Congestion avoidance: optimization of vehicle routing planning for the logistics industry

C. Verbeeck and P. Vansteenwegen

University of Ghent, Department of industrial management,
{Cedric.Verbeeck,Pieter.Vansteenwegen}@ugent.be

Abstract

This research focuses on the development of efficient solution methods to solve time dependent orienteering problems (TD-OP) in real time. Orienteering problems are used in logistic and touristic cases were an optimal combination of locations needs to be selected and the routing between the locations needs to be optimized. In the time dependent variant the travel time between two locations depends on the departure time at the first location.

Keywords: congestion, vehicle routing planning, orienteering problem, time dependency

The orienteering problem (OP) integrates the Knapsack Problem (KP) and the Travelling Salesperson Problem (TSP). In contrast to the TSP not all vertices need to be visited but each vertex has a given score. The OP's goal is to maximize the total score collected by visiting a selection of vertices, while the TSP tries to minimize the travel time or distance. However, determining the shortest path between the selected vertices helps to be able to visit more vertices and increases the collected score during the available time. In addition to this a feasible path should start and end at a predetermined vertex.

Orienteering problems are typically used in logistic planning tools where each vertex resembles a customer and the score reflects the profit margin. Furthermore they serve as the basis problem formulation of personalized touristic trip planners where a vertex stands for a point of interest and the score indicates the personal interest of the tourist. This research focuses on time-dependent orienteering problems (TD-OP) which means that the travel time between two vertices depends on the departure time at the first vertex. This specific problem formulation allows us to tackle congestion related issues in routing problems. To the best of our knowledge, this problem is only discussed by [1, 2, 3, 4]. This research focuses on developing metaheuristics to obtain solutions in real-time. The existing metaheuristics for the time-dependent vehicle routing problem (TD-VRP), a related problem, serve as an interesting starting point.

To model time dependency we adopted a speed model that allows us to efficiently calculate the travel time between two vertices (i,j) based upon the road category and departure time at vertex i. This extension to the speed model for the TD-VRP [5] consists of 5 road categories c simulating realistic congestion patterns and a typical day is divided in 4 time slots k. Therefore a speed level v_{ijk} is defined for every combination of a time slot and road category. Finally the travel time between two vertices can be calculated by iteratively adding the result of the following rule in all consecutive time slots: $T_{ijk} = remaining\_distance * speed_{ijk}$. Secondly every arc needs to be assigned to a specific road category. The datasets used for the TD-VRP solution methods don't resemble a real live road network as arcs between two vertices were randomly assigned to a road category. Therefore we transformed the existing datasets of the orienteering problem to time dependent instances by manually inserting congestion patterns imitating a real live road network (e.g. realistic morning and evening peaks between city centers and living areas).

A first time dependent local search move and local evaluation metric are already successfully implemented. This move iteratively tries to insert non-included vertices into an existing solution thus improving its total score. To prevent a full evaluation of a solution after an insertion attempt, we store for every included vertex the maximum amount of time that this vertex can be postponed before the solution becomes infeasible. This enables an efficient checking and updating mechanism.

Based on this local search move three basic metaheuristic frameworks were implemented as a first test, namely, an artificial immune system (AIS), an iterated local search (ILS) and an ant colony system (ACS). This choice was motivated by the fact that generally very complex problems require simple solution mechanics. Subsequently using greedy components that rely on the ratio of the score and distance turn out to be less computational expensive and drastically enhance the performance.

The current results indicate that obtaining solutions in real-time is feasible as the maximum computation time for the largest datasets is still smaller than 6 seconds and the average runtime is 2 seconds. Currently the ILS framework outperforms the AIS and ACS, especially on small instances. However ACS and AIS deliver both significantly better results on the larger datasets.

Before developing more local search moves or other metaheuristic frameworks, these preliminary results need to be analyzed in detail to explain the difference in performance. This will help to design an appropriate solution method that strikes the optimal balance between the quality of the results and the computation time.

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