Guest editorial: special issue on automated design and adaptation of heuristics for scheduling and combinatorial optimisation

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Scheduling and combinatorial optimisation problems appear in many practical applications in production and service industries and have been the research interest of researchers from operations research and computer science. These problems are usually challenging regarding both complexity and dynamic changes, which requires the development of innovative solution methods. In the last decade, there has been a growing interest in applying computational intelligence techniques to help facilitate the design of algorithms and to enhance the generalization of solutions. This special issue aims to present the most recent advances in scheduling and combinatorial optimisation with a special focus on two themes: (1) automated heuristic design, and (2) self-adaptive algorithms. Following an open call for papers, we received 19 submissions, and six papers are finally accepted for publication. These 6 papers, reflecting the two main themes of the special issue, tackle different challenging problems in the field including production scheduling, scheduling in cloud computing, 2D bin packing, traveling thief problems, and dynamic pickup and delivery problems. To solve these problems, novel solution methods based on genetic programming, cooperative coevolution, ensemble learning, and evolutionary multi-objective optimization, have been proposed and shown very promising results as compared to the state-of-the-art methods in the literature.

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Three papers in this special issue focus on the applications of genetic programming (GP) for evolving heuristics for dynamic and complex optimisation problems. This reflects the steady growth of research on GP for automated heuristic design in recent years. In “Evolving dispatching rules for optimising many-objective criteria in the unrelated machine environment”, the authors present the first attempt to take into account many objectives when evolving dispatching rules for unrelated machine scheduling problems with GP. The experimental results show that evolved dispatching rule can outperform standard rules in the literature for more than half of the optimised criteria. Moreover, it is shown that the combination of criteria can have a huge impact on the achieved results, with algorithms performing much better if correlated criteria are optimised together. For certain combinations of criteria, rules evolved by the proposed many-objective GP can outperform those evolved with the single-objective GP.

In “Comparison of ensemble learning methods for creating ensembles of dispatching rules for the unrelated machines environment”, the authors investigate different ways to take advantages of ensemble learning approaches, including boosting, bagging, and cooperative coevolution, to improve the performance of GP for evolving dispatching rules. Also, an ensemble subset search is developed to further improve the performance of the ensemble learning approaches. The influence of the ensemble size and the ensemble combination method are also carefully investigated in this paper. Extensive experiments are conducted to compare different ensemble learning approaches. The analyses show that GP with the proposed single ensemble combination, bagging, and boosting produce the most favourable results. The generated ensembles are significantly better than the rules evolved with standard GP. The proposed ensemble subset search can further improve the results of boosting and bagging GP methods. This paper suggests that ensemble learning is potentially a very useful technique for automated heuristic design.

In “Optimizing agents with genetic programming: an evaluation of hyperheuristics in dynamic real-time logistics”, the authors apply GP to evolve heuristics for agents in dynamic real-time logistics. This is a promising application and shows how GP can be used in a complex dynamic environment. Moreover, it also shows that the heuristics evolved by GP can outperform optimisation algorithms employed in the decentralised and centralised multi-agent system. Rigorous simulation experiments based on real-world scenarios are conducted to show how the evolved heuristics can cope with different levels of dynamism, urgency, and scale. These results strengthen the relevance of decentralized agent-based approaches in dynamic logistics.

Self-adaptive algorithms have been investigated in three papers in this special issue. The main focus of these papers is to develop adaptive mechanisms which can help the proposed algorithms effectively utilise low-level heuristics and efficiently allocate the computational budget. In “A hyperheuristic approach based on low-level heuristics for the travelling thief problem”, the authors use GP for online heuristic selection to evolve combinations of heuristics to find good problem solutions. The experimental results show that the proposed method is significantly

better than the standard genetic algorithm and it can outperform the state-of-the-art algorithms on several small and mid-sized TTP instances.

In “Evolutionary hyper-heuristics for tackling bi-objective 2D bin packing problems”, the authors develop a multi-objective evolutionary framework to build selective hyper-heuristics for solving instances of the 2D bin packing problem. The approach consists of a multi-objective evolutionary learning process, using specifically tailored genetic operators, to produce sets of variable length rules representing hyper-heuristics. Each hyper-heuristic builds a solution to a given problem instance by sensing the state of the instance, and deciding which single heuristic to apply at each decision point. The extensive experiments show that the proposed method significantly outperforms the well-known baseline single heuristics in the different metrics such as measure convergence, diversity, distribution and spread of solutions in the Pareto-approximated set.

The paper “Cooperative evolutionary heterogeneous simulated annealing algorithm for google machine reassignment problem” proposes a cooperative evolutionary heterogeneous simulated annealing algorithm for the real-world google machine reassignment problem. The core of the proposed algorithm is an efficient heterogeneous simulated annealing method and a cooperative mechanism to prevent the algorithm from getting stuck in a local optimum. Extensive experiments were carried out on 30 real-world instances provided by Google at ROADEF/EURO challenge 2012 competition, which are very diverse in terms of the number of processes, resources and machines. The obtained results show that the proposed method outperforms the current state-of-the-art algorithms, providing new best solutions for eleven instances.

These six contributions encompass a wide range of research topics in automated design and adaptation of heuristics. Thus, it is appealing to both the experts in the field and those who want a snapshot of the current breadth of research in this exciting field. GP, as a dominating approach in this special issue, has continued to demonstrate its power for solving complex and dynamic scheduling and combinatorial optimisation problems. We expect that this special issue can extend the application areas of GP to automatic design, learning and adaptation of heuristics for combinatorial optimisation problems from the continuous symbolic regression and classification problems.

The guest editors express their appreciation to the authors for their excellent research, which will undoubtedly encourage engaging work in this exciting field. We would like to thank all the reviewers involved for their invaluable input and Professor Lee Spector as the EiC for his support to initiate this special issue.