Efficient Computation of Deterministic Extensions for Dynamic Abstract Argumentation Frameworks

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Abstract Argumentation

An *(abstract) argumentation framework* [1] (*AF*) is a pair $\langle A, \Sigma \rangle$, where A is a set of *arguments* and $\Sigma \subseteq A \times A$ is a set of *attacks*.

– It allows representing dialogues, making decisions, and handling inconsistency;

– An AF can be viewed as a direct graph, whose nodes are arguments and whose edges are attacks.

Semantics for AFs

An argumentation semantics specifies the criteria for identifying a set of arguments considered to be "reasonable" together, called *extension*. A *complete extension* (co) is an admissible set that contains all the arguments that it defends. A complete extension S is said to be:

– *preferred* iff it is maximal (w.r.t. $\subseteq$);

– ***grounded*** iff it is minimal;

– ***ideal*** iff it is contained in every preferred extension and it is maximal.

Grounded and ideal semantics are called *deterministic* or *unique status* as their sets of extensions are singletons.

Updates

An *update* u for an AF $\mathcal{A}_0$ consists in modifying $\mathcal{A}_0$ into an AF $\mathcal{A}$ by adding or removing arguments or attacks.

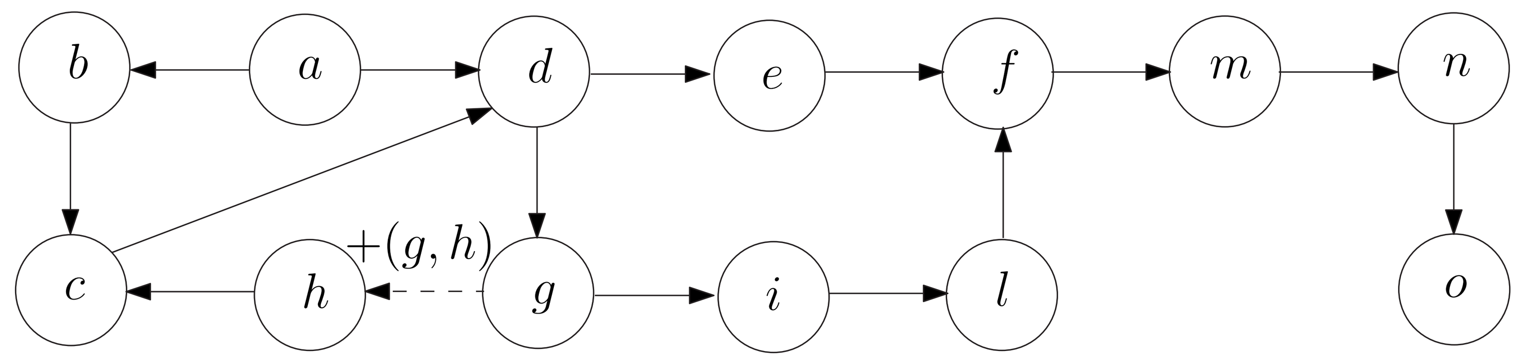
– $+(a, b)$ (resp. $-(a, b)$) denotes the addition (resp. deletion) of an attack (a, b);

– $u(\mathcal{A}_0)$ means applying $u = \pm(a, b)$ to $\mathcal{A}_0$;

– **multiple (attacks) updates** can be simulated by a single attack update.

Dynamic Argumentation Frameworks

– An argumentation framework models a temporary situation as **new arguments and attacks can be added/removed** to take into account new available knowledge.



AF $\mathcal{A}_0$ is updated to AF $\mathcal{A}$ by adding attack (g, h), that is $\mathcal{A} = +(g, h)(\mathcal{A}_0)$.

– According to the most popular argumentation semantics, i.e. *grounded*, *complete*, *ideal*, *preferred*, *stable*, and *semi-stable*, the initial AF $\mathcal{A}_0$ admits the extension $E_0 = \{a, h, g, e, l, m, o\}$;

– The extension for the updated framework $\mathcal{A} = u(\mathcal{A}_0)$ becomes $E = \{a, c, g, e, l, m, o\}$.

– **Should we recompute the semantics of updated AFs from scratch?**

– For the grounded and ideal semantics, **the extension E can be efficiently computed incrementally** *by looking only at a small part of the AF, which is "influenced by" the update operation.*

– In the example AF, the influenced part is just $\{h, c\}$. Only the status of h and c can change after performing update $+(g, h)$; we do not need to compute the status of the other arguments.

Contributions

1) We introduce the **concept of *influenced set*** which consists of the arguments whose status could change after an update. The influenced set refines the previously proposed set of *affected arguments* [3] and makes the computation more efficient.

