On General Epistemic Abstract Argumentation Frameworks

Extended Abstract

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ABSTRACT

Epistemic Abstract Argumentation Framework (EAAF) extends Dung's framework (AAF) by allowing the representation of epistemic attacks. So far, the semantics of EAAF has been defined only for a restricted class of frameworks, namely *acyclic* EAAF, where epistemic attacks do not occur in any cycle. In this paper, we provide an intuitive semantics for (general) EAAF that naturally extends that for AAF as well as that for acyclic EAAF.

KEYWORDS

Formal Argumentation; Epistemic Argumentation.

ACM Reference Format:
Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2024. On General Epistemic Abstract Argumentation Frameworks: Extended Abstract. In *Proc. of the 23rd International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2024), Auckland, New Zealand, May 6 – 10, 2024*, IFAAMAS, 3 pages.

1 INTRODUCTION

In the last decades, Argumentation [18, 33] has become an important research field in the area of autonomous agents and multi-agent systems [3, 13, 14, 21, 22, 25, 27–32]. Dung's Abstract Argumentation Framework (AAF) is a simple yet powerful formalism for modeling disputes between two or more agents [23]. An AAF consists of a set of *arguments* and a binary *attack* relation over the set of arguments that specifies the interactions between arguments: intuitively, if argument a attacks argument b, then b is acceptable only if a is not. Hence, arguments are abstract entities whose status is entirely determined by the attack relation. An AAF can be seen as a directed graph, whose nodes represent arguments and edges represent attacks. Several argumentation semantics—e.g. *grounded* (gr), *complete* (co), *preferred* (pr), and *stable* (st) [23]—have been defined for AAF, leading to the characterization of σ*-extensions*, that intuitively consist of the sets of arguments that can be collectively accepted under semantics σ.

Proc. of the 23rd International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2024), N. Alechina, V. Dignum, M. Dastani, J.S. Sichman (eds.), May 6 – 10, 2024, Auckland, New Zealand. © 2024 International Foundation for Autonomous Agents and Multiagent Systems (www.ifaamas.org).

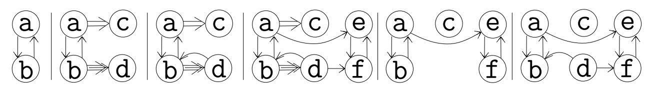

Figure 1: (From left to right) AAF Λ_1, acyclic EAAF Δ_1, general EAAFs Δ_2 and Δ_3, reducts Δ_3^{τ} and $\Delta_3^{\tau'}$. An arrow of the form $\Rightarrow$ (resp. $\Rrightarrow$) represents a weak (resp. strong) epistemic attack.

Consider the AAF Λ_1 shown in Figure 1 describing the following scenario. A party planner invites Alice (a) and Bob (b) to join a party. Alice replies that she will not join the party if Bob does, whereas Bob replies that he will not join the party if Alice does. An argument x states that "*(the person whose initial is)* x *joins the party*". There are two pr-extensions $E_1 = \{a, \neg b\}$ and $E_2 = \{\neg a, b\}$ stating that only Alice or only Bob will attend the party, respectively. Herein, an extension is a set of argument literals, where the occurrence of a positive/negative literal x/¬x means that argument x is accepted/rejected—the remaining arguments, if any, are said to be undecided. Thus, E_1 and E_2 suggest that the participation of Alice and Bob to the party is uncertain.

To deal with uncertain information represented by the presence of multiple extensions, credulous and skeptical reasoning has been introduced. Specifically, an argument is credulously/skeptically true (or accepted) if it is contained in any/all extensions. However, uncertain information in AAF under multiple-status semantics proposed so far cannot be exploited to determine the status of arguments by taking into account the information given by the whole set of extensions, as in the case of credulous and skeptical acceptance. To overcome such a situation, and thus provide a natural and compact way for expressing such kind of conditions, the Epistemic AAF (EAAF) has been recently proposed in [9], where the concept of epistemic arguments and attacks is introduced. Informally, epistemic attacks allow considering all extensions and not only the current one. Therefore, a *strong* (resp. *weak*) *epistemic attack* from a to b is such that a defeats b if a occurs in any/all extensions.

