ECAI 2010
H. Coelho et al. (Eds.)
IOS Press, 2010

doi:10.3233/978-1-60750-606-5-995

Acceptability semantics accounting for strength of attacks in argumentation

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Abstract. We consider argumentation systems with several attack relations of different strength. We focus on the impact of various strength attacks on the semantics of such systems. First, we refine the classical notion of defence, by comparing the strength of an attack with the strength of a counter-attack. Then, we propose different ways to compare defenders, and sets of defenders. That enables us to define admissible sets offering a best defence for their elements.

1 Argumentation framework with attacks of various strength

Argumentation is based on the evaluation of interacting arguments (which support opinions, claims, decisions,...) and the selection of acceptable sets of arguments. Most of the argumentation-based proposals are instantiations of the Dung's abstract system [2], which is reduced to a set of arguments (completely abstract entities) and a binary attack relation, which captures the conflicts between arguments. The increasing interest for the argumentation formalism has led to numerous extensions of the basic abstract system, particularly for making a distinction between various kinds of attacks [4, 7, 8], and more precisely for taking into account the relative strength of the attacks [3, 5, 7, 6].

Starting from the abstract argumentation system with varied-strength attacks proposed by [6], we redefine the notion of defence and come to novel extensional semantics accounting for strength of attacks. We consider the abstract system defined in [6]:

Def 1 (Argumentation system with attacks of various strength – $\mathbf{AS_{vs}}$) *An* argumentation system with attacks of various strength *is a triple $\langle \mathbf{A}, \mathbf{ATT}, \succeq \rangle$ where $\mathbf{A}$ is a finite set of arguments, $\mathbf{ATT}$ is a finite set of binary attack relations $\langle \xrightarrow{1}, \ldots, \xrightarrow{n} \rangle$ on $\mathbf{A}$ and $\succeq$ is a binary relation on $\mathbf{ATT}$.*

The relation $\succeq$ represents a relative strength between the attack relations. It is only assumed reflexive. The corresponding strict relation is denoted by $\succ$. $\mathbf{AS}$ denotes the classical system $\langle \mathbf{A}, \bigcup_i \xrightarrow{i} \rangle$ associated with the argumentation system $\mathbf{AS_{vs}} = \langle \mathbf{A}, \mathbf{ATT}, \succeq \rangle$.

Classically, if an argument A is attacked by an argument B, any attacker of B is relevant for inhibiting the attack on A, thus defending A. With attacks of different strength, it is natural to require that the attack on B is strong enough to reinstate A.

The following definition captures the idea of relevant defender:

Def 2 (vs-defence – vs means "various-strength") *Let A, B, $C \in \mathbf{A}$ such that $C \xrightarrow{j} B$ and $B \xrightarrow{i} A$. C* vs-defends *A against B (or C is a* vs-defender *of A against B) iff $\xrightarrow{i} \not\succ \xrightarrow{j}$ (i.e. the attack from B to A is not strictly stronger than the one from C to B).*

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Note that a vs-defender exactly corresponds to a "not weak defender" proposed in [6]. We define a vs-admissible (vs-adm for short) set as a conflict-free set which proposes a valuable defence for each of its elements:

Def 3 (vs-admissibility) *Let $S \subseteq \mathbf{A}$. S is* conflict-free *in $\mathbf{AS_{vs}}$ iff $\forall A, B \in S$, $\nexists \xrightarrow{i} \in \mathbf{ATT}$, s.t. $B \xrightarrow{i} A$ (iff S is conflict-free in the associated $\mathbf{AS}$ in Dung's sense). S* vs-defends *A iff $\forall B \in \mathbf{A}$, if B attacks A then $\exists C \in S$ such that C vs-defends A against B. S is* vs-adm *iff S is conflict-free and $\forall A \in S$, S* vs-defends *A.*

vs-admissibility requires the classical notion of conflict-free; so, for any vs-adm set S, no attack may occur between elements of S. And, as vs-defence refines classical defence, each vs-adm set is also admissible (adm for short) in Dung's sense. The converse is false: Let $C \xrightarrow{j} B \xrightarrow{i} A$, with $\xrightarrow{i} \succ \xrightarrow{j}$; $\{C, A\}$ is adm but not vs-adm. Note also that the empty set is vs-adm. From the notion of vs-admissibility, it is straightforward to revisit classical semantics, as, for instance, the preferred semantics, which produces maximal (for set-inclusion) adm sets of arguments (for the stable, grounded and complete semantics – see [1]).

