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From preferences over arguments to preferences over attacks in abstract argumentation: A comparative study

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Abstract—Dung’s argumentation framework has been extended to consider preferences over arguments or over attacks, in a qualitative or in a quantitative way. In this paper, we investigate the relationships between preferences over arguments and preferences over attacks. We give conditions on the definition of preferences over attacks from preferences over arguments. Following these principles, we propose different instantiations of an AFvs (argumentation framework with attacks of various strengths), when preferences over arguments are available. Our proposal is compared to existing work, particularly regarding the conditions in which the defence holds.

Keywords—Reasoning Agents, Knowledge Representation, Argumentation.

I. INTRODUCTION

Argumentation has become an influential approach in Artificial Intelligence to model cognitive tasks such as inconsistency handling and defeasible reasoning (e.g. [1], [2], [3]), decision making (e.g. [4]), or negotiation between agents (e.g. [5]). It is based on the evaluation of interacting arguments, which may support opinions, claims or decisions. Usually, the interaction takes the form of conflicts between arguments, and the fundamental issue is the selection of acceptable sets of arguments, based on the way they interact and the key concept of defence. Most of the argumentation-based proposals are instantiations of the abstract system proposed by Dung [6], which is reduced to a set of arguments (completely abstract entities) and a binary relation, called attack, which captures the conflicts between arguments. The increasing interest for the argumentation formalism has led to numerous extensions of the basic abstract system which are more appropriate to the applications.

A first extension of Dung’s system has included a preference relation between arguments, which models their relative strength. For instance, an argument built from certain knowledge is stronger than an argument relying upon default knowledge (see e.g. [7], [8], [9], [10]).

Other extensions have been proposed to make a distinction between various types of conflict: [11], [12] in a logical setting, [13] in case of symmetric attacks, [14] in a multi-agent setting, [15], [16] with weighted attacks. Behind these proposals, there is a common idea that attacks may have different strength and can be compared according to their relative strength. However, there is so far no consensus about how it should be used to define extensional semantics, according to which acceptable sets of arguments are selected. Some works towards that direction have been proposed in [17], [18], [19], where an abstract argumentation system with varied-strength attacks has been defined and a new kind of defence, the vs-defence, has been introduced.

Our purpose is to take advantage of that abstract system in order to investigate the relationships between preferences over arguments and preferences over attacks. We consider quantitative as well as qualitative approaches for expressing these preferences. Some results for the quantitative setting have been presented in [20]. We pursue that work by providing a comparative study of different proposals. Sect. II gives the background about the modelling of strength (of arguments and of attacks) in abstract argumentation. Sect. III presents our proposals for moving from preferences over arguments to preferences over attacks. These proposals are compared with existing ones in Sect. IV and Sect. V is devoted to concluding remarks.

II. BACKGROUND

A. Dung’s argumentation framework

In Dung’s abstract framework [6], arguments are supposed to be given and conflicts between arguments are represented by a binary attack relation.

Def. 1: An argumentation framework (AF) is a pair \((\mathbf{A}, \mathbf{R})\) of a finite set \(\mathbf{A}\) of arguments and a binary (attack) relation \(\mathbf{R}\) over \(\mathbf{A}\). \(\mathbf{ARB}\) means that \(A\) attacks \(B\).

An AF may be represented by a directed graph \(G\) whose nodes represent arguments and edges represent the attack relation. Acceptable sets of arguments can be defined from the concepts of conflict-freeness and defence.

Def. 2: A set \(S \subseteq \mathbf{A}\) is conflict-free iff\(^2\) there are no \(A, B \in S\) such that \(\mathbf{ARB}\). Let \(A, B, C \in \mathbf{A}\). \(C\) defends \(A\) against \(B\) iff \(\mathbf{BRA}\) and \(\mathbf{CRB}\). A set \(S\) defends \(A\) iff for each \(B\) such that \(\mathbf{BRA}\), there exists \(C \in S\) such that \(C\) defends \(A\) against \(B\). \(S\) is admissible iff \(S\) is conflict-free and defends all its elements.

\(^1\)We assume that \(\mathbf{A}\) represents the set of arguments proposed by rational agents at a given time; so it makes sense to assume that \(\mathbf{A}\) is finite.

\(^2\)iff: if and only if
B. Preferences between arguments: PAF or WAF

Strengths of arguments have been introduced in two ways:

- a qualitative way in Preference Argumentation Frameworks (PAF) [3]: an AF is associated with a partial preordering $\succeq$ over $A$; so a PAF is a triplet $(A, R, \succeq)$.
- a quantitative way in Weighted Argumentation Frameworks (WAF) [16]: an AF is associated with a function $\omega : A \rightarrow R$; so a WAF is also a triplet $(A, R, \omega)$.

Notations: Let $\succeq$ be a binary relation on $A$.

- The corresponding strict relation is denoted by $\succ$ and defined by $A \succ B$ iff $(A \succeq B$ and not$(B \succeq A)$. Note that $\succ$ is irreflexive and asymmetric.
- $A \sim B$ denotes $(A \succeq B$ and $B \succeq A)$; it means that $A$ and $B$ are equivalent.
- $A \not\sim B$ denotes (not$(A \succeq B$ and not$(B \succeq A)$); it means that $A$ and $B$ are incomparable.

