Design principles and performance analysis of a selection hyper-heuristic across multiple problem domains

M. Misir[1,2], K. Verbeeck[1,2], P. De Causmaecker[2], and G. Vanden Berghe[1,2]

[1]KAHO Sint-Lieven, CODeS research group,
{mustafa.misir,katja.verbeeck,greet.vandenberghe}@kahosl.be
[2]K.U.Leuven, Department of Computer Science, CODeS research group,
{patrick.decausmaecker}@kuleuven-kortrijk.be

Abstract

The present study is concerned with the design and analysis of a selection hyper-heuristic for solving different problems using different heuristic sets under different execution time limits. Several adaptive hyper-heuristic components were devised to provide high performance for the aforementioned cases. For properly combining these components, a number of coordination mechanisms were developed. The proposed approach composed of these elements was tested using a high-level search framework that currently consists of six of problem domains. The empirical results indicated that the method suggested is capable of adapting itself under different circumstances and efficiently coordinating its subcomponents. It delivered clear performance difference compared to a group of hyper-heuristics from the literature. In addition, it showed superior performance as the winner of an international competition on HyFlex, i.e. the Cross-domain Heuristic Search Challenge 2011.

Keywords: hyper-heuristics, HyFlex, CHeSC

Selection hyper-heuristics have been studied to solve problem instances from various problem domains in a problem-independent manner. The underlying motivation is to employ many heuristics operating on a solution space in order to use their strengths. The primary aim for studying hyper-heuristics is to develop an approach to solve any problem instance without human intervention. However, most of the hyper-heuristic studies concentrate on only one problem domain. Therefore, it is hard to show their capabilities concerning generality. In this study, a fully adaptive selection hyper-heuristic was designed for the generality purpose. This approach consists of the following mechanisms: *heuristic subset selection*, *heuristic selection*, *heuristic hybridisation*, *heuristic parameter adaptation*, *move acceptance* and *re-initialisation*.

The adaptive dynamic heuristic set (ADHS) [2, 3] strategy focuses on specifying proficient heuristic subsets to be used for a certain number of iterations. The heuristic selection process from these subsets was accomplished by a simple performance-based selection rule. In addition, a relay hybridisation mechanism was introduced to determine heuristic pairs that improved current best solutions during earlier iterations. A decision criterion was additionally employed to decide whether to apply a single heuristic or a pair of heuristics from hybridisation. Also, a reward-punishment strategy was used for adapting the parametric heuristics. Together with these mechanisms, a move acceptance strategy with strong diversification abilities, i.e. adaptive iteration limited threshold accepting (AILLA) [2, 3], was used. In the case the diversification provided by AILLA is not good enough to get out of a local optimum, then the current solution is re-initialised. The proposed approach was implemented on the high-level framework, HyFlex [1], to show its performance across six problem domains, i.e. *max SAT*, *bin packing*, *permutation flowshop scheduling*, *personnel scheduling*, *travelling salesman* and *vehicle routing*. In addition, a number of hyper-heuristics involving components from the literature were tested to make a comparison.

The developed hyper-heuristic outperformed all the tested hyper-heuristics with reference to their average performance. Regarding the hyper-heuristic components, the hyper-heuristics with AILLA performed better than the other acceptance mechanisms. The heuristic subset selection approach, ADHS, provided significant performance improvement with a performance-based selection rule compared to the simple random heuristic selection mechanism. Furthermore, the relay hybridisation method easily detected effective heuristic pairs for each problem domain. Also, the re-initialisation operation helped the search process to discover good quality solutions for the problem instances with fast improvement opportunities. Besides the performance of the hyper-heuristic on these tests, it came first among 20 algorithms in the Cross-domain Heuristic Search Challenge (CHeSC'2011).

References

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