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Advanced Solving Technology for Dynamic and Reactive Applications

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1 Aims of the Project

The project *Advanced Solving Technology for Dynamic and Reactive Applications* (henceforth called ASTRA) is part of the DFG-funded Research Unit *HYBRIS: Hybrid Reasoning for Intelligent Systems* (www.hybrid-reasoning.org/). The Unit started in 2012 with the aim of investigating different combinations of both qualitative and quantitative reasoning. Among the quantitative aspects addressed are time, uncertainty, preferences, continuous state spaces, and quantitative data such as point clouds or text, from which meaningful symbolic descriptions can be extracted.

The principal investigators of ASTRA are Gerhard Brewka (Leipzig), Gabriele Kern-Isberner (Dortmund) and Torsten Schaub (Potsdam). In a nutshell, the project aims to provide hybrid reasoning methods that are sufficiently expressive to handle complex decision-making problems. So far our research focused on answer set solving technology for incremental and reactive reasoning, preferential reasoning, and finite linear constraint solving. Also, basic techniques for reactive multi-context systems and argumentative reasoning were developed.

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Currently we are realizing new methods to be built on top of the existing systems, extending the range of reasoning methods and addressing in particular uncertain reasoning. In particular, we study combinations of uncertain reasoning and answer set programming (ASP), respectively argumentation. In addition we want to substantially generalize existing preferential reasoning methods. We also study new forms of theory-based reasoning, and further investigate reactive and interactive forms of reasoning.

On top of the advanced reasoning methods, we will build a general framework for complex hybrid problem solving, focusing on interactive, hybrid methods for decision making and for argumentation. The developed methods and frameworks will be tested in applications from the field of logistics, namely logistic systems design, autonomous logistic vehicles, and RoboCup logistics.

To provide a clearer idea of our research we focus in what follows on two of the various aspects of the project, namely on extensions of answer set programming with constraints and on applications in logistics.

2 Constraints in Answer Set Programming

Although ASP thrives in tackling more and more industrial problems, certain aspects are more naturally modeled using variables over finite domains. Consider a planning problem that involves scheduling different machines, each of them producing goods, while consuming energy and material at the same time. Resources like runtime, power, fuel and storage are difficult to handle with propositional approaches, since each combination of values in a constraint needs to be explicitly represented. Therefore, in ASP, a dedicated treatment of numeric variables and constraints is needed as done in constraint processing. In ASTRA, we extended ASP with constraints over integers while preserving its declarative nature and excellent performance. This resulted in the hybrid ASP solver *clingcon* [1] that enhances the learning techniques of an ASP solver with the inferences induced by the underlying constraint satisfaction problem in a lazy way. That is, the relevant knowledge is only made explicit when needed. This is useful in reactive solving [2], for instance, in online planning with continuous domains and durations. It allows us to add or delete constraints to capture evolving constraint satisfaction problems. Also, new resources can be added to an operational solving process using additional constraint variables and domains.

3 Hybrid Reasoning in Logistics Based on ASP

Logistics problems are highly diverse regarding their shape and complexity, and their solutions involve lots of expert knowledge, combinatorial considerations, and calculations. ASP is an excellent methodology both to model expert knowledge, due to its nonmonotonic features, and to solve combinatorial problems. In the following we briefly describe three ASP-based approaches to important logistics problems, the first two developed in collaboration with Fraunhofer IML, Dortmund.[1]

Cellular Transport Systems are goods-to-person order picking systems in which autonomous vehicles provide picking stations with article bins. We set up a multi-agent system where the vehicles are modelled as ASP agents selecting driving jobs from a horizon. The horizon is a number of possible driving jobs the vehicles may execute next. The agents are provided with knowledge restricted to the scope of their specific tasks which plays a critical role for their performance, especially when the planning horizon is large. The approach is tailored to work in a real-life environment, and its evaluation shows a considerable improvement of performance without any physical adjustment of the system. Details and results on the ASP implementations and comparisons to their imperative counterparts can be found in [5,4], indicating advantages concerning the length of code and flexibility of the solving process.

Warehouse planning is a strategic task which requires large amounts of expert knowledge and many different capabilities from any holistic tool applied to it. We designed a software tool which benefits from the strengths of ASP, especially complete declarativity, understandability and solving efficiency, to facilitate warehouse planners [6]. The tool supports in particular process planning, technology dimensioning, and selection and layout generation as well as alternative assessment. The inclusion of expert knowledge enables even unexperienced designers to create a number of feasible and valuable planning alternatives. The main concepts used are a separation of the planning process, the use of ontological knowledge structures and the inclusion of imperative functions within the ASP encodings.

An approach to *multi-agent target assignment and path finding*, a common task in autonomous warehouse systems, is presented in [3]. The declarative representation in ASP has the advantage that it is easily customizable, that is, different variants of the problem arising in different domains can easily be modeled. Empirical evaluations show that the approach actually scales up and allows practical applications to be solved.

[1] Our current logistics applications are not yet based on *clingcon* as the system was not available when this work started. This will change in the near future.

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