Consider the AAF Λ_1 and assume there are two more people: Carol (c) and David (d). Carol's answer is that she will not attend the party if it is sure (i.e. it is skeptically true) that Alice will, whereas David answers that he will not attend the party if the participation of Bob is possible (i.e. it is credulously true). Intuitively, the party planner should conclude that, as the participation of both Alice and Bob is uncertain, Carol will attend the party, whereas David will not. This situation can be modeled by means of the EAAF Δ_1 of

Figure 1 where a attacks c with a weak epistemic attack, whereas b attacks d with a strong epistemic attack. Under the preferred semantics, there are two extensions: $E_1 = \{a, \neg b, c, \neg d\}$ modeling the fact that Alice and Carol will attend the party, whereas Bob and David will not; and $E_2 = \{\neg a, b, c, \neg d\}$ modeling the fact that Bob and Carol will attend the party, whereas Alice and David will not.

2 GENERAL EPISTEMIC AAF

The semantics of EAAF has been defined only for *acyclic* EAAF (called well-formed in [9, 11]), where (weak and strong) epistemic attacks cannot be involved in any cycle (as e.g. Δ_1). This is a quite strong limitation as cycles involving epistemic attacks are as natural as those involving standard attacks, which are common in real-life argumentation frameworks—the role and effect of cycles in argumentation have been deeply investigated [15, 16, 19, 20, 24, 26].

Continuing our example, assume now that Bob changes his mind and says that he will not join the party if Alice or David do. The updated situation can be modeled through the (cyclic) EAAF Δ_2 (see Figure 1), where the addition of the standard attack (d,b) leads to the cycle (b, d, b) involving the epistemic attack (b, d).

An Epistemic AAF is a quadruple $\Delta = \langle A, \Omega, \Psi, \Phi \rangle$ where A is a set of arguments, $\Omega \subseteq A \times A$ is a set of (standard) attacks, $\Psi \subseteq A \times A$ is a set of weak (epistemic) attacks, and $\Phi \subseteq A \times A$ is a set of strong (epistemic) attacks such that $\Omega \cap \Psi = \Omega \cap \Phi = \Psi \cap \Phi = \emptyset$ and $\Omega[2] \cap (\Psi[2] \cup \Phi[2]) = \emptyset$, where $P[i]$ denotes the projection of relation P on the i-th element (with $i \in [1, 2]$). Hence, the set of attacks are pairwise disjoint, and arguments cannot be jointly attacked through standard and epistemic attacks. The latter ensures that epistemic arguments, i.e. arguments attacked through epistemic attacks, are *deterministic* [6]. We represent attacks $(a, b) \in \Omega$ by $a \rightarrow b$, $(a, b) \in \Psi$ by $a \Rightarrow b$, $(a, b) \in \Phi$ by $a \Rrightarrow b$. An EAAF $\langle A, \Omega, \Psi, \Phi \rangle$ can be seen as a directed graph, where A denotes the set of nodes and Ω, Ψ, and Φ denotes three different kinds of edges. In the following, we consider the acceptability of (argument) literals, that is either an argument a or its negation $\neg a$. We use $\neg S$ to denote the set $\{\neg a \mid a \in S\}$, and S^* to denote $S \cup \neg S$. Moreover, for any set of literals S, we use $S^+ = \{a \mid a \in S\}$, $S^- = \{a \mid \neg a \in S\}$, and $S^u = \{a \mid a \in A \setminus (S^+ \cup S^-)\}$ to denote the set of arguments that occur as positive, negative, and neither positive nor negative literals in S, respectively. For any EAAF $\Delta = \langle A, \Omega, \Psi, \Phi \rangle$, a set W of (consistent) sets of literals in A^* such that all $S \in W$ assign the same status (either true, false, or undefined) to every epistemic argument is called *world view* of Δ. Intuitively, we can think of a world view as a set of candidate extensions where we take a decision on the status of epistemic arguments. The definitions of defeated and acceptable arguments for EAAF extends that of AAF [23], by taking into account the additional concept of world view that is used to decide if an argument is epistemically defeated/acceptable. Given an EAAF Δ, a world view W of Δ, and a (consistent) set $S \in W$, the sets of arguments defeated/accepted w.r.t. S and W are:

