are synthetic, five instances are selected from TSPLIB, and one instance is proposed in [3]. Experimental results validate that our algorithm is able to locate and maintain multiple optimal solutions, which exhibits promising performance for discrete multimodal optimization.

2 NICHING ANT COLONY SYSTEM

2.1 The Overall Algorithm

Initially, the niches' pheromone is initialized by tour length produced by the nearest neighbor heuristic[1]. In each iteration, first, the algorithm formulates several niches based on the current ant colony and the sharing-path distance measure. Accordingly, the ants are divided into a few groups. Afterwards, each ant builds a tour according to both the pheromone and the heuristic information. When building the tours, the ants in different niches only know the local pheromone information in the corresponding niche and tend to search different areas of the landscape. Then, the pheromone updating rules are designed to build a dynamic relationship between the groups of ants and the environment. Particularly, the pheromone matrices are updated according to local and global updating rule. Then, a new generation starts, and a new set of niches are generated.

2.2 Niche Formulation

In order to locate the optima in the landscape, niches are dynamically updated in every iteration. After every ant constructing their tour, the best ant creates the first niche, while the remaining ants join the nearest niche or create a new niche. When creating niches, two thresholds are employed to determine the choice of each ant. The first is the niche radius ND which is given by

$$ND = 2 \cdot \ln N \tag{1}$$

where ND is niche distance and N is the number of cities in the MMO-TSP.

The other is ε which is an acceptable level given by

$$\varepsilon = \frac{L_{oa}}{c} \tag{2}$$

where L_{oa} is the length of the optimal ant in each iteration and c is a constant number. When a new niche is created, its local pheromone matrix is initialized according to the global pheromone values in the last iteration and the niching information, which is given by

$$\tau(r,s) = \frac{\sum_{j \in 1,2,3,\cdots,t} \tau_j(r,s)}{t} \qquad \forall r,s \in 1,2,3,\cdots,N \tag{3}$$

Here, t is the number of niches and N is the number of cities.

2.3 Distance Measure

In our algorithm, we employ the sharing-tour distance to measure the similarity between two individuals in MMO-TSP. To be more specific, the distance between two solutions is defined according to the number of shared paths divide the total number of paths. The more paths the two tours share, the shorter the distance between them is.

2.4 Population Division

In the NACS, the population division rule is as follows: m ants are divided into t (i.e. the number of niches) groups. We propose a dynamic resource allocation strategy that the number of ants assigned into each niche is determined by the quality of this niche. Specifically, the size of each group is denoted as $m_1, m_2, \cdots m_t$, where m_i is given by

$$m_i = \frac{\frac{1}{l_i}}{\sum_{j \in 1,2,3,\cdots,s} \frac{1}{l_j}} \tag{4}$$

where l_i is the length of the best solution in the ith niche.

2.5 Pheromone Updating

2.5.1 Local Pheromone Updating Rule. The first part is local pheromone updating rule. When some ants building a solution of MMO-TSP, it updates the pheromone level of the corresponding niche using

$$\tau_i(r,s) = (1-\rho) \cdot \tau_i(r,s) + \rho \cdot \Delta\tau_i(r,s) \tag{5}$$

2.5.2 Global Pheromone Updating Rule. In NACS, only the optimal ant in each niche is allowed to perform the global pheromone updating rule after it has completed its tour. It is intended to guide the ants to explore different problem subspaces. The global updating rule is defined as

$$\tau_i(r,s) = (1-\lambda) \cdot \tau_i(r,s) + \lambda \cdot \Delta\tau_i(r,s) \tag{6}$$

Here

$$\Delta\tau_i(r,s) = \begin{cases} L_{oa}^{-1} & \text{if } \tau_i(r,s) \in \text{BestSolutionOfNiche} \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

3 EXPERIMENTAL STUDIES

To investigate the effectiveness of NACS, we compare our approach with other two algorithms: the Ant Colony System with an Archive (ACS-archive), and the Niching Ant Colony System with a single pheromone matrix (NACS-SPM). The result shows that NACS has a great exploration ability that it is able to locate and maintain multiple distinct optima during the optimization. Experiments' results of TSP instances mentioned in [2] is shown in Table 1.

Table 1: The Result of Three Algorithms in the Last Iteration Or Archive (Best Case)

	ACS-Archive		NACS-SPM		NACS	
	#Solu	Best	#Solu	Best	#Solu	Best
self8-1	2	187.444	2	187.444	**3**	**187.444**
self8-2	**2**	**309.436**	**2**	**309.436**	**2**	**309.436**
self10-1	**2**	**225.133**	**2**	**225.133**	**2**	**225.133**
self10-2	**2**	**236.212**	**2**	**236.212**	**2**	**236.212**
test16	1	918.353	2	918.353	**9**	**918.353**
chn31	3	15377.7	1	15377.7	**15**	**15377.7**
oliver30	3	423.741	1	423.741	**11**	**423.741**
rand50	**2**	**5555.53**	1	5555.53	**2**	**5555.53**
ulysses22	2	75.3097	1	75.3097	**12**	**75.3097**
ulysses16	2	73.9876	1	73.9876	**10**	**73.9876**

4 CONCLUSION

This paper proposed a new niching algorithm named NACS for discrete multimodal optimization. NACS takes the advantages of ACS but makes modifications in some respects: the ant colony is divided into groups, niching is used to assist maintaining population diversity, multiple pheromone metrics are employed, and new pheromone updating rules are performed to build a dynamic relationship between the ant colony and environment. The experimental result demonstrates NACS's ability to solve MMO-TSPs.

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