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Discrete Optimization

A new approach to solving the multiple traveling salesperson problem using genetic algorithms

Arthur E. Carter [a,1], Cliff T. Ragsdale [b,*]

[a] *College of Information Science and Technology, Radford University, P.O. Box 6933, Radford, VA 24142, United States*
[b] *Department of Business Information Technology, Pamplin College of Business, 1007 Pamplin Hall, Virginia Tech, Blacksburg, VA 24061, United States*

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Abstract

The multiple traveling salesperson problem (MTSP) involves scheduling $m > 1$ salespersons to visit a set of $n > m$ locations so that each location is visited exactly once while minimizing the total (or maximum) distance traveled by the salespersons. The MTSP is similar to the notoriously difficult traveling salesperson problem (TSP) with the added complication that each location may be visited by any one of the salespersons. Previous studies investigated solving the MTSP with genetic algorithms (GAs) using standard TSP chromosomes and operators. This paper proposes a new GA chromosome and related operators for the MTSP and compares the theoretical properties and computational performance of the proposed technique to previous work. Computational testing shows the new approach results in a smaller search space and, in many cases, produces better solutions than previous techniques.

Keywords: Genetic algorithms; Scheduling; Traveling salesman

1. Introduction

The multiple traveling salesperson problem (MTSP) can be used to model many practical problems. The MTSP is similar to the notoriously difficult traveling salesperson problem (TSP) that seeks an optimal tour of n cities, visiting each city exactly once with no sub-tours. In the MTSP, the n cities must be partitioned into m tours, with each tour resulting in a TSP for one salesperson. The MTSP is more difficult than the TSP because it requires determining which cites to assign to each salesperson, as well as the optimal ordering of the cities within each salesperson's tour.

* Corresponding author. Tel.: +1 540 231 4697.
E-mail addresses: aecarter@radford.edu (A.E. Carter), crags@vt.edu (C.T. Ragsdale).
[1] Tel.: +1 540 831 5238.

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Perhaps the most common application of the MTSP is in the area of scheduling. The scheduling of jobs on a production line is often modeled as a TSP. If the production operation is expanded to have multiple parallel lines to which the jobs can be assigned, the problem can be modeled as a MTSP (Carter and Ragsdale, 2002). Another problem that is often modeled as a MTSP is the vehicle scheduling problem (VSP). The VSP consists of scheduling a set of vehicles, all leaving from and returning to a common depot, to visit a number of locations such that each location is visited exactly once (Park, 2001). A variation on the TSP that can also be modeled as a MTSP involves using one salesperson to visit n cities in a series of m smaller tours. This describes the scheduling problem of sales/service personnel that visit n cities over a period of time but travel during the week and return home on weekends.

Due to the combinatorial complexity of the MTSP, it is necessary to employ heuristics to solve problems of realistic size. Genetic algorithms (GAs) represent one type of heuristic that researchers have applied to the TSP. More recently, researchers studying the VSP have expanded the use of GAs developed for the TSP to also address the MTSP. Most of the research on using GAs for the VSP has focused on using two different chromosome designs for the MTSP. Both of these chromosome designs can be manipulated using classic GA operators developed for the TSP; however, they are also prone to produce redundant solutions to the problem. This research introduces a new chromosome for the MTSP that works with classic GA TSP operators while dramatically reducing the number of redundant solutions in the solution space, thereby improving the efficiency of the search.

The remainder of this paper is organized as follows. First, we review the literature on solving the TSP and MTSP using GAs. Next, we provide an overview of GAs focused on the characteristics associated with well-designed chromosomes. Next, the two chromosomes traditionally used for the MTSP are presented and contrasted with our new proposed chromosome. Finally, a computational comparison of the various solution approaches is presented followed by concluding remarks and suggestions for future research in this area.

2. Literature review

A number of different methods have been proposed for obtaining either optimal or near optimal solutions for the TSP. The methods used to solve the TSP range from classic methodologies based on linear programming (Wong, 1980) and branch-and-bound (Little et al., 1963; Bellmore and Malone, 1971) to artificial intelligence methods such as neural networks (Shirrish et al., 1993), tabu search (Glover, 1990), and GAs (Goldberg and Lingle, 1985). For a good overview of the TSP and various proposed solutions methodologies for this problem see Lawler et al. (1985).

Given the combinatorial complexity of TSPs of realistic size, a solution methodology that efficiently solves TSPs to global optimality remains elusive. While advances have been made in solving the TSP, those advances have come at the expense of increasingly complex computer code (Chatterjee et al., 1996).

Most of the work on solving MTSPs using GAs has focused on the VSP (Malmborg, 1996; Park, 2001). The VSP consists of scheduling a fleet of m vehicles to visit n cities with each city being visited by one and only one vehicle. The VSP typically includes constraints on the number of cities each vehicle can visit due to the capacity of each vehicle and the size of the load to be picked up at each city. In some cases, the cities must be visited within specific time windows. These issues lead to a number of different possible configurations for the VSP: those with or without time windows, those with heterogeneous or homogeneous vehicle capacities, and those with travel distance and/or fleet size restrictions. A variety of objectives can also be considered, including: minimize the total (or maximum) distance, minimize the number of vehicles required, and minimize the number of time window violations.

3. Overview of GAs

Genetic algorithms (GAs) are a relatively new optimization technique that can be applied to TSPs. The basic ideas behind GAs evolved in the mind of John Holland at the University of Michigan in the early 1970s (Holland, 1975). GAs were