- $Def(W, S) = \{b \in A \mid (\exists a \in S \,.\, a \rightarrow b) \vee (\exists T \in W \,.\, \exists a \in T \,.\, a \Rrightarrow b) \vee (\forall T \in W \,.\, \exists a \in T \,.\, a \Rightarrow b)\}$.
- $Acc(W, S) = \{b \in A \mid \forall a \in A \,.\, ((a \rightarrow b) \text{ implies } a \in Def(W, S)) \wedge ((a \Rrightarrow b) \text{ implies } \forall T \in W \,.\, a \in Def(W, T)) \wedge ((a \Rightarrow b) \text{ implies } \exists T \in W \,.\, a \in Def(W, T))$.

Given an EAAF $\Delta = \langle A, \Omega, \Psi, \Phi \rangle$ and a world view W of Δ, a set $S \in W$ is said to be *W-conflict-free* if $S^+ \cap Def(W, S) = \emptyset$; *W-admissible* if it is W-conflict-free, $S^+ \subseteq Acc(W, S)$ and $S^- \subseteq Def(W, S)$; and *W-complete* if it is W-conflict-free, $S^+ = Acc(W, S)$ and $S^- = Def(W, S)$. Moreover, a W-complete set S is said to be *W-preferred* (resp. *W-stable*, *W-grounded*) if S^+ is $\subseteq$-maximal (resp. if $S^+ \cup S^- = A$, if S^+ is $\subseteq$-minimal). Given a world view W for EAAF Δ, we use τ_W (or simply τ if W is understood) to denote an assignment of truth values to the epistemic arguments $\epsilon(\Delta)$ of Δ w.r.t. W, that is, $\tau_W = S \cap \epsilon(\Delta)^*$ where S is any element of W.

The last ingredient we need to introduce the semantic of EAAF is the concept of reduct. Intuitively, the reduct of an EAAF is an AAF which is determined by a choice of the truth values (i.e. acceptance statuses) of the epistemic arguments. Given an EAAF Δ and a truth value assignment τ for the epistemic arguments $\epsilon(\Delta)$ of Δ, the reduct of Δ w.r.t. τ (denoted by Δ^τ) is the AAF obtained from Δ by *i*) deleting all epistemic attacks and every argument in τ^-, and *ii*) adding a self-attack to every argument in τ^u. Given an EAAF Δ, a semantics σ, and a truth assignment τ for the epistemic arguments $\epsilon(\Delta)$ of Δ, we denote by $\sigma(\Delta, \tau) = \{S \cup \tau \mid S \in \sigma(\Delta^\tau)\}$ the set of σ-extensions of Δ under assignment τ, where $\sigma(\Delta^\tau)$ is the set of σ-extensions of AAF Δ^τ. That is, $\sigma(\Delta, \tau)$ extends the σ-extensions of the reduct Δ^τ with the acceptance status τ of epistemic arguments. Then, a world view W for a given EAAF Δ is a σ-world view for Δ if for every $S \in W$ there exists a unique set $T \in \sigma(\Delta, \tau_W)$ such that $Def(W, S) = T^-$ and $Acc(W, S) = T^+$, and vice versa. Moreover, for $\sigma = \mathtt{st}$, $\tau_W^u = \emptyset$. Thus, a σ-world view W can be obtained by *i*) fixing a truth value assignment τ_W for the epistemic arguments, *ii*) determining the set of σ-extensions entailed by the reduct $W = \sigma(\Delta, \tau_W)$, and *iii*) checking that for every $S \in W$, the conditions $Def(W, S) = S^-$ and $Acc(W, S) = S^+$ hold, that is each extension in W is confirmed by the defeated and accepted sets.