2) We present an **incremental algorithm for recomputing the grounded semantics**. It first identifies the restricted subgraph of the given AF containing the arguments influenced by the update, and then computes the status of influenced arguments only.

3) We show that an argument a belongs to the ideal extension if and only if there is a *coherent winning strategy* for it and there is no coherent winning strategy for all arguments which attack (even indirectly) a.

4) We present an **incremental algorithm for the efficient recomputation of the ideal semantics** which is based on the previously mentioned result and takes advantage of both the set of influenced arguments and the efficient algorithm for computing grounded extensions.

5) **Experiments** showing the effectiveness of our approach on both real and synthetic AFs.

Experiments

Datasets `REAL` and `SYN1` provided as benchmarks by ICCMA (`http://argumentationcompetition.org`) for experiments on grounded semantics and dataset `SYN2` built for ideal semantics:

– `REAL` consists of 19 AFs $\langle A_0, \Sigma_0 \rangle$ with $|A_0| \in [5K, 100K]$ and $|\Sigma_0| \in [7K, 143K]$

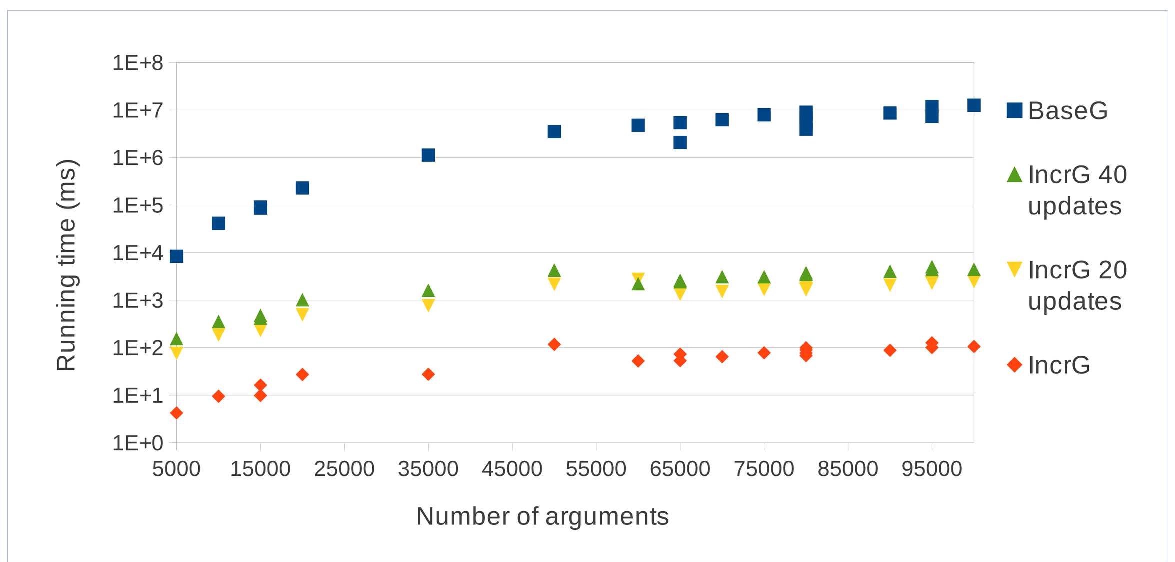
– `SYN1` consists of 24 AFs $\langle A_0, \Sigma_0 \rangle$ with $|A_0| \in [1K, 4K]$ and $|\Sigma_0| \in [14K, 172K]$

– `SYN2` consists of 20 AFs for each of the number of arguments in $\{50, 75, 100, 125, 150, 175\}$