Def 4 (preferred vs-extension) *Let $S \subseteq \mathbf{A}$ be a vs-adm set. S is a* preferred vs-extension *of $\mathbf{AS_{vs}}$ iff $\nexists S' \subseteq \mathbf{A}$ such that $S \subset S'$ and S' is vs-adm.*

Ex 1 *Consider $\mathbf{AS_{vs}}$ with $\mathbf{A} = \{A, B, C_1, C_2\}$, $\mathbf{ATT} = \langle \xrightarrow{i}, \xrightarrow{j}, \xrightarrow{k} \rangle$ with $\xrightarrow{i} = \{(B, A)\}$, $\xrightarrow{j} = \{(C_1, B)\}$, $\xrightarrow{k} = \{(C_2, B)\}$, and $\succeq$ defined by $\xrightarrow{j} \succeq \xrightarrow{i}$. $\mathbf{AS_{vs}}$ can be depicted by the graph:*

$$\begin{tikzcd} C_1 \arrow[r, "j"] & B \arrow[r, "i"'] & A \\ C_2 \arrow[ur, "k"'] & & \end{tikzcd}$$

If $\xrightarrow{i} \succ \xrightarrow{k}$, C_1 is the only vs-defender of A, otherwise C_1 and C_2 are vs-defenders of A.

In both cases, $\{A, C_1, C_2\}$ is the only preferred vs-extension.

2 Semantics accounting for the quality of defence

A vs-adm set proposes a valuable defence for each of its elements. The next step is to take into account the existence of attacks of various strength for evaluating the quality of a valuable defence, and for selecting vs-adm sets which offer a best defence. If an argument B attacks an argument A, comparing two attacks against B enables to compare two defenders of A against B. So, we propose to compare defences at different levels: comparing two vs-defenders of a same argument, comparing two sets which collectively vs-defend a same argument and comparing two vs-adm sets.

Def 5 (Comparison of vs-defenders) *Let $A, B, C_1, C_2 \in \mathbf{A}$ such that both C_1 and C_2 are vs-defenders of A against B with $C_1 \xrightarrow{j} B$ and $C_2 \xrightarrow{k} B$. C_1* is better than *C_2 iff $\xrightarrow{j} \succeq \xrightarrow{k}$. C_1 is* strictly better than *C_2 iff $\xrightarrow{j} \succ \xrightarrow{k}$.*

Now, let S_1 and S_2 be two sets which collectively vs-defend A. We say that the defence of A offered by S_2 is as strong as the defence of A offered by S_1, denoted by $S_2 \sqsupseteq_A S_1$, iff S_2 improves the defence of A offered by S_1 on at least one defender of A. The corresponding strict relation is denoted by $S_2 \gg_A S_1$.

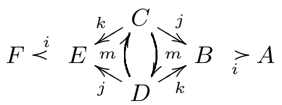
Def 6 (Set-comparison wrt the defence of an argument) *Let S_1 and S_2 be two sets of arguments which vs-defend A. $S_2 \sqsupseteq_A S_1$ iff there exist $C_1 \in S_1$ and $C_2 \in S_2 \setminus S_1$ such that C_1 and C_2 are vs-defenders of A and C_2 is* strictly better than *C_1.*
$S_2 \gg_A S_1$ iff ($S_2 \sqsupseteq_A S_1$ and not $S_1 \sqsupseteq_A S_2$).

Ex 2 *Assume that C_1, C_2 and C_3 are three vs-defenders of A against B with C_3 strictly better than C_2 and C_2 strictly better than C_1. We have $\{C_1, C_2, C_3\} \gg_A \{C_1, C_3\}$ since C_2 is strictly better than C_1 and C_2 does not belong to $\{C_1, C_3\}$. In contrast, according to the definition proposed in [6], these sets are uncomparable.*

The third step towards the evaluation of the quality of the defence is the comparison of two vs-adm sets. A vs-adm set vs-defends each of its elements. So, it makes sense to compare two vs-adm sets wrt one or several elements of their intersection. So the defence proposed by S_2 is said globally as strong as the defence proposed by S_1 if S_2 offers a stronger defence than S_1 for at least one common element.

