Artificial Intelligence 231 (2016) 151–181

Contents lists available at ScienceDirect

Artificial Intelligence

www.elsevier.com/locate/artint

Design and results of the Fifth Answer Set Programming Competition ☆,☆☆

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ARTICLE INFO

Article history:
Received 29 December 2014
Received in revised form 5 August 2015
Accepted 21 September 2015
Available online 30 September 2015

Keywords:
Answer Set Programming
Solver competition
Computational logic

ABSTRACT

Answer Set Programming (ASP) is a well-established paradigm of declarative programming that has been developed in the field of logic programming and non-monotonic reasoning. Advances in ASP solving technology are customarily assessed in competition events, as it happens for other closely related problem solving areas such as Boolean Satisfiability, Satisfiability Modulo Theories, Quantified Boolean Formulas, Planning, etc. This paper reports about the fifth edition of the ASP Competition by covering all aspects of the event, ranging from the new design of the competition to an in-depth analysis of the results. The paper comprises also additional analyses that were conceived for measuring the progress of the state of the art, as well as for studying aspects orthogonal to solving technology, such as the effects of modeling. A detailed picture of the progress of the state of the art in ASP solving is drawn, and the ASP Competition is located in the spectrum of related events.

1. Introduction

Answer Set Programming (ASP) [8,13,33,31,34,47–49,61,65,71] is a well-established declarative programming approach to knowledge representation and reasoning, proposed in the area of logic programming and non-monotonic reasoning. The idea of ASP is to represent a given problem by means of a logic program whose stable models or answer sets correspond to solutions, and then to use an ASP solver for computing solutions. The availability of high-performance implementations, e.g. [3,26,43,45,52,57,60,62,63,66,82], made ASP a powerful tool for developing advanced applications. Nowadays, ASP has been employed in many research areas ranging from Artificial Intelligence to Databases and Bioinformatics; moreover, it has already been used in industrial systems, e.g. [72,78,91].

The advances in ASP solving technology are customarily assessed in competition events [14,46,27,19,2], as it happens for other closely related problem solving areas such as Boolean Satisfiability (SAT), Satisfiability Modulo Theories (SMT), Quantified Boolean Formulas (QBF), and Planning, to mention a few. ASP Competitions are (usually) biennial events; however,

☆ This is an extended and revised version of [16].
☆☆ This paper was submitted to the Competition Section of the journal.

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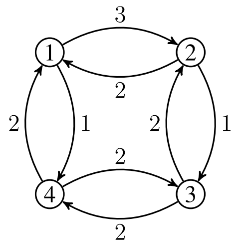
http://dx.doi.org/10.1016/j.artint.2015.09.008
0004-3702/

(a) A directed graph



(b) Fact representation of the graph in (a)

$arc(1,2) \leftarrow$	$cost(1,2,3) \leftarrow$	$node(1) \leftarrow$
$arc(2,1) \leftarrow$	$cost(2,1,2) \leftarrow$	$node(2) \leftarrow$
$arc(2,3) \leftarrow$	$cost(2,3,1) \leftarrow$	$node(3) \leftarrow$
$arc(3,2) \leftarrow$	$cost(3,2,2) \leftarrow$	$node(4) \leftarrow$
$arc(3,4) \leftarrow$	$cost(3,4,2) \leftarrow$	
$arc(4,3) \leftarrow$	$cost(4,3,2) \leftarrow$	
$arc(1,4) \leftarrow$	$cost(1,4,1) \leftarrow$	
$arc(4,1) \leftarrow$	$cost(4,1,2) \leftarrow$	

Fig. 1. An example graph with arc costs that constitutes a TSP instance.

the fifth edition departed from tradition and took place in 2014, affiliated with the 30th International Conference on Logic Programming (ICLP 2014), in order to join the FLoC Olympic Games at the Vienna Summer of Logic.

The Fifth ASP Competition [17] featured a revised setup with novelties involving every aspect of the design from the definition of tracks to the scoring scheme. The new design aims at lowering the efforts of participating in the event, and further pushes the adoption of the recent standard language ASP-Core-2 [15] introduced in 2013. Indeed, in 2013, the ASP-Core-2 language was not fully supported yet by most implementations, and/or the participants did not have enough time to integrate new language features in a completely satisfactory way. Taking these considerations into account, the Fifth ASP Competition was based on the System track of the 2013 edition,[2] reusing the available benchmarks but also adding novel problem encodings.

The benchmark domains were classified by the language features used in encodings (e.g. choice rules, aggregates, presence of queries), rather than by problem "complexity" considered in past events [18]. The competition tracks were devised in accordance with the new benchmark classification and by carefully considering the increasing effort needed for the implementation of specific language features. This was intended not only to widen participation, but also to properly analyze benchmarks and solvers' performance from the perspective of the language. Concerning participants, competitors in the 2013 edition as well as newcomers were invited to participate.

This paper provides a comprehensive report of the Fifth ASP Competition along with an in-depth analysis of results, originally published on the competition homepage [17]. For one, novel problem encodings were devised to furnish an extended benchmark collection and to assess the impact of modeling on the ASP solving process. For another, the most successful systems submitted in 2013 were run against new versions to evaluate the progress. Moreover, the competition setup is compared to those in other problem solving areas. As a result, this paper draws a detailed picture of the state of the art in ASP solving, and locates the ASP Competition in the spectrum of related events.

The remainder of this paper is structured as follows. Section 2 provides the reader with proper preliminaries about the ASP-Core-2 language. The competition setup is discussed in Section 3, while Sections 4 and 5 present the domains and ASP systems, respectively, taking part in the competition. Section 6 announces the competition winners and analyzes the results. In Section 7, the competition design is compared to those of previous editions as well as related events. Section 8 concludes the paper, also pointing out some recommendations for future editions.

2. The ASP-Core-2 language: syntax and semantics

The input language for competition benchmarks, represented in terms of a uniform (first-order) problem encoding along with (ground) facts specifying a problem instance, follows the ASP-Core-2 standard [15]. The syntax of ASP-Core-2 includes elements from classical first-order logic, i.e. terms, atoms, and connectives, as well as extensions like integer arithmetic, aggregates, weak constraints, and queries. These constituents provide a conceptually simple yet powerful modeling language for expressing computational problems with diverse features and complexity. For example, a data representation of the directed graph with arc costs displayed in Fig. 1(a) is shown in Fig. 1(b), where nodes, arcs, and their associated costs are specified in terms of facts over corresponding predicates. Given such instance data, the following ASP-Core-2 program encodes the well-known Traveling Salesperson Problem (TSP):

$$\{hc(X,Y) : arc(X,Y)\} = 1 \leftarrow node(X) \tag{1}$$

$$\leftarrow node(Y), \#\mathtt{count}\{X : hc(X,Y)\} \neq 1 \tag{2}$$

$$reach(X) \leftarrow \#\mathtt{min}\{Y : node(Y)\} = X \tag{3}$$

$$reach(Y) \leftarrow reach(X), hc(X,Y) \tag{4}$$

[2] In the 2013 edition, the "System track" was conceived to assess ASP systems on a fixed set of problem encodings. A detailed comparison with the 2013 format is reported in Section 7.