symmetry

MDPI

Article

A Novel Algorithm for Capacitated Vehicle Routing Problem for Smart Cities

Mohammad Sajid [1], Jagendra Singh [2], Raza Abbas Haidri [3], Mukesh Prasad [4], Vijayakumar Varadarajan [5,*], Ketan Kotecha [6,*] and Deepak Garg [2]

[1] Department of Computer Science, Aligarh Muslim University, Aligarh 202002, India; msajid.cs@amu.ac.in
[2] School of Engineering and Applied Science, Bennett University, Greater Noida 203206, India; jagendra.singh@bennett.edu.in (J.S.); deepak.garg@bennett.edu.in (D.G.)
[3] Department of Computer Science and Information Technology, Khwaja Moinuddin Chishti Language University, Luckhnow 226013, India; razahaidri@kmclu.ac.in
[4] School of Computer Science, Faculty of Engineering, University of Technology Sydney, Sydney, NSW 2007, Australia; mukesh.prasad@uts.edu.au
[5] School of Computer Science and Engineering, The University of New South Wales, Sydney, NSW 2052, Australia
[6] Symbiosis Centre for Applied Artificial Intelligence, Faculty of Engineering, Symbiosis International University, Pune 412115, India
* Correspondence: v.varadarajan@unsw.edu.au (V.V.); director@sitpune.edu.in (K.K.)

Abstract: Smart logistics is an indispensable building block in smart cities development that requires solving the challenge of efficiently serving the demands of geographically distributed customers by a fleet of vehicles. It consists of a very well-known NP-hard complex optimization problem, which is known as the capacitated vehicle routing problem (CVRP). The CVRP has widespread real-life applications such as delivery in smart logistics, the pharmaceutical distribution of vacancies, disaster relief efforts, and others. In this work, a novel giant tour best cost crossover (GTBCX) operator is proposed which works stochastically to search for the optimal solutions of the CVRP. An NSGA-II-based routing algorithm employing GTBCX is also proposed to solve the CVRP to minimize the total distance traveled as well as to minimize the longest route length. The simulated study is performed on 88 benchmark CVRP instances to validate the success of our proposed GTBCX operator against the nearest neighbor crossover (NNX) and edge assembly crossover (EAX) operators. The rigorous simulation study shows that the GTBCX is a powerful operator and helps to find results that are superior in terms of the overall distance traveled, length of the longest route, quality, and number of Pareto solutions. This work employs a multi-objective optimization algorithm to solve the capacitated vehicle routing problem (CVRP), where the CVRP is represented in the form of a two-dimensional graph. To compute the values' objective functions, the distance between two nodes in the graph is considered symmetric. This indicates that the genetic algorithm complex optimization algorithm is employed to solve CVRP, which is a symmetry distance-based graph.

Keywords: smart logistics; capacitated vehicle routing problem; Pareto optimality; non-dominated sorting

Citation: Sajid, M.; Singh, J.; Haidri, R.A.; Prasad, M.; Varadarajan, V.; Kotecha, K.; Garg, D. A Novel Algorithm for Capacitated Vehicle Routing Problem for Smart Cities. *Symmetry* **2021**, *13*, 1923. https://doi.org/10.3390/sym13101923

Academic Editor: José Carlos R. Alcantud

Received: 4 September 2021
Accepted: 11 October 2021
Published: 13 October 2021

1. Introduction

Smart logistics is an indispensable building block in developing smart cities, and the efficient delivery of the demands of geographically distributed customers plays a major role [1–3]. As depicted in Figure 1, the CVRP problem is concerned with discovering the optimal paths for a given fleet of motor vehicles to fulfill the demands of physically distributed customers [3]. The CVRP and its variants are widely used in many real-life applications, such as smart logistics [1,2], critical data collection in IoT platforms [4], renting-sharing problems for urban bicycles [5], the routing and scheduling of chains of retail stores [6], distributing medical supplies for emergencies [7], crop harvesting and