Def 7 (Set-comparison of vs-adm sets) *Let S_1 and S_2 be two vs-adm sets. $S_2 \gg= S_1$ iff there exists an argument A in $S_1 \cap S_2$ such that $S_2 \gg_A S_1$. $S_2 \gg S_1$ iff ($S_2 \gg= S_1$ and not $S_1 \gg= S_2$).*

Ex 3 *This example has been taken from [6].*



Assume that C and D are two vs-defenders of A and F. Let $S_1 = \{A, C, F\}$ and $S_2 = \{A, D, F\}$. S_1 and S_2 are vs-adm.

If we assume that $\xrightarrow{j} \succ \xrightarrow{k}$, we have $S_1 \gg_A S_2$ and $S_2 \gg_F S_1$. So, S_1 and S_2 are equivalent wrt Def 7.

Finally, we come to novel extensional semantics accounting for the quality of the defence. What seems to be relevant is to choose vs-adm sets that fulfil two requirements : (1) offering a strongest defence for their elements (or in other words, a defence which cannot be improved wrt an argument without being damaged wrt another argument) (2) being maximal for set-inclusion (in order to avoid the empty set as an output). This leads to two proposals depending on the priority between these two requirements. The first one produces maximal for set-inclusion strong-adm sets.

Def 8 (Max-strong-adm set) *Let $S \subseteq \mathbf{A}$. S is a* strong-adm set *iff S is vs-adm and S is maximal for the relation $\gg$ (see Def 7) among the vs-adm sets. S is* max-strong-adm *iff S is strong-adm and $\nexists S' \subseteq \mathbf{A}$ such that $S \subset S'$ and S' is strong-adm.*

As the empty set is strong-adm, there always exists at least one max-strong-adm set.

Ex 4 *It is a variant of Ex 3, replacing $D \xrightarrow{k} B$ by $D \xrightarrow{j} B$. Assume that $\xrightarrow{j} \succ \xrightarrow{k}$. $\{A, C\}$ and $\{A, D\}$ are strong-adm, the defence is at best for A. $\{A, D, F\}$ is also strong-adm, the defence is at best for A and for F. However, $\{A, C, F\}$ is not strong-adm since $\{A, D, F\} \gg \{A, C, F\}$. So, the max-strong-adm sets are $\{A, C\}$ and $\{A, D, F\}$.*

Analogous ideas have been developed in [6], leading to the notion of top-admissibility. Our proposal comes to strong-admissibility through several defence comparisons, whereas [6] gives a direct definition of top-admissible (top-adm for short) sets, and proposes nothing to select some top-adm sets. We have proved that top-adm sets are strong-adm, but the converse does not hold (see [1]).

An alternative proposal of semantics consists in comparing the global defence offered by preferred vs-extensions. In other words, the quality of the defence is considered only for maximal vs-adm sets. That leads to select strong-preferred sets :

Def 9 (Strong-preferred set) *Let $S \subseteq \mathbf{A}$ be a preferred vs-extension. S is* strong-preferred *iff S is maximal for the relation $\gg$ (Def 7) among the preferred vs-extensions.*

Ex 4 (cont'd) *The preferred vs-extensions are $\{A, D, F\}$ and $\{A, C, F\}$. As $\{A, D, F\} \gg \{A, C, F\}$, the only strong-preferred set is $\{A, D, F\}$.*

However in some cases, there exists no strong-preferred extension.

Both semantics aim at selecting maximal vs-adm sets defending at best their elements. However, they do not consider the quality of the defence at the same level. A max-strong-adm set S gathers all the arguments that S defends at best. It is as each argument of S would be treated separately. In constrast, a strong-preferred set offers a globally strongest defense for a maximal set of arguments. A deeper discussion of these novel semantics can be found in [1].

3 Concluding remarks

Our proposal is a further contribution to the development of argumentation with various attacks of different strength, based on the abstract framework introduced by [6]. The common basic idea is to use the relative strength of the attacks for disregarding some of the defences. In [6], this idea is formalised by the notion of defense condition, a set of requirements in the relative strength of attacks and counter-attacks. [6] handles expansive sets of defence conditions, and proposes several interesting semantic notions. In contrast, we focus on only one defence condition, the vs-defence, and we come to extensional semantics, by revisiting classical ones, and by investigating defence comparisons.

A subject for further research is the definition of other semantics, related to the decision problem of credulous acceptability: namely, focussing on one particular argument, a classical issue is to compute a proof, under the form of a minimal admissible set containing this argument. Taking into account attacks of various strength suggests to search for the best proofs.

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