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Ulrich Vogel: A flexible metaheuristic framework for solving rich vehicle routing problems

Route planning is one of the most studied research topics in the operations research area. While the standard vehicle routing problem (VRP) is the classical problem formulation, additional requirements arising from practical scenarios such as time windows or vehicle compartments are covered in a wide range of so-called rich VRPs. Many solution algorithms for various VRP variants have been developed over time as well, especially within the class of so-called metaheuristics. In practice, routing software must be tailored to the business rules and planning problems of a specific company to provide valuable decision support. This also concerns the embedded solution methods of such decision support systems. Yet, publications dealing with flexibility and customization of VRP heuristics are rare. To fill this gap this thesis describes the design of a flexible framework to facilitate and accelerate the development of custom metaheuristics for the solution of a broad range of rich VRPs.
The first part of the thesis provides background information to the reader on the field of vehicle routing problems and on metaheuristic solution methods - the most common and widely-used solution methods to solve VRPs. Specifically, emphasis is put on methods based on local search (for intensification of the search) and large neighborhood search (for diversification of the search), which are combined to hybrid methods and which are the foundation of the proposed framework.
Then, the main part elaborates on the concepts and the design of the metaheuristic VRP framework. The framework fulfills requirements of flexibility, simplicity, accuracy, and speed, enforcing the structuring and standardization of the development process and enabling the reuse of code. Essentially, it provides a library of well-known and accepted heuristics for the standard VRP together with a set of mechanisms to adapt these heuristics to specific VRPs. Heuristics and adaptation mechanisms such as templates for user-definable checking functions are explained on a pseudocode level first, and the most relevant classes of a reference implementation using the Microsoft .NET framework are presented afterwards.
Finally, the third part of the thesis demonstrates the use of the framework for developing problem-specific solution methods by exemplifying specific customizations for five rich VRPs with diverse characteristics, namely the VRP with time windows, the VRP with compartments, the split delivery VRP, the periodic VRP, and the truck and trailer routing problem. These adaptations refer to data structures and neighborhood search methods and can serve as a source of inspiration to the reader when designing algorithms for new, so far unstudied VRPs. Computational results are presented to show the effectiveness and efficiency of the proposed framework and methods, which are competitive with current state-of-the-art solvers of the literature. Special attention is given to the overall robustness of heuristics, which is an important aspect for practical application.