Information Sciences 316 (2015) 266–292

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

A novel hybrid shuffled frog leaping algorithm for vehicle routing problem with time windows

Jianping Luo *, Xia Li, Min-Rong Chen, Hongwei Liu

Shenzhen Key Lab of Advanced Communications and Information Processing, College of Information Engineering, Shenzhen University, Shenzhen 518060, PR China

ARTICLE INFO

Article history:
Received 10 September 2014
Received in revised form 30 March 2015
Accepted 3 April 2015
Available online 16 April 2015

Keywords:
Hybrid heuristic
Combinatorial optimization
Evolutionary computation
Shuffled frog leaping algorithm
Vehicle routing problem

ABSTRACT

This paper proposes a novel hybrid shuffled frog leaping algorithm (HSFLA) for vehicle routing problem with time windows (VRPTW). The diversity control strategy is developed to construct the memeplexes of the HSFLA and avoid ending the search prematurely. The modified clone selection procedure is presented to improve the quality of the solutions and bring more diversity to the population. Improved and extended extremal optimization (EO) with alternative move operators is also introduced to the exploitation of the algorithm. Furthermore, the adaptive soft time windows penalty measure is proposed to allow the existence of infeasible solutions in the evolution process. Our approach is estimated and compared with other state-of-the-art heuristics using Solomon and Cordeau VRPTW test sets. The experimental results show that the presented algorithm is very effective for handling VRPTW.

1. Introduction

The vehicle routing problem with time windows (VRPTW) is among the best-known and most important problems in the logistics and transportation fields. It is linked with numerous practical applications, including parcel deliveries in various industries, goods transportation, refuse collection, relief supply, as well as complex and strategic decision support tools, in which routing decisions are combined with inventory or warehouse location, fleet composition, and so on [30]. VRPTW requires determining the optimal set of routes of a fleet of identical vehicles with restricted capacity such that all customers, whose demands are known, are serviced exactly once within each time window. The time windows impose that the vehicle must begin the service to the customer within the earliest and latest times allowed by the customer for the start of the service. The objective of the problem is to find a set of minimum-cost routes for vehicles from a central supply depot. Fig. 1 shows an example of VRPTW, where the depot is denoted as 0 and the customers are denoted as 1–9. The solution includes three routes: 0-7-5-3-2-0, 0-6-8-9-0, and 0-1-4-0.

On the other hand, Eusuff and Lansey [23] presented a metaheuristic optimization method called shuffled frog leaping algorithm (SFLA), which mimics the memetic evolution of a group of frogs when seeking the location that has the maximum amount of available food. The method is a combination of deterministic and random approaches. The deterministic strategy allows the algorithm to use response surface information effectively to guide the heuristic search as in a particle swarm optimizer (PSO). The random elements ensure the flexibility and robustness of the search pattern. In this algorithm, frogs are seen as hosts for memes and described as a memetic vector. Each meme consists of a number of memotypes.

* Corresponding author.
E-mail address: camelrock@126.com (J. Luo).

http://dx.doi.org/10.1016/j.ins.2015.04.001
0020-0255/

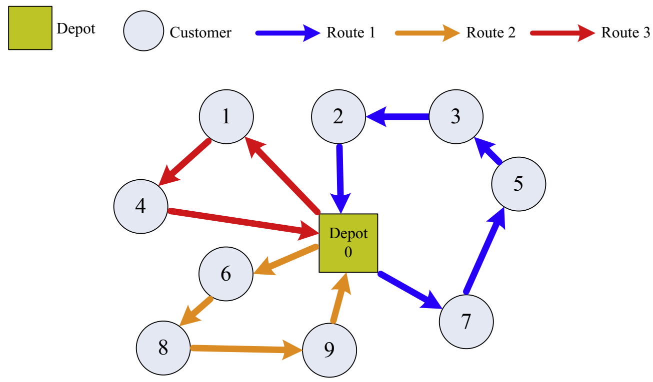

Fig. 1. An example of vehicle routing problem with time windows.

The memotypes represent an idea in a manner similar to a gene representing a trait in a chromosome in a genetic algorithm. The frogs can communicate with one another and can improve their memes by infecting (passing information to) each other. Memes are improved when the position of an individual frog is changed by adjusting its leaping step size. Based on this abstract model of virtual frogs, SFLA draws on PSO as a local search tool, as well as on the idea of competitiveness and mixing information from parallel local searches, to reach a global solution from the shuffled complex evolution algorithm [20].

In this paper, we propose a hybrid improved shuffled frog leaping algorithm (HSFLA) to address VRPTW. In the proposed approach, we present the diversity control strategy to construct the memeplexes of SFLA. The improved clone selection procedure (CSP) is applied to the evolution of the population, and the modified and extended extremal optimization (EO) local search procedure with alternative move operators is proposed. Furthermore, the adaptive soft time windows penalty approach is developed to speed up the exploiting of the algorithm.

The major contributions of this study can be summarized as follows:

(1) A novel hybrid heuristic based on the memetic evolution is proposed to address VRPTW. The experimental results show that the presented algorithm demonstrates excellent performance in handling VRPTW.
(2) The novel neighborhood search based on the modified and extended EO procedure with alternative move operators is proposed to enable a more effective exploitation of the algorithm.
(3) The efficient diversity control strategies that are applied to the construction of memeplexes, the modified clone selection procedure, and the adaptive soft time windows penalty measure are developed to avoid premature convergence.

This paper is structured as follows: Section 2 describes the mathematical models of VRPTW. Section 3 discusses related work. The novel hybrid shuffled frog leaping algorithm framework for VRPTW is introduced in Section 4. Section 5 focuses on the experiments for the problems. We analyze the optimization performance for both the Solomon and Cordeau instances [61,15]. Section 6 presents the conclusion.

2. Mathematical models for VRPTW

In this paper, we address not only the classic single-depot (center) VRPTW but also the multi-depot (center) VRPTW (MDVRPTW). The traditional VRPTW is a special case of the MDVRPTW when the number of depots is equal to 1. To facilitate discussion, the classic VRPTW and MDVRPTW are grouped into VRPTW category. Therefore, VRPTW includes classic VRPTW and MDVRPTW hereafter.

VRPTW can be described as delivery to multiple customers with multiple vehicles from multiple certain depots. Each customer has a fixed time window, i.e., requiring vehicles in the specified time window to conduct the service. The location and demand of each customer are certain. The maximum load and maximum travel distance (TD) of each vehicle are also certain. The goods supplied from centers meet the needs of all customers. The service time cannot be earlier than the earliest time of the time window and cannot be later than the latest time of the time window. The problem can be defined on a multigraph $G = (C, D, E)$, where C is the customer vertex set that includes N customers, D is the depot vertex set that includes M depots, and E is the arc set. The set $V = \{C \cup D\}$ is the node set. The demand of the i-th customer is q_i. The distance between points i and j is c_{ij}. The system has L vehicles, and $K = \{k_1, k_2, \ldots, k_L\}$ is the set of all vehicles. The maximum capacity of vehicle i is $Q_i (i = 1, 2, \ldots, L)$. $K(d)$ denotes the vehicle set of the depot $d (d \in D)$, k_d denotes the maximum vehicle number of depot d, and $C(d)$ denotes the customer set of the depot $d (d \in D)$. Each vehicle starts traveling from a depot and returns to the same depot after completing the services to customers. The purpose of the problem is to require reasonable arrangements for vehicle