Evolutionary Approach for Minimizing Consumed Energy in a Personal Rapid Transit Transportation System with a Multi-Depot Network Topology

[Extended Abstract]

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ABSTRACT

This paper deals with real world application of the Multiple depot vehicle routing problem. In fact, we focus on a transportation system called Personal Rapid Transit problem(PRT) in order to minimize total energy consumption in a multiple depot network topology while considering the battery capacity of vehicles. For that purpose, we describe a specific implemented Genetic Algorithm to solve our presented problem. We present experimental results on the instances adapted from the literature. The implemented algorithm proved to present satisfactory results in a reduced computational time.

Categories and Subject Descriptors

F.2.2 [**Artificial intelligence**]: Problem Solving, Control Methods, and Search —*Heuristic methods*; I.2.9 [**Artificial intelligence**]: Robotics—*Autonomous vehicles*

Keywords

Personal Rapid Transit ; Routing ; Heuristic ; Multi-Depot Vehicle Routing Problem

1. INTRODUCTION

A PRT is an automated transportation tool that provides an on-demand, non-stop transportation service. PRT uses electric computer-guided and small sized vehicles for 1 to 6 passengers. PRT vehicles run on a dedicated network of small guide-ways. Contrary to traditional urban transportation tools (tramway, train bus) where people need to wait in specified stations for vehicles to come in a predefined schedule, PRT empty vehicles are waiting at PRT stations for passengers to take them. PRT offers transit service on-demand which means that when a passenger at a PRT station ask for transportation service, the central control system will dispatch immediately to him an empty vehicle to take him directly to its destination. This flexible service offers a much lower waiting time for passengers. This is one of the main appealing features of PRT. PRT also due to the small size of its vehicles offers a much faster travel service with a very low energy consumption[1]. These features make PRT one of the most ecological and promising urban transportation tools. Recent studies showed that PRT have the possibilities to compete bus and light rail transportation systems[5]. Work about routing problems related to PRT was concerned mainly with minimization of waiting time of passengers [2] or the minimization of energy consumption [5]. **However, no works have considered multiple depots static routing problem for PRT system. We should note also that the battery issues of PRT vehicles is not well studied in the literature.** Therefore and following these gaps in the literature, this paper analyzes the behavior of a battery constrained PRT by introducing a multidepot routing problem related to it.

Our aim is to minimize its energy consumption of a battery constrained PRT system in a static deterministic context. We first model our problem as a multidepot asymmetric distance constrained vehicle routing problem. We then introduce a genetic algorithm to determine feasible solutions.

After the general introduction of the PRT system and concepts, Section 2 presents the routing problem related to PRT. Section 3 outlines the genetic method used to define the feasible solutions of our problem. Section 4 presents the experimental results. Finally, conclusions and future works are presented in Section 5.

2. PROBLEM DEFINITION

In this section, we present our specific definition of the static multiple depots PRT problem under consideration. The PRT is composed of PRT network N. N is composed of M stations and D depots. Let suppose to have a list of travel of passengers to satisfy of cardinality n and an unlimited number of PRT vehicles initially located in the different depots D with limited battery capacity B. The exact number of used vehicles is considered in our problem

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as a decision variable. Each trip is characterized by the departure time, arrival time, departure station and arrival station. The objective of our problem is to satisfy all the PRT' travel request with respect to the battery capacity of vehicles while minimizing its energy consumption. Let $G = V, E$ be a directed graph. $V = V_{i\,i=0}^{n+D}$ being its list of vertices where $v_0, v_1, ..., v_D$ are the depot vertices. Each vertex v_i; $i \in [1, n]$ has an associated passenger trip. An edge in the graph G between two trip' nodes i and j verify that a vehicle could serve trip j after finishing serving trip i. This latter is made possible by verifying the time of finishing trip i in addition to the time needed to travel from arrival station of trip i to the departure station of trip j. The cost of an edge in this graph represents the consumed energy to serve that specific trip. We add also edges from each depot nodes to the trip nodes representing the possibility of a vehicle to move from the depot to serve a trip. These edges have as a cost the energy consumed from the depot to the departure station of the trip node in addition to the consumed energy for serving the particular trip node. Finally, we add edges from the trip nodes to the depots nodes. These edges have as a cost the energy needed to travel from the arrival station of the trip node to the depot node. Our objective is to find the set of roads starting at a depot node and ending at a depot node that cover each node trip exactly once and that minimize the total electric energy consumption.

3. GENETIC ALGORITHM FOR SOLVING THE REAL WORLD APPLICATION OF THE MDADCVRP

In this section, we present a genetic algorithm (GA) for solving the problem under consideration. We use a typical GA to solve the problem.

Next, we present the main feature of our specific GA. i) Problem representation We used in our work the permutation representation. The genotype is represented with an array of several PRT trips. ii) Initial population: The initial population in our GA is generated randomly. In the initialization phase, we generate a set of random permutations which is considered as our initial population. iii) Fitness function: We adapted in this work the Split function of Prins for the capacitated vehicle routing problem[6]. This method have the possibility to find for each permutation the best way of splitting it to a several tour while respecting some constraints. We adapt this method to our context while taking at each time the least cost of the trip to a depot from the different depots considered in our problem. iv) Crossover: In our work, we simply choose a random point in the permutation and take first part from the first parent and the missing trips from the second parent while respecting their order of appearance. This crossover is named the one-point crossover. v) Mutation: In our work, we take a permutation and exchange two trips chosen randomly. This mutation is named the exchange mutation.

4. PRELIMINARY COMPUTATIONAL RESULTS

In this section, we present the preliminary computational results of our exact approach to solve the presented PRT problem. In order to validate our proposed approach, 100 instances were generated in which the size of the problem (i.e. the number of travels) is varied between 10 travels and 100 travels by steps of 10. For each number of travels, 10 instances are generated. The instances generator is adapted to our context from the one of the literature [4], [3]. To evaluate our results, we used the the GAP metric which is obtained as follows: GAP = $(\frac{(SOL-LB)}{LB}) \times 100$. We should note that LB is the linear relaxation of a valid DCVRP mathematical formulation. We obtained an average GAP of 2.85 % in 0.231 seconds. Our first observation from these results is that our method generate good solutions in a relative reduced computational time. In addition, for instances with less than 40 travels the quality of the solutions is quite acceptable with 0.8 % or less in term of GAP. We should note also that the average gaps observed grow when the instance size increases to reach a maximum value of about 6.435% for the energy. However the average time is still below 0.3 seconds. This latter represents an interesting behavior for the GA as our problem presents some specific characteristics related to it as its low scarcity rate. These preliminary results are encouraging in terms of small instances problem solvability.

5. CONCLUSIONS AND FUTURE WORKS

This paper presented the PRT transportation mode as a promising solution to enhance urban transportation tools efficiency and efficacy. The PRT have the potential to offer a unique transportation experience for its users. In this paper, we presented a new MDADCVRP related to PRT. Also, we proposed and tested a GA to deal with our problem. Our preliminary computational results are very promising in term of finding feasible solutions in a relatively short computational time. As an extension, the development of more sophisticated exact and heuristics is under consideration. Also, we would like to expand our problem to include more than a single objective related to PRT.

6. REFERENCES

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