

Introduction to the Special Issue on Autonomous Search

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Editors: Youssef Hamadi, Eric Monfroy and Frédéric Saubion

Keywords: Adaptive search, Self configuration of search, Self optimization of search, Meta-search, Learning for Search.

In the fall of 2007, we organized the first international workshop on Autonomous Search, co-located with the International Conference on Principles and Practice of Constraint Programming (CP'2007), which took place at Providence (RI). This event was an occasion to gather about 30 researchers from various research areas of constraint programming and operation research communities. Through this workshop, we wanted to promote works interested in the dynamic and autonomous adaptation of search procedures since recent progresses in the processing of combinatorial problems have demonstrated that search algorithms can become extremely efficient when they take advantage of unsuccessful attempts to drive their exploration. For instance in modern DPLLs, the collect of conflicts feeds the variable selection heuristic, and the quality of unit propagation can control the use of the restart strategy. We believe that a more principled and autonomous approach for search efficiency has to be started now in Constraint Programming. Therefore, following this workshop, we decided to provide, in this special issue, a short overview of some aspects of autonomous search through a selection of representative works.

An Autonomous Search system has the ability to advantageously modify its internal components when exposed to changing external forces and opportunities. It corresponds to a particular case of adaptive systems whose objective is to improve its problem solving performance by adapting its search strategy to the problem at hand. Internal components correspond to the various algorithms involved in the search process - heuristics, inferences, etc. External forces correspond to the evolving information collected during this search process. This information can be either directly collected on the problem or indirectly computed through the perceived efficiency of individual components.

In this issue, we have selected three contributions to this new rising trend, covering two important families of combinatorial problems, namely constraint satisfaction problems (CSP) and Boolean satisfiability problems (SAT). From the methodological point of view, these works also address two main solving paradigms: complete methods, using exhaustive tree-based techniques and incomplete approaches, including evolutionary algorithms.

- The first paper, *Local Restarts in SAT* by Vadim Ryvchin and Ofer Strichman, proposes to dynamically manage the restart policy of efficient DPLL-based SAT solvers. Restart is a

key component of modern SAT solvers such as MiniSAT and its use is usually subjected to parameters that define when it should be applied. While previous approaches are based on global and predefined evaluation of the search state, the authors propose here to use a local estimation of the need of restarting according to new dynamic criteria. This work is therefore a good example of the use of reactivity during the search allowing a dynamic control of one of the basic heuristics of the solver. It highlights that new specific features are needed to evaluate the current search state in order to schedule the application of basic search techniques in complex and efficient solvers.

- The second paper, *Tailoring a Mixture of Search Heuristics* by Smiljana Petrovic and Susan Epstein, focuses on complete solvers for constraint satisfaction problems. These techniques usually build a tree by enumerating values of the variables at each node, and include consistency techniques to prune the remaining search space. There exists many heuristics for choosing the suitable variables and values along the tree, which usually have a great impact on the overall performance of the solver. However, knowing beforehand which combination of heuristic to apply is a difficult problem, usually solved by compromising with a good average-strategy. In this work, the authors propose a general method to automatically learn good heuristics by including a dynamic weighting scheme based on observed performances. Successive applications allow then the solver to progressively identify good choices and to improve the reliability of the solver.
- In the last paper, *From parameter control to search control: Parameter Control Abstraction in Evolutionary Algorithms* by Jorge Maturana and Frédéric Saubion, a generic method to control parameters of evolutionary algorithms is investigated for the resolution of constraint satisfaction problems. Evolutionary algorithms are often subjected to multiple parameters, for instance to adjust the application probability of the variation operators that they use. These parameters are difficult to set and this tuning relies most of the time on empirical knowledge. In this work, the authors define a general method to abstract parameters by means of a more global criterion related to the management of the exploration and the exploitation of the search space. Including learning and modeling stages, this method allows the user to define high level control processes that can be either more supervised or more adaptive.

Through the panel of work presented in this special issue, it appears that two main points have to be carefully studied. First, one has to clearly understand the behaviour of the resolution mechanisms and, secondly, one should benefit from dynamic control techniques. Of course, other important features could be taken into account such as the structure of the instances and the model's properties.

We hope that these works will help to convince Constraint programmers that the development of autonomous search systems constitutes a difficult but rewarding challenge for the community.