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A discrete invasive weed optimization algorithm for solving traveling salesman problem

Yongquan Zhou [a,b], Qifang Luo [a], Huan Chen [a], Anping He [a,b], Jinzhao Wu [a,b]

[a] College of Information Science and Engineering, Guangxi University for Nationalities, Nanning 530006, China
[b] Guangxi Key Laboratory of Hybrid Computation and IC Design Analysis, Nanning 530006, China

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ABSTRACT

The Traveling Salesman Problem (TSP) is one of the typical NP-hard problems. Efficient algorithms for the TSP have been the focus on academic circles at all times. This article proposes a discrete invasive weed optimization (DIWO) to solve TSP. Firstly, weeds individuals encode positive integer, on the basis that the normal distribution of the IWO does not change, and then calculate the fitness value of the weeds individuals. Secondly, the 3-Opt local search operator is used. Finally, an improved complete 2-Opt (I2Opt) is selected as a second local search operator for solve TSP. A benchmarks problem selected from TSPLIB is used to test the algorithm, and the results show that the DIWO algorithm proposed in this article can achieve to results closed to the theoretical optimal values within a reasonable period of time, and has strong robustness.

1. Introduction

The traveling salesman problem (TSP) is one of the most cited NP-hard combinatorial optimization problems because it is so intuitive and easy to understand but difficult to solve. It is a challenging optimization problem of significant academic value as it is often used as a benchmark problem when new solution approaches are developed. Intensive research efforts have therefore been directed toward the development of both exact and heuristic algorithms for the TSP [1]. In fact, the TSP and its variants have several important applications, such as, drilling of printed circuit boards, X-ray crystallography, computer wiring, vehicle routing and scheduling, control of robots, among others. Therefore, solving this class of problems is both of academic interest and practical importance, and consequently, it has been an important topic of active research. So searching for an efficient algorithm has an important theoretical and practical significance. From the graph theory point of view, TSP problem can be described as weighted graph:$G=(V,E,w)$, where $V$is vertex set, $|V|=n$ is the number of vertex, $E$is edge set, $w:E\rightarrow R^+$is weight function. The purpose of TSP is to find a Hamilton loop that all the vertices are visited once and only once. Let $T=<v_1,v_2,\cdots,v_n,v_1>$, and $\forall 1\le i\ne j\le n, v_i\ne v_j$, moreover $1\le i\le n, <v_i,v_{\mathrm{mod}(i,n)+1}>\in E$. Let $TSP(G)$be the set of all TSP loop. Define$w(T)=w(<v_1,v_n>)+\sum_{i=1}^{n-1}w(<v_i,v_{i+1}>)$, so TSP problem is finally to find a Hamilton loop T^* that make $w(T)$ minimal, that is to say $T^*=\arg\{w(T)\}\rightarrow \min, \forall T\in TSP(G)$.

No efficient algorithm exists for the TSP and all its relevant variants or problems of the same class. The need to quickly find good (not necessarily optimal) solutions to these problems has led to the development of various approximation algorithms such as metaheuristics. Metaheuristic algorithms have demonstrated their potential and effectiveness in solving a wide variety of optimisation problems and have many advantages over traditional algorithms. Two of the advantages are simplicity and flexibility. Metaheuristics are usually simple to implement, but they often can solve complex problems and can thus be adapted to solve many real-world optimization problems, from the fields of operations research, engineering to artificial intelligence. In addition, these algorithms are very flexible, and they can deal with problems with diverse objective function properties, either continuous, or discrete, or mixed. Such flexibility also enables them to be applied to deal a large number of parameters simultaneously.

At present, all the methods to solve TSP can be divided into two categories, one is exact methods that guarantee the optimal solution, and the other is approximation algorithm. The exact methods can guarantee to get the optimal solution, but with the expansion of the scale of the problem, the solving time required increase with an exponential, so it is difficult to apply to solve large scale problems. The common exact methods include dynamic programming method [2] (DM), branch and bound method [3]. While Approximation algorithm can get more

E-mail addresses: yongquanzhou@126.com (Y. Zhou), l.qf@163.com (Q. Luo), 15977776020@126.com (H. Chen), hapetis@gmail.com (A. He), Wu_jz@gmail.com (J. Wu).