Consider the EAAF Δ_3 (Figure 1) and the assignment $\tau = \{c, \neg d\}$. The reduct Δ_3^τ is shown in Figure 1. Its preferred extensions are $\{a, \neg b, c, \neg e, f\}$, $\{\neg a, b, c, e, \neg f\}$, and $\{\neg a, b, c, \neg e, f\}\}$. Thus, $\mathtt{pr}(\Delta_3, \tau) = W = \{S_1 = \{a, \neg b, c, \neg d, \neg e, f\}, S_2 = \{\neg a, b, c, \neg d, e, \neg f\}, S_3 = \{\neg a, b, c, \neg d, \neg e, f\}\}$. As $Def(W, S_i) = {S_i}^-$ and $Acc(W, S_i) = {S_i}^+$, for $i \in [1..3]$, then W is a pr-world view. For $\tau' = \{c, d\}$, we have that $\mathtt{pr}(\Delta_3, \tau') = W' = \{S_1' = \{a, \neg b, c, d, \neg e, \neg f\}\}$. Since c is epistemically attacked by a, we have that $c \notin Acc(W', S_1')$ (i.e. $S_1' \neq Acc(W', S_1)$), entailing that W' is not a pr-world view.

3 CONCLUSION

We have investigated general (possibly cyclic) EAAFs and introduced a natural, declarative semantics that extends that of AAF as well as that of acyclic EAAF. Differently from the case of acyclic EAAF, whose semantics prescribes a single world view, an EAAF may have multiple world views. In general, we may have cyclic EAAFs with multiple or single world views. Future work will be devoted to the investigation of the computational complexity of canonical argumentation problems in general EAAF, as done for other frameworks extending AAF e.g. [1, 2, 4–10, 12, 17].

ACKNOWLEDGMENTS

We acknowledge the support from project Tech4You (ECS0000009), and PNRR MUR projects FAIR (PE0000013) and SERICS (PE00000014).

REFERENCES

[1] Gianvincenzo Alfano, Marco Calautti, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2023. Explainable acceptance in probabilistic and incomplete abstract argumentation frameworks. *Artif. Intell.* 323 (2023), 103967.

[2] Gianvincenzo Alfano, Sergio Greco, Domenico Mandaglio, Francesco Parisi, and Irina Trubitsyna. 2023. Complexity of Verification and Existence Problems in Epistemic Argumentation Framework. In *Proc. of ECAI*, Vol. 372. 77–84.

[3] Gianvincenzo Alfano, Sergio Greco, and Francesco Parisi. 2021. Incremental Computation in Dynamic Argumentation Frameworks. *IEEE Intell. Syst.* 36, 6 (2021), 80–86.

[4] Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, Gerardo I. Simari, and Guillermo Ricardo Simari. 2021. Incremental computation for structured argumentation over dynamic DeLP knowledge bases. *Artif. Intell.* 300 (2021), 103553.

[5] Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2021. Argumentation Frameworks with Strong and Weak Constraints: Semantics and Complexity. In *Proc. of AAAI*. 6175–6184.

[6] Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2022. Incomplete Argumentation Frameworks: Properties and Complexity. In *Proc. of AAAI*. 5451–5460.

[7] Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2022. On Preferences and Priority Rules in Abstract Argumentation. In *Proc. of IJCAI*. 2517–2524.

[8] Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2023. Abstract Argumentation Framework with Conditional Preferences. In *Proc. of AAAI*. 6218–6227.

[9] Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2023. Epistemic Abstract Argumentation Framework: Formal Foundations, Computation and Complexity. In *Proc. of AAMAS*. 409–417.

[10] Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2023. On acceptance conditions in abstract argumentation frameworks. *Inf. Sci.* 625 (2023), 757–779.

[11] Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2023. Stable Semantics for Epistemic Abstract Argumentation Framework. In *Proc. of Arg&App@KR*. 11–25.

[12] Gianvincenzo Alfano, Sergio Greco, Francesco Parisi, and Irina Trubitsyna. 2024. Complexity of Credulous and Skeptical Acceptance in Epistemic Argumentation Framework. In *Proc. of AAAI*. (to appear).

[13] Leila Amgoud, Yannis Dimopoulos, and Pavlos Moraitis. 2007. A unified and general framework for argumentation-based negotiation. In *Proc. of AAMAS*. 158.

