Evaluating and Optimizing Metaheuristic Algorithms: A step ahead in VRP research

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Abstract

The evaluation of heuristic performance on vehicle routing problems (VRP) is most commonly done through empirical testing on some benchmark problem set. This makes it difficult to estimate the robustness of proposed algorithms. An algorithm working well on a set of standard test problems does not necessarily perform well on any particular data set and is usually extremely sensitive to changes in the data. Therefore a scientific basis is needed for heuristic evaluation and comparison, and is the subject of this research project.

Keywords: Vehicle Routing Problem, Heuristic Algorithms, Statistical Evaluation

The vehicle routing problem with time windows (VRPTW) is an extension for the traditional vehicle routing problem, an extensively studied class of combinatorial optimizations problems with a broad range of real-life applications. Finding an optimal solution for the NP-hard VRPTW is difficult, even for relatively small problem instances. Therefore, research has focused on heuristic solution approaches. Through the years a lot of heuristic procedures have been proposed and can be categorized into three categories: construction heuristics, improvement heuristics (local searches) and the more powerful metaheuristics in which the two former categories are incorporated [1] [2].

What is lacking, however, is an agreed-upon methodology for analyzing and comparing heuristic performance on VRP problems. At the moment, the most widespread method of heuristic evaluation is empirical analysis, i.e. evaluating the performance on a set of standard test problems. Heuristics are rarely compared by means of statistical techniques, even though empirical evaluation does not give any indication on the robustness of the algorithm. Solomons benchmark instances are an example of a popular benchmark set for analyzing VRP heuristic algorithms. There are, however, some problems arising from this competitive testing of heuristic algorithms, in which a newly developed algorithm is proven to work better than known algorithms if it outperforms the latter on a standard set of benchmark problems. Otherwise it is considered a failure. This competitive emphasis tells us which algorithms are better, but does not give any explanation as to why these are better [3]. The lack of a scientific basis leads to researchers being able to present the results of their algorithm in such a way that it makes the algorithm look good. A heuristic algorithm performing well on some set of standard benchmark problems does not generalize, however, to it working well on any problem set [4] [5].

In order to arrive at statistical meaningful conclusions, experimental design should be employed for evaluating the (interacting) effects of problem characteristics, algorithms parameters and heuristic components on overall algorithm performance and results should be compared by appropriate techniques. Few researchers have already done research on the matter of controlled experimentation, e.g. [6]. These researchers follow an ANOVA (Analysis Of Variance) approach and treat both problem characteristics and algorithmic properties, the two factors affecting algorithmic performance, as factors with a limited set of levels. This treatment as categorical variables has some limitations, such as the fact that only insights are gained for the measured levels. Secondly, when considering only a high and low level, the detection of non-linear effects is impossible. Therefore this research will abandon the traditional ANOVA approach and apply a regression perspective in order to gain complete insights over the full range of algorithmic parameter values and problem characteristics.

The aim of this research project is to develop a new methodological framework to analyze VRP algorithm performance that allows statistical inference from a sample of problem instances. This methodological framework will allow researchers to (1) optimize VRP algorithms and (2) perform a statistical sound comparison of multiple algorithms.

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