ASPARTIX-V19 - System Description

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Abstract. In this solver description we present ASPARTIX-V, in its 2019 edition, which participates in the International Competition on Computational Models of Argumentation (ICCMA) 2019. ASPARTIX-V is capable of solving all classical (static) reasoning tasks part of ICCMA'19 and extends the ASPARTIX suite of systems by incorporation of recent ASP language constructs (e.g. conditional literals), domain heuristics within ASP, and multi-shot methods. In this version of ASPARTIX-V we partially deviate from an earlier focus on monolithic approaches (i.e., one-shot solving via a single ASP encoding) to further enhance performance.

1 Solver Description

In this paper we describe ASPARTIX-V (Answer Set Programming Argumentation Reasoning Tool - Vienna) in its 2019 edition. ASPARTIX-V19 solves several reasoning tasks on argumentation frameworks (AFs) [1] and is based on earlier versions of ASPARTIX and its derivatives [4,2,3,6,10]. ASPARTIX-V19 supports all the standard tasks of ICCMA 2019, i.e. credulous/skeptical acceptance and computing all/-some extension(s) for complete, preferred, stable, semi-stable, stage, grounded, and ideal semantics. Given an AF as input, in the format of apx, ASPARTIX-V delegates the main reasoning to an answer set programming (ASP) solver (e.g., [8]), with answer set programs encoding the argumentation semantics and reasoning tasks. The basic workflow is shown in Figure 1, i.e., the AF is given in apx format (facts in the ASP language), and the AF semantics and reasoning tasks are encoded via ASP rules, possibly utilizing further ASP language constructs. In the next section we highlight specifics of the current version and in particular differences to prior versions. ASPARTIX, and its derivatives, are available online under www.dbai.tuwien.ac.at/research/argumentation/aspartix/. The docker of the competition version ASPARTIX-V19 is available at https://hub.docker.com/r/aspartix19/aspartix19-repo.

2 Differences to earlier Versions

In this competition version of the ASPARTIX system we deviate from classical ASPARTIX design virtues. First, while traditional ASPARTIX encodings are modular in the sense that fixed encodings for semantics can be combined with the generic encodings of reasoning tasks, we use semantics encodings specific to a reasoning task. Second, when appropriate, we apply multi-shot methods for reasoning, which is in contrast

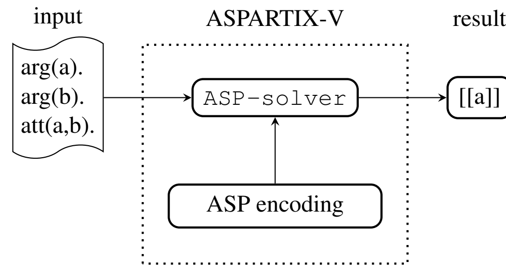

Fig. 1. Basic workflow of ASPARTIX-V

to the earlier focus on so-called monolithic encodings, where one uses a single ASP-encoding and runs the solver only once (as illustrated in Figure 1). Third we make use of advanced features of the ASP-language, and utilize clingo v5.3.0 and v4.4.0 [1] [8].

Next, we list and overview some of the ASP-techniques novel to the ASPARTIX system. First, we exploit the concept of conditional literals [7, Section 3.1.11], which has first been applied for ASP-encodings of argumentation semantics in [6]. For example we simplified the encoding of grounded semantics (cf. Listing 1). Moreover, conditional literals enable us to give ASPARTIX style encodings of the translations from AF semantics to ASP semantics provided in [11]. Second, we exploit clingo domain heuristics [9] (see also [7, Chapter 10]), in order to compute subset-maximal extensions while only specifying constraints for the base semantics [5].

3 Implementation Details

When not stated otherwise, for a supported semantics we provide an ASP-encoding such that when combined with an AF in the apx format the answer-sets of the program are in a one-to-one correspondence with the extensions of the AF. Given an answer-set of such an encoding the corresponding extension is given by the $\mathtt{in}(\cdot)$ predicate, i.e., an argument a is in the extensions iff $\mathtt{in}(\mathtt{a})$ is in the answer-set. With such an encoding we can exploit a standard ASP-solver to compute some extension (SE) by computing an answer-set; enumerate all extensions (EE) by enumerating all answer-sets; decide credulous acceptance (DC) of an argument a by adding the constraint $\leftarrow \mathtt{in}(\mathtt{a})$ to the program and testing whether the program is satisfiable, i.e., a is credulously accepted if there is at least one answer set; and decide skeptical acceptance (DS) of an argument a by adding the constraint $\leftarrow \mathit{not}\ \mathtt{in}(\mathtt{a})$ to the program and testing whether the program is unsatisfiable, i.e., a is skeptically accepted if there is no answer set.

3.1 Conditional literals

We make use of the *conditional literal* [7]. In the head of a disjunctive rule literals may have conditions, e.g. consider the head of rule "$\mathbf{p}(X) : \mathbf{q}(X) \leftarrow$". Intuitively, this

[1] https://potassco.org/

represents a head of disjunctions of atoms $\mathbf{p}(a)$ where also $\mathbf{q}(a)$ is true. Rules might as well have conditions in their body, e.g. consider the body of rule "$\leftarrow \mathbf{p}(X) : \mathbf{q}(X)$", which intuitively represents a conjunction of atoms $\mathbf{p}(a)$ where also $\mathbf{q}(a)$ is true.