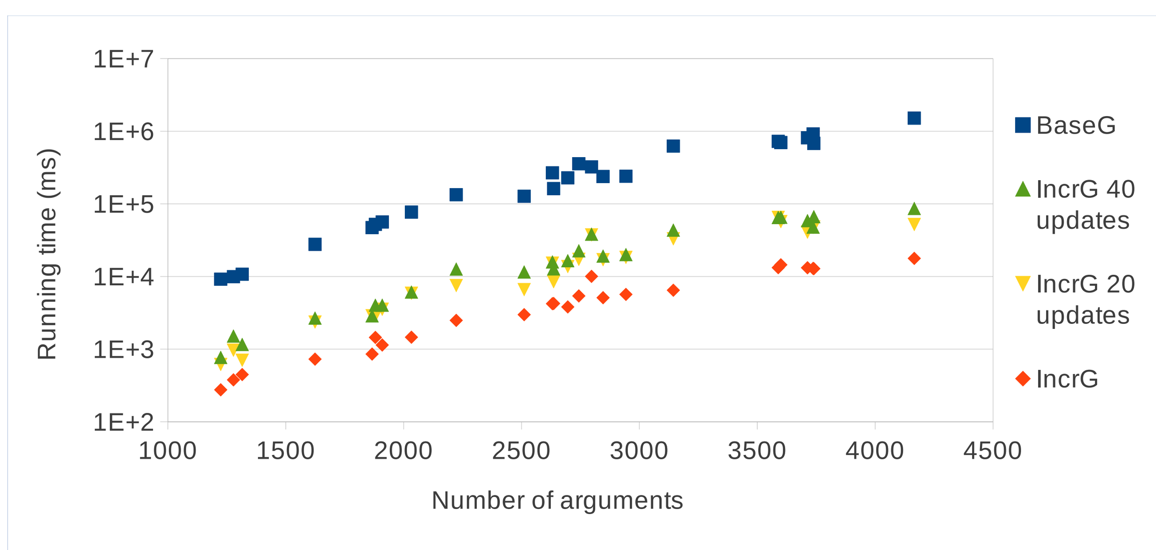
Algorithms:

(i) ***BaseG*** and ***BaseI*** compute the grounded and ideal semantics E of the updated AF $u(\mathcal{A}_0)$ from scratch: *BaseG* finds the fixpoint of the characteristic function of an AF as implemented in the libraries of *Tweety* [4]; *BaseI* uses the algorithm implemented by Dung-O-Matic engine.

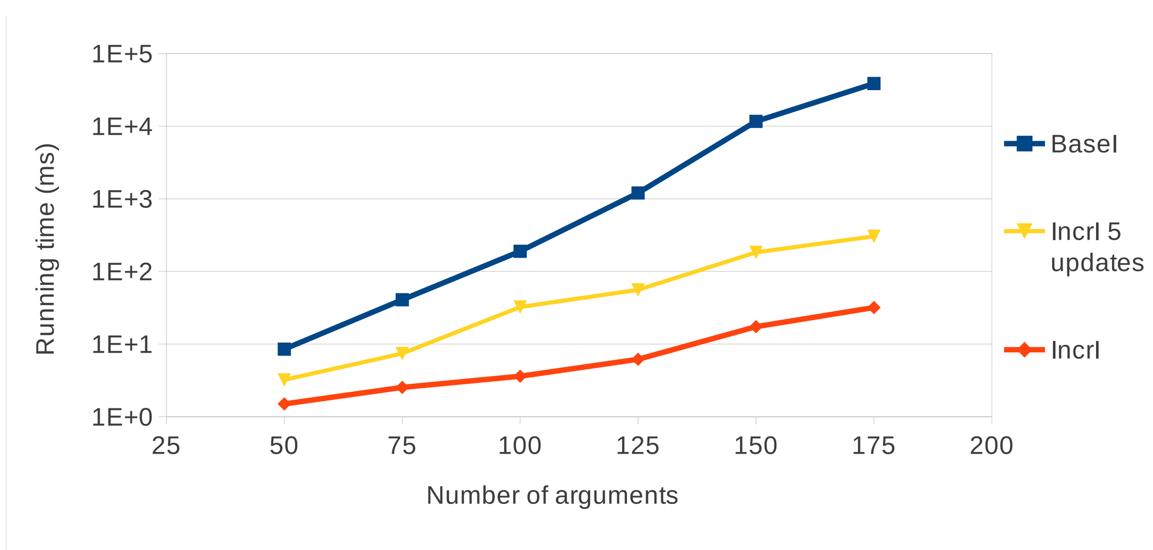
(ii) ***IncrG*** and ***IncrI*** incrementally compute the grounded and ideal extension E of $u(\mathcal{A}_0)$ by implementing our algorithms.



BaseG vs *IncrG* over `REAL`



BaseG vs *IncrG* over `SYN1`



BaseI vs *IncrI* over `SYN2`

Selected References

[1] Phan Minh Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artif. Intell.*, 77(2):321–358, 1995.

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[3] Bei Shui Liao, Li Jin, Robert C. Koons. Dynamics of argumentation systems: A division-based method. *Artif. Intell.*, 175(11), 1790–1814, (2011).

[4] Thimm, M.: Tweety. A comprehensive collection of java libraries for logical aspects of artificial intelligence and knowledge representation. In: Proc. of Int. Conf. on Principles of Knowledge Represent. and Reasoning (KR) (2014).