[14] Leila Amgoud and Mathieu Serrurier. 2008. Agents that argue and explain classifications. *Auton. Agents Multi Agent Syst.* 16, 2 (2008), 187–209.

[15] Pietro Baroni and Massimiliano Giacomin. 2003. Solving Semantic Problems with Odd-Length Cycles in Argumentation. In *Proc. of ECSQARU*. 440–451.

[16] Ringo Baumann and Markus Ulbricht. 2021. On Cycles, Attackers and Supporters - A Contribution to The Investigation of Dynamics in Abstract Argumentation. In *Proc. of IJCAI*. 1780–1786.

[17] Dorothea Baumeister, Matti Järvisalo, Daniel Neugebauer, Andreas Niskanen, and Jörg Rothe. 2021. Acceptance in incomplete argumentation frameworks. *Artif. Intell.* (2021), 103470.

[18] Trevor J.M. Bench-Capon and Paul E. Dunne. 2007. Argumentation in Artificial Intelligence. *Artif. Intell.* 171 (2007), 619 – 641.

[19] Trevor J. M. Bench-Capon. 2016. Dilemmas and paradoxes: cycles in argumentation frameworks. *J. Log. Comput.* 26, 4 (2016), 1055–1064.

[20] Gustavo Adrian Bodanza, Fernando A. Tohmé, and Guillermo Ricardo Simari. 2016. Beyond admissibility: accepting cycles in argumentation with game protocols for cogency criteria. *J. Log. Comput.* 26, 4 (2016), 1235–1255.

[21] Álvaro Carrera and Carlos Angel Iglesias. 2015. A systematic review of argumentation techniques for multi-agent systems research. *Artif. Intell. Rev.* 44, 4 (2015), 509–535.

[22] Yannis Dimopoulos, Jean-Guy Mailly, and Pavlos Moraitis. 2019. Argumentation-based Negotiation with Incomplete Opponent Profiles. In *Proc. AAMAS*. 1252–1260.

[23] Phan Minh Dung. 1995. On the Acceptability of Arguments and its Fundamental Role in Nonmonotonic Reasoning, Logic Programming and n-Person Games. *Artif. Intell.* 77 (1995), 321–358.

[24] Wolfgang Dvorák, Matthias König, and Stefan Woltran. 2021. On the Complexity of Preferred Semantics in Argumentation Frameworks with Bounded Cycle Length. In *Proc. of KR*. 671–675.

[25] Xiuyi Fan and Francesca Toni. 2012. Agent Strategies for ABA-based Information-seeking and Inquiry Dialogues. In *Proc. of ECAI*, Vol. 242. 324–329.

[26] Marie-Christine Lagasquie-Schiex. 2023. Handling support cycles and collective interactions in the logical encoding of higher-order bipolar argumentation frameworks. *J. Log. Comput.* 33, 2 (2023), 289–318.

[27] Peter McBurney and Simon Parsons. 2009. Dialogue Games for Agent Argumentation. In *Argumentation in Artificial Intelligence*. Springer, 261–280.

[28] Santiago Ontañón and Enric Plaza. 2007. An Argumentation-Based Framework for Deliberation in Multi-agent Systems. In *Int. Workshop, ArgMAS*, Vol. 4946. 178–196.

[29] Francesco Parisi and Gerardo I. Simari. 2021. Guest Editorial Argumentation-Based Reasoning. *IEEE Intell. Syst.* 36, 2 (2021), 3–5.

[30] Simon Parsons, Carles Sierra, and Nicholas R. Jennings. 1998. Agents That Reason and Negotiate by Arguing. *J. Log. Comput.* 8, 3 (1998), 261–292.

[31] Henry Prakken. 2009. Models of Persuasion Dialogue. In *Argumentation in Artificial Intelligence*. 281–300.

[32] Henry Prakken and Giovanni Sartor. 1998. Modelling Reasoning with Precedents in a Formal Dialogue Game. *Artif. Intell. Law* 6, 2-4 (1998), 231–287.

[33] Guillermo R. Simari and Iyad Rahwan (Eds.). 2009. *Argumentation in Artificial Intelligence*. Springer.