A bottleneck of previous encodings for grounded semantics was the grounding step of the solver, i.e., the instantiation of variables with constants typically produces large programs. By utilizing conditional literals we were able to provide a compact encoding (cf. Listing 1) with significant smaller grounded programs.

Listing 1. Encoding for grounded semantics (using conditional literals)

in(X) ← **arg**(X), **defeated**(Y) : **att**(Y,X).
defeated(X) ← **arg**(X), **in**(Y), **att**(Y,X).

Moreover, conditional literals allow for an ASPARTIX style implementation of the translations from argumentation framework to grounded logic programs provided in [11]. For example consider our one line encoding of stable semantics in Listing 1 and the encoding of preferred semantics in Listing 3.

Listing 2. Encoding for stable semantics (using conditional literals)

in(Y) ← **arg**(Y), *not* **in**(X) : **att**(X,Y).

Listing 3. Encoding for preferred semantics (using conditional literals)

defended(X) | **defeated**(X) ← **arg**(X).
defended(X) ← **arg**(X), **defeated**(Y) : **att**(Y,X).
defeated(X) ← **defended**(Y), **att**(Y,X).
← **defended**(X), *not* **defeated**(Y), **att**(Y,X).
← **defeated**(X), *not* **defended**(Y) : **att**(Y,X).
in(X) ← **defended**(X), *not* **defeated**(X).

3.2 Domain heuristics

Clingo provides an option to specify user-specific domain heuristics in the ASP-program which guides the ASP-solver. In particular one can define heuristics in order to select the answer-sets that are subset-maximal/minimal w.r.t. a specified predicate. Inspired by [5] we use such heuristics to compute preferred extensions by utilizing an encoding for complete semantics and identifying the subset-maximal answer-sets w.r.t. the `in(·)` predicate (cf. Listing 4). Moreover, we use domain heuristics and three-valued labelling-based characterizations of complete semantics via the predicates `in(·)`, `out(·)`, and `undec(·)` in order to compute the subset-maximal ranges of complete and conflict-free sets, i.e. we compute the subset-minimal answer-sets w.r.t. the `undec(·)` predicate. This can be exploited for computing some semi-stable or stage extensions. However, the domain heuristics only return one witnessing answer-set for each minima and thus this technique is not directly applicable to the corresponding enumerations tasks (we would miss some extensions if several extensions have the same range). In the next section we present a multi-shot method addressing this problem.

Listing 4. Encoding for preferred semantics (using domain heuristics)

%% Complete labellings
in(X) | **out**(X) | **undec**(X) ← **arg**(X).
in(X) ← **arg**(X), **out**(Y) : **att**(Y,X).
out(X) ← **in**(Y), **att**(Y,X).
← **in**(X), *not* **out**(Y), **att**(Y,X).
← **out**(X), *not* **in** (Y): **att**(Y,X).
← **in**(X), **out**(X).
← **undec**(X), **out**(X).
← **undec**(X), **in**(X).
%% We now apply heuristics to get the complete labeling with subset−maximal in(.) set
#heuristic **in**(X) : **arg**(X). [1,true]

3.3 Multi-Shot Methods

We utilize multi-shot strategies and pre-processing of the AF for several semantics and reasoning tasks. In the current section, we briefly describe these methods.

For credulous and skeptical reasoning with complete, preferred, grounded, and ideal semantics we do not need to consider the whole framework but only those arguments that have a directed path to the query argument (notice that this does not hold true for stable, semi-stable and stage semantics). We perform pre-processing on the given AF that removes arguments without a directed path to the queried argument before starting the reasoning with an ASP-solver.

For computing the ideal extension we follow a two-shot strategy. That is, we first use an encoding for complete semantics and the brave reasoning mode of clingo to compute all arguments that are credulously accepted/attacked w.r.t. preferred semantics. Second, we use the outcome of the first call together with an encoding that computes a fixed-point which corresponds to the ideal extension. For reasoning with ideal semantics we use an encoding for ideal sets and perform credulous reasoning on ideal sets in the standard way.

Semi-stable extensions correspond to those complete labellings for which the set of undecided arguments is subset-minimal. In our approach, we utilize an encoding for complete semantics extended by an `undec(·)` predicate and process the answer-sets. We check whether models without an `undec(·)` predicate have been computed; in that case, semi-stable extensions coincide with stable extensions. In the other case, we compute all subset-minimal sets among all undecided sets using the set class in python and return the corresponding models.

For enumerating stage extensions we use a multi-shot strategy. First we use domain heuristic to compute the maximal ranges w.r.t. naive semantics (as each range maximal conflict-free set is also subset-maximal it is sufficient to only consider naive sets). Second, for each of the maximal ranges we start another ASP-encoding which computes conflict-free sets with exactly that range (this is equivalent to computing stable extension of a restricted framework). Each of these extensions corresponds to a different stage extension of the AF.

For reasoning with semi-stable and stage semantics we use a multi-shot strategy similar to that for enumerating the stage extensions. First we use domain heuristics to

compute the maximal ranges w.r.t. complete or naive semantics. In the second step we iterate over these ranges and perform skeptical (credulous) reasoning over complete extensions (conflict-free sets) with the given range. For skeptical acceptance, we answer negatively as soon as a counterexample to a positive answer is found when iterating the extensions; otherwise, after processing all maximal ranges we answer with YES. Analogously, for credulous acceptance, we check in each iteration whether we can report a positive answer; otherwise, after processing all maximal ranges, we return NO.

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