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Special issue on mathematical contributions to metaheuristics editorial

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Using mathematical models in the framework of heuristic algorithms is no news in applied computer science if we consider, for instance, the development of linear programming to assist with the scheduling of the airlift during the Berlin blockade right after World War II. Similar applications, though possibly not with such grand results, have been developed ever since. So, why this special issue, primarily meant for putting an emphasis on the possibility of embedding sound mathematical techniques into robust algorithmic approaches to optimization? The reason is twofold.

First, the literature has demonstrated the possibility of using extremely effective algorithmic schemes, namely metaheuristics, for solving hard optimization problems. However, current metaheuristics make no use of explicit mathematical tools. Second, innovative mathematical tools have been proposed, refined and shown quite effective on optimization problems that are combinatorial, stochastic or continuous in nature. These tools, however, target the exact solution of these problems.

The use of mathematics in heuristics design, and most notably in metaheuristics design, has been largely neglected in the optimization literature and more generally by the optimization community. For example, in the last installment of the Meta-

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heuristics International Conference there were very few references to important mathematical programming concepts such as duality theory and bounds on optimal solution values. However, recent developments in integer and stochastic programming and in mixed-integer programming tools suggest that it need not be that way, and that contributions to the improvement of the state of the art in optimization can be derived also from mathematics in heuristics.

This special issue consists of contributions to the recently established *Matheuristics* workshop series. The Matheuristics workshops are proposed as a forum for researchers working either on exploiting mathematical programming (MP) techniques in a (meta)heuristic framework or on granting to mathematical programming approaches the cross-problem robustness and constrained-CPU-time effectiveness that characterize metaheuristics. Discriminating landmark is some form of exploitation of the mathematical formulation of the problems of interest.

Despite its deep roots, the field is still in its infancy. It is still too early to determine the main directions along which mathematics can prove useful in metaheuristics design. This was well evident at the Matheuristics workshops, which hosted presentations on topics ranging from local branching or related techniques to optimized metaheuristics operators, and from tools for graph theory advancement to completely new heuristic paradigms, such as the corridor method or kernel search. This special issue includes some examples of this variety of contributions.

The article "Mixed-Integer Programming Models for Nesting Problems" by Matteo Fischetti and Ivan Luzzi addresses a relevant industrial problem that requires the placement of objects into a generic container so that no two objects overlap, where the goal is to find an optimal collection of objects that can be placed. The authors introduce a new MIP model for a subproblem arising in the construction of heuristic nesting solutions, and show its potentials in finding improved MIP solution techniques. This is still not appropriate to deal with the complexity of real-world nesting instances, but it can be very useful to address some simplified—but NP-hard nonetheless—subproblems arising in heuristic solution methods.

In the area of stochastic multiobjective combinatorial optimization, Walter J. Gutjahr's "A Provably Convergent Heuristic for Stochastic Bicriteria Integer Programming" proposes a general framework procedure called APS (Adaptive Pareto Sampling) for determining the set of Pareto-optimal solutions of bicriteria combinatorial optimization problems under uncertainty, and shows a convergence result for the proposed heuristic. Special attention is given to the case where the corresponding deterministic bicriteria combinatorial optimization problem can be formulated as a bicriteria integer linear program.

In "Algorithms for the Non-Bifurcated Network Design Problem," Enrico Bartolini and Aristide Mingozzi propose a number of algorithms, both exact and heuristic, for a special network design problem. Of particular interest for this issue is an innovative heuristic framework which builds on top of a partial enumeration approach by iteratively refining the previously obtained solutions and bounds. This is an innovative construction method, which shows some promise for further analysis.

Finally, "Benders Decomposition, Lagrangean Relaxation and Metaheuristic design" by Marco Boschetti and Vittorio Maniezzo revisits two well-known decomposition techniques and shows how these can be easily converted into metaheuristic

frameworks. The paper is quite didactic in structure, trying to make the point that many results originally presented in an exact solution context can actually be translated to effective heuristic design contributions. Several computational results substantiate this claim.

In conclusion, we would like to thank all the authors that submitted articles, as well as all the reviewers, for the efforts devoted to this issue. We believe that the result constitutes a significant achievement in the direction of establishing mathematics as a credible tool for obtaining fast and reliable solutions to real-world problems.