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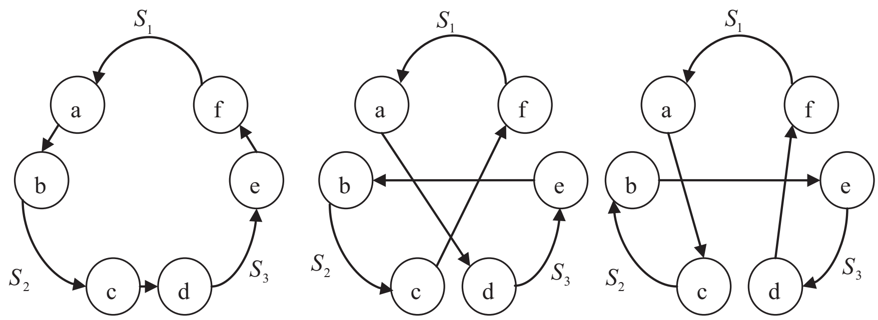

Fig.1. Schematic diagram of 3-Opt.

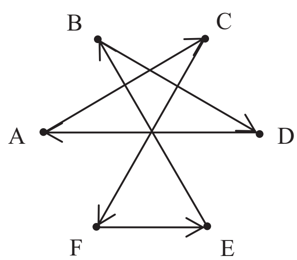

Fig. 2. Tour*ACFEBD*.

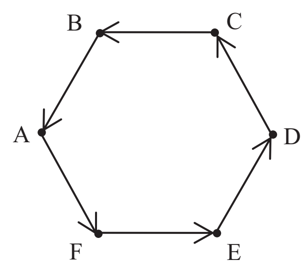

Fig. 6. Tour*AFEDCB*.

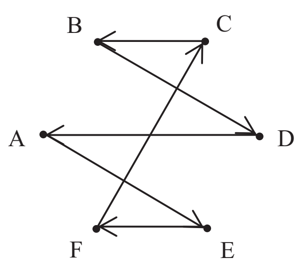

Fig. 3. Tour*AEFCBD*.

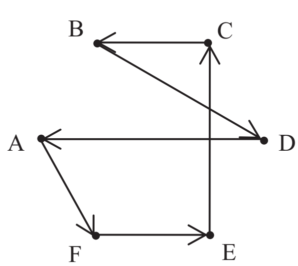

Fig. 4. Tour*AFECBD*.

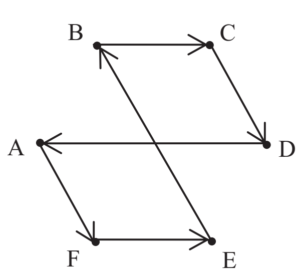

Fig. 5. Tour*AFEBCD*.

accurate solution in polynomial time, thus they are suitable for solving large-scale problems. Approximation algorithms can be divided into two categories also; one is local search algorithms which related to the problems' characteristics, such as 2-Opt [4], 3-Opt [5], LK [6], the LKH [7] and Inver-over [8]. These algorithms can make effective use of the relevant characteristics of the problem to find the local optimal solution of the problem, but with the scale of the problem increase, the computation will greatly increase. The other is heuristic optimization methods developed so far for searching nearly optimal solution in solving TSP such as ant colony algorithm [9] (ACO), genetic algorithm (GA) [10], simulated annealing algorithm (SA) [11], particle swarm optimization (PSO) [12], artificial neural networks (ANN) [13,24,34], and artificial immune algorithm (AIS) [14]. These algorithms do not depend on the problem itself, thus have strong global search capability, while easy to fall into local optimum. In recent years, many scholars combine local search with metaheuristic algorithms to produce a new hybrid algorithm for solving TSP, such as [15] genetic operators and LK are mixed; [16] proposed a method that combines the ant colony algorithm and mutation strategy; Samanlioglu et al. [17] proposed a method of combining genetic algorithm with a 2-Opt; Peng Gang et al. [18] proposed an improved complete 2-Opt (Complete 2-Opt, C2OPT), Yongquan zhou et.al proposed a discrete glowwom swarm algorithm (DGSO) [45], Xin-She Yang et.al proposed a discrete cuckoo search algorithm (DCS) [46] and the improved genetic algorithm is adopted, they can get satisfactory solution in fewer iterations. Besides, the above mentioned exact and heuristic algorithms, metaheuristic algorithms, have been applied successfully to the TSP by a number of researchers.

This article, a novel discrete invasive weed optimization (DIWO) to solve TSP is proposed. In the DIWO algorithm, Firstly, weeds individuals encode positive integer, on the basis that the normal distribution of the IWO does not change, and then calculate the fitness value of the weeds individuals. Secondly, the 3-Opt local search operator is used to weeds individuals. Finally, an Improve complete 2-Opt (I2Opt) is selected as a second local search operator for solve TSP. Benchmarks selected from TSPLIB are used to test the algorithm, and the results show that the algorithm proposed in this article can achieve to result closed to the theoretical optimal values within a reasonable period of time, and has strong robustness.

The rest of the article is organized as follows. In Section 2, the basic IWO is simply introduced. In Section 3 the DIWO, complete 2-opt, 3-Opt and I2Opt is proposed and explained in detail. Simulation and