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Online algorithm for dynamic dial a ride problem and its metrics

Athanasios Lois[a*], Athanasios Ziliaskopoulos

[a] "*University of Thessaly, Pedion Areos, Volos 38222, Greece*"

Abstract

In this paper, an online regret based dial-a-ride (OR-DARP) algorithm is introduced and its performance evaluated on an actual demand responsive transit (DRT) system. The innovative part of the algorithm is the design of the optimization engine. A signal communication scheme between the trip dispatcher and the algorithm is used to improve utilization of the available idle time that can then be devoted to the optimization engine. The basic concept is as follows: a. Every trip request is treated as an emergency request demanding an immediate answer, b. The optimization engine runs continuously, thereby consuming every idle time fragment unless interrupted by a new trip request. The trip data are real, and they are sourced from a DRT system operating at a municipality in northern Greece where a static dial-a-ride algorithm was used as the optimization engine. Given the fact that these trips data provide all trip details plus the show-up time (the most important feature for our study), these data are the ideal basis for an “a posteriori” evaluation of the proposed online approach. Another contribution of this paper is the identification of the critical parameters in the trade-off between benefits gained from continuing to optimize an online system versus the losses of non-served demands. This important issue when applying online algorithms has not been studied extensively in the literature so far (to the best of our knowledge).

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Keywords: "Online dial-a-ride; regret optimization;cost metrics; profits metrics; performance metrics"

* Corresponding author. Tel.: +30-24210-74651; fax: +30-24210-74400. E-mail address: lois@uth.gr

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1. Introduction and Literature review

In this paper, we introduce an online regret based dial-a-ride algorithm and we study its performance under heavy demand situations. The basic structure of our algorithm is founded on the utilization of two separate sub-algorithms for handling incoming trip requests and continuously improving the solution. The first algorithm mainly examines trip requests myopically (minimal optimization) and makes a fast yes/no decision regarding trip acceptance. The second algorithm is focused on optimization and uses all available idle time between trip requests to improve the solution. In comparison with similar algorithms proposed by other authors, our algorithm benefits from a new concept. The optimization process is not based on rigidly defined constant optimization time windows (e.g. 10 seconds, 1 minute, 5 minutes). It operates continuously to improve the solution, exploiting even small fragments of idle time between incoming trip requests. The main focus of this paper is to identify critical points in the benefits of the optimization procedures under a heavy or cascading load. The scheme was evaluated on an actual demand responsive transit (DRT) system, operating in the former municipality of Philippi in Northern Greece. The computational results indicate that

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there is a specific point, regarding the number of trip requests, after which it is more profitable to accept more minimally optimized trip requests than to insist on heavy optimization for existing trip requests.

Existing studies in the field of online dial-a-ride problems presented are as follows. Psaraftis, H. N. (1980) presented an exact method for the dynamic DARP as an adaptation of the static version for the same problem. Although Psaraftis' version has been limited to very small problem instances due to the combinatorial nature of the problem, it remains one of the few exact methods that help gain insight into the problem. Madsen et al. (1995) have presented an algorithm for a real-life multi-vehicle dynamic DARP consisting of up to 300 daily requests for the transportation of elderly and handicapped people in Copenhagen. The problem had many constraints such as time windows, multi-dimensional capacity restrictions, customer priorities and a heterogeneous vehicle fleet. When a new request arrives, it is inserted in a current route using an efficient insertion algorithm based on that of Jaw et al(1986). Computational results on real-life instances with up to 300 requests and 24 vehicles have shown that the algorithm was fast enough to be used in a dynamic context and that it is capable of producing good quality solutions. Teodorovic and Radivojevic (2000) developed a fuzzy logic model for the online DARP problem. They combine fuzzy logic reasoning in the insertion procedure to make the decision about which vehicle will accept the new request. The model was tested for a set of 900 trip demands and a fleet of 30 vehicles with seemingly reasonable results. Diana et al. (2006) proposed a probabilistic model that requires only the knowledge of the demand distribution over the service area, and the quality of the service. The quality of service is defined in terms of time windows associated with pickup and delivery nodes. Given a number of n trip requests in a service area, the objective is to estimate the number of vehicles needed to serve these requests. To benchmark the model, they compare it to a simulation approach that requires knowledge of the complete daily schedule. The requests were scheduled using a parallel regret insertion algorithm introduced by Diana et al. (2004). Computational results proved that the probabilistic model produced better results concerning the minimum number of vehicles required to service all trip requests. However, for the largest problem instance, the model gave worse results. Horn (2002) provides a software environment for fleet scheduling and dispatching of demand responsive services. The system can handle in advance as well as immediate requests. New incoming requests are inserted into existing routes according to least cost insertion. A steepest descent improvement phase was running periodically. Also, automated vehicle dispatching procedures, to achieve a good combination of efficient vehicle deployment and customer service, are included. The system was tested in the modeling framework LITRES-2 by Horn (2002b), using a 24-hours real-life data set of taxi operations with 4282 customer requests. Attanasio et al. (2004) presented a modified version of the static tabu search algorithm presented by Cordeau et al. (2003) to handle the online nature of the DARP. The online algorithm can be described as follows: A static solution is constructed on the basis of the requests known at the start of the planning horizon. When a new request arrives, the algorithm performs a feasibility check, i.e., it searches for a feasible solution to include the new service request. If the new request is accepted, the algorithm performs post-optimization, i.e., it tries to improve the current solution. One practical problem with this approach is the difficulty of solving the problem in a shorter time interval than the updating interval. Coslovich et al. (2006) presented an algorithm which follows a two-phase strategy for the insertion of a new request into an existing route. An off-line phase is first used to create a feasible neighborhood of the current route through a 2-opt solution improvement mechanism. An on-line phase is then used to insert the new request with the objective of minimizing user dissatisfaction. Marco Diana (2006) presented a study about the importance of information flow related to temporal attributes for a dynamic DRT system. Authors focused on three characteristics of the information flow. These characteristics were: Percentage of real time requests, interval between call-in and requested pickup time, and the length of computational time. They handled demands in batch mode. Demands were grouped and processed by algorithms in time slots of 5 minutes, 1 minute, 10 seconds. Because of this grouping and batch processing, customers have to be called back to be notified of the acceptance or rejection of their request. The authors tested two different algorithms to draw conclusions about the influence on the solution quality. The first algorithm was the dynamic version of the algorithm proposed by Jaw et al. (1986) and it is based on the best insertion method. The second algorithm was the dynamic version of an older algorithm proposed by the authors, based on the regret method. In their formulation, the quality of the schedule is given by the number of rejected requests and by the value of the objective function z. Their experiments were based on trip requests gathered by the transportation service for elderly and disabled people in Los Angeles County. In order to run specific scenarios, authors made some assumptions concerning: the number of requests known in advance, the expected value of time intervals between call-