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Editorial

A wide spectrum of optimization problems is known from combinatorial optimization and mathematical programming. Fascinating problems, such as the traveling salesman problem, the quadratic assignment problem, routing, scheduling and timetabling problems, etc., have attracted many researchers since the mid 20th century. Because of the practical relevance of good solutions to such problems, many investigations on heuristics aiming at finding near-optimal solutions have been done. The term *metaheuristics* is common for optimization heuristics that are not specific to one particular problem.

In general, metaheuristics cannot guarantee the optimality of a found solution. However, in many cases they are very effective and efficient in solving even large size problems. Plenty of difficult optimization problems in a huge variety of areas, including bioinformatics, logistics, engineering, business, etc., have been tackled successfully with metaheuristic approaches, for example simulated annealing, genetic and evolutionary algorithms, tabu search, ant colony optimization, scatter search or iterated local search. For many problems, the resulting algorithms are considered state-of-the-art methods.

For many years the main focus of research was on the application of single metaheuristics to given problems. In recent years, it has become evident that the concentration on a sole metaheuristic is rather restrictive for advancing the state of the art when tackling both academic and practical optimization problems. A skillful combination of concepts of different metaheuristics can lead to more efficient behavior and greater flexibility when dealing with real-world and large-scale problems. The incorporation of typical operations research (OR) techniques, e.g., integer or linear programming techniques, can be very beneficial. Also, the combination of metaheuristics with other techniques known from artificial intelligence (AI) can be very fruitful. Combinations of metaheuristic components with components from other metaheuristics or optimization strategies from AI and OR are called *hybrid metaheuristics*.

The design and implementation of hybrid metaheuristics raises problems going beyond questions about the design of a single metaheuristic. Choice and tuning of parameters is for example rendered more difficult by the problem of how to achieve a proper interaction of different algorithm components. Interaction can take place at low-level, using functions from different metaheuristics, or at high-level, e.g., using a portfolio of metaheuristics for automated hybridization.

This special issue of the *Journal of Mathematical Modelling and Algorithms* is devoted to this interdisciplinary topic and contains six papers covering a wide spectrum of subjects.

The paper by Talbi and Bachelet presents an architecture for the implementation of cooperative metaheuristics on a parallel distributed system. The metaheuristic presented by the authors is composed of four main components: A diversifying agent, an intensifying agent, an adaptive memory and a search agent. The agents communicate through the adaptive memory and they have different search goals. The authors introduce their framework by describing an application to the quadratic assignment problem and present an implementation for each of the four components.

The contribution of Ribeiro, Plastino and Martins is a representative example of the successful integration of metaheuristics with other techniques from AI. The paper discusses the use of data mining techniques for guiding the solution construction process. The authors illustrate an application of this idea to the set packing problem, combining GRASP with a pattern extraction mechanism. Data mining techniques are employed to extract promising patterns from a set of selected solutions. These patterns are then used to guide the subsequent solution construction phase.

Metaheuristics can also be successfully hybridized with OR techniques, as shown by Umetani, Yagiura and Ibaraki, who present a rather complex hybrid technique to attack the one-dimensional cutting stock problem, which arises in industrial applications. The problem is tackled by iterated local search equipped with specific neighborhood structures. Since such neighborhoods can be very large, the authors incorporate linear programming (LP) and sensitivity analysis to efficiently explore them. LP is used to reduce the size of the explored neighborhood, while sensitivity analysis enables LP problems to be quickly solved.

Di Gaspero and Schaerf describe an approach based on a portfolio of neighborhoods. In this case, the hybridization takes place at low level, i.e., at the level of neighborhoods used by a local search. The authors study different operators on neighborhoods and they test combinations with a token-ring heuristic and a heuristic based on kickers on two variants of the timetabling problem.

The same level of integration characterizes the article by Bianchi, Birattari, Chiarandini, Manfrin, Mastrolilli, Paquete, Rossi-Doria and Schiavinotto. The paper presents a study in which a stochastic variant of the vehicle routing problem is tackled by a set of metaheuristics comprising simulated annealing, tabu search, iterated local search, ant colony optimization, and evolutionary algorithms. The authors investigate in detail whether an easy to compute approximation of the objective function is advantageous for the common local search operation. They further analyze a hybridization with a known TSP solver.

Finally, López-Ibáñez, Paquete and Stützle report on the successful integration of population-based techniques and local search when tackling the

bi-objective quadratic assignment problem. All combinations of a multi-objective ant colony optimization and a strength Pareto evolutionary algorithm – as population-based parts – and either iterative improvement or robust tabu search – as local search techniques – are investigated under constant total time conditions for both structured and unstructured instances of the problem.

It can be stated that research on hybrid metaheuristics is mostly based on experimental work, thus being methodologically probably more related to natural sciences than to computer science. The proper design of experiments and the validity of analyses of experimental work for algorithms is a key aspect in hybrid metaheuristics. The attention of researchers to this aspect seems to be very important for the future of the field.

The contributions of this special issue comprise a selection of papers submitted after the First International Workshop on Hybrid Metaheuristics (HM 2004), held in Valencia (Spain) in August 2004. The workshop was very successful and highlighted the interest of researchers and practitioners in this field. This interest has been also confirmed by the number of submissions to the subsequent workshop HM 2005 (Barcelona, Spain, August 2005). The six papers appearing in this issue have been selected from 29 submissions. Special attention has been paid to the evaluation of the experimental analysis, which is crucial for empirical studies. We are very grateful to the reviewers for their effort in thoroughly reviewing the papers; their comments were extremely helpful for the selection of the contributions and, we believe, also for the authors themselves. We would like to thank all the authors who showed their interest in this special issue, and Professor Vic Rayward-Smith for giving us the opportunity of editing it.

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