A Library of Vehicle Routing Problems

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1 Introduction

Sörensen et al. [1] identify a gap between the Vehicle Routing Problem (VRP) addressed by the scientific community and problems faced by commercial software vendors, who have to solve real-world problems on a day to day basis. The authors note the relative simplicity of the models used in the scientific literature, when compared to the models that must be tackled in the real-world. One of the author's own experience as a software vendor bears this out. In an internal survey of 21 Optrak customers, 100% have heterogeneous fleets, time windows and asymmetric time/distance networks, 95% have to deal with the complexities of driver break and working time legislation, 57% feel the combination of their operations and their customers' time-windows necessitate some form of rush-hour speed modelling and 76% have non-trivial vehicle loading and packing problems (stacking, intermediate containers, compartments etc.) and 70% have vehicle access restrictions to sites of some form or another. While some, but certainly not all, of these issues are dealt with in the scientific literature, even the"rich vehicle routing problem" research does not appear to embrace them to the extent that commercial vendors do [1].

In the same paper, Sörensen et al. also identified a "lack of advanced metaheuristic techniques in commercial software", effectively saying that software developers are largely ignoring what is probably the main thrust of current academic work in the field. We suspect that this is partly due to the academic community failing to demonstrate that their solutions are applicable to the needs of the commercial world, or at least failing to get that message across to the industrial community.

So why are academics not tackling real-world problems? In discussing this issue with researchers at several UK universities, the primary reasons given is the lack of suitable data and a lack of a clear definition as to what actually constitutes a real-world problem.

The purpose of this paper is to introduce a library of problems derived directly from commercial Vehicle Routing implementations. These problems span a range of applications from commercial waste oil collection to newspaper delivery. The provenance of the data means that for each problem type, multiple problem data sets are available.

In order to properly describe the problem data, an object-oriented data model has been created that is sufficiently general to cover the variety of problems presented. In order to describe the constraints on the solution, a domain-specific language (DSL) [2] has been created that not only represents the constraints in a readily comprehensible manner, but also compiles into a automatic solution validation engine - which should provide researchers with a valuable checking mechanism as they compile their own solutions. The library is provided via a web-based service that will allow both downloads of data and uploads of candidate solutions with automatic tabling of results.

Finally, solutions to all problems created with the Optrak software will be published for each problem, allowing a proper comparison of the results of modern metaheuristic or other algorithms with a more traditional heuristic approach.

2 The Model

Sörensen et al. [1] state that the normal mixed integer-linear programming formulations for VRP [3] are not employed for real-world problems due to the difficulty of construction. The approach proposed here is to use an immutable Objected-Oriented Programming (OOP) model to describe the data and interrelationships between the entities and a functional language-based notation to express the constraints. This confers a number of benefits, one of the most important of which is that OOP models can be more readily understood by domain experts. In other words, they provide a mechanism of capturing the essence of a real-world problem that can be communicated to, and validated by, the people who know the problem intimately. A second reason for using an OOP paradigm is that the notion of inheritance is an ideal way to express the difference between the specific real-world models and the "basic" core model. For example, a customer delivery site entity can be extended with attributes such as unloading facilities and constraints that limit the suitability of vehicles.

But the model is not simply a reformulation of the standard models. A number of critical real-world factors are taken into account that are not found in the standard VRP [3] or classification schemes such as [4] or [5]. Probably the most significant departure is the elimination of the concept of demand in favour of the order. This reflects the commercial reality behind most distribution - goods are ordered for delivery. But this is not a simple name change. Customers can have multiple orders that have different delivery constraints including due dates and can be delivered separately or together - but when delivered together, the time to make a delivery is less than the sum of two separate deliveries - thus making the decision to deliver together or separately an important part of the problem.

Other important differences include the modelling of (un)loading times based on a combination of products and vehicle and site facilities and a generic packing model for the vehicle loading based on a nested container representation.

The use of the DSL to specify the differences between models also enables a very flexible approach to the treatment of the cost function. A cost function can formulated from any of the model elements, such as vehicle or labour costs. Standard elements such as time windows or delivery quantities can be treated as hard constraints or treated as soft constraints and incorporated into the cost function. Further specialisation can create additional cost functions for a given problem, allowing multiple objective functions.

All data sets will be supplied with pre-calculated time/disance matrices based on road networks. Where appropriate and where data is available this will include time-varying data to reflect rush-hour speeds.

3 Model Examples

At the conference, we will present models that have been created and applied to specific problems. From the standard academic research these will be the VRP with time windows as defined in [6], and the VRP with pickup and delivery problem as defined in [7]. From real-world instances the following problems will be presented:

- Newspaper and magazine delivery A problem demonstrating the need to manage orders separately.
- Paper and printing products delivery A commercial problem from a large paper merchant.
- Fuel oil delivery A small fuel oil delivery problem illustrating the modelling of compartmented vehicles and a multi-day delivery horizon with different due dates.

4 The Data Library

Permission has been obtained from a number of Optrak customers to provide problem sets derived from their data. This means that a large body of data sets will be made available for each problem variant. This is of particular value for hyper-heuristics where training on some data sets can be used to control behaviour on other instances.

Facilities will be provided to allow the upload of solutions for validation by the executable DSL. The upload format will require embedded metadata with the provenance of the solution (e.g. researchers, algorithms types, and references, alternatively the commercial package) and execution details such as time taken and processors used. This will enable automatic tabulation and reporting of results of all valid solutions.

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