Dissertation Corner

Handling Constrained Optimization Problems and Using Constructive Induction to Improve Representation Spaces in Learnable Evolution Model

Doctoral Thesis by Janusz Wojtusiak

The learnable evolution model (LEM) is an evolutionary optimization method which uses machine learning to guide the evolution process (Michalski, 2000). At each step of evolution a machine learning program is applied to induce hypotheses why some candidate solutions perform better and others perform worse. These hypotheses are then instantiated in order to produce new candidate solutions.

This dissertation investigates two closely related problems in the learnable evolution model: the automatic improvement of representation spaces using constructive induction, and the handling of constraints in optimization problems. The former includes an investigation of different aspects of representation space transformations in the context of optimization problems, the development of algorithms that perform these transformations, and algorithms for creating new candidate solutions (via instantiation) in the improved representation spaces. Handling specific types of constraints is closely related to the instantiation task in the modified representation spaces; therefore, the same methods can be used for solving both problems. Moreover, transformations of representation spaces may help in handling constraints of other types, that is, constraints that cannot be handled directly during the instantiation process.

The most important contributions of this dissertation include:

- Classification of constraints into four classes based on the difficulty of handling them in the learnable evolution model. The most important distinction is made between instantiable and general constraints. This distinction is made by the presence of an efficient method for solving them in the instantiation process.
- Design and implementation of methods for handling instantiable constraints given in the form of ordered conditions [ATTR rel EXPR]. Although this type of constraint is very limited and few real world optimization problems may have constraints in this form, they are important for instantiation of conditions with constructed attributes. This is because the algorithm for constructing new attributes can be constrained to create only attributes in this form.
- Design and implementation of three methods for handling general constraints in the learnable evolution model. The methods are specifically designed to work with the learnable evolution model and are based on trimming rules hypothesized from high performing candidate solutions, approximation of the feasible area using machine learning, and using infeasible solutions as a contrast set for learning.
- Design and implementation of methods for automatically improving representation spaces in LEM. Two methods based on data-driven constructive induction are discussed in this dissertation. One of the methods constructs new attributes only in the instantiable form mentioned above, and the other constructs more general attributes.
- Design of methods for instantiating in the modified spaces. The methods are based on the fact that conditions that include constructed attributes can be treated as constraints.

The developed algorithms are implemented in the LEM3 (Wojtusiak and Michalski, 2006) and AQ21 (Wojtusiak et al., 2006) systems and tested on a set of constrained and non-constrained benchmark optimization problems. Additionally, two real world applications are presented in this dissertation. The first one concerns optimization of parameters of complex systems, and the second concerns finding the best discretization of numeric attributes.

Bibliography

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