A WAF enables to construct a particular PAF as follows:

\textbf{Def. 3:} Let WAF $= (A, R, \omega)$. The PAF corresponding to WAF is the triplet $(A, R, \succeq)$ where $\forall A, B \in A$, $A \succeq B$ iff $\omega(A) \geq \omega(B)$.

In this case, the resulting preordering $\succeq$ is total (no incomparable arguments in the PAF).

C. Preferences between attacks

Strengths of attacks have also been introduced in a qualitative way and in a quantitative way. The first modelling is given in [18], [19] (a variant has been introduced in [17]):

\textbf{Def. 4:} An argumentation framework with attacks of various strength $(\text{AF}_\text{VS})$ is a triplet $(A, \text{ATT}, \succeq)$ where $A$ is a finite set of arguments, $\text{ATT}$ is a finite set of attack relations $\{\to, \ldots, \ldots, \}$ over $A$ and $\succeq$ is a binary relation over $\text{ATT}$.

Each $\to \subseteq A \times A$ represents a conflict relation, and $\succeq$ enables to express a relative strength between these relations. The relation $\succeq$ is only assumed reflexive (it may be partial, and transitive or not). The corresponding strict relation, equivalence relation and incomparability relation will be respectively denoted by $\succ$, $\sim$, and $\neq$.

In [18], [19], the strength of attacks has been used for refining the notion of defence. When $\text{BR}A$ and $\text{CR}B$, it is natural to account for the relative strength of the attacks in order to define the defence of $A$ by $C$. If the attack on $B$ is too weak to inhibit the attack on $A$, it will not be relevant for reinstating $A$. Let $\text{AF}_\text{VS} = (A, \text{ATT}, \succeq)$, the following definition captures the idea of relevant defender:

\textbf{Def. 5:} Let $A, B, C \in A$ such that $C \not\to B$ and $B \not\to A$. $C$ vs-defends $A$ against $B$ (or $C$ is a $\text{vs-defender}^4$ of $A$ against $B$) iff $\not\to \not\to \not\to$ (i.e. the attack from $B$ to $A$ is not strictly stronger than the one from $C$ to $B$).

\textbf{Note:} if $\not\to$ is empty, the classical notion of defence is recovered.

The second modelling is given in [20]. It is a quantitative approach inspired by [16].

\textbf{Def. 6:} An argumentation framework with varied-strength defeat (AFV) is a triplet $(A, R, \text{Vdef})$ where $A$ is a finite set of arguments, $R$ is an attack relation and $\text{Vdef}$ is a function from $R$ to the interval $[0,1]$. $\text{Vdef}(A,B)$ represents the degree of certainty of the statement “$A$ attacks $B$”.

Note that, according to the previous definition, [20] considers that the case when $\text{Vdef}(A,B) = 0$ is equivalent to $\text{not}(A$ attacks $B)$. In other words, attacks that have a $\text{Vdef}$ value equal to 0 are removed from $R$.

A new notion of defence is defined in an AFV:

\textbf{Def. 7:} Let $A, B, C \in A$ such that $\text{CR}B$ and $\text{BR}A$ (so with $\text{Vdef}(C,B) \not= 0$ and $\text{Vdef}(B,A) \not= 0$). $C$ vdef-defends $A$ against $B$ (or $C$ is a vdef-defender of $A$ against $B$) iff $\text{Vdef}(C,B) \geq \text{Vdef}(B,A)$ (i.e. the attack from $C$ to $B$ is at least as strong as the attack from $B$ to $A$).

Note that the intuition for extending the notion of defence is the same in both frameworks $\text{AF}_\text{VS}$ and AFV. The only difference lies in the nature of the preference relation over attacks: an $\text{AF}_\text{VS}$ uses a preordering (allowing for incomparable attacks), whereas in an AFV the preference relation is based on a function with values on a linearly ordered scale (thus providing a total ordering over attacks).

D. From preferences between arguments to weighted attacks

In [20], different instantiations of an AFV\textsuperscript{6} by a PAF or a WAF have been proposed, according to the following intuition: the larger the preference of $A$ over $B$, the stronger the attack from $A$ to $B$.

\textbf{Def. 8:} Let PAF $= (A, R, \succeq)$. Two different AFV $= (A, R, \text{Vdef})$ can be built according to the following definitions for $\text{Vdef}$: let $(A, B) \in R$,

\begin{itemize}
  \item $\text{Vdef}_1^0(A,B) = 0$ if $B \succ A$, 1 otherwise
  \item $\text{Vdef}_2^0(A,B) = 0$ if $B \succ A$, 1 if $A \succeq A \succ B$, 1/2 otherwise
\end{itemize}

\textbf{Def. 9:} Let WAF $= (A, R, \omega)$. Three different AFV $= (A, R, \text{Vdef})$ can be built according to the following definitions for $\text{Vdef}$: let $(A, B) \in R$,

\begin{itemize}
  \item $\text{Vdef}_\text{bool}^\omega(A,B) = 0$ if $\omega(B) > \omega(A)$, 1 otherwise
  \item $\text{Vdef}_1^\omega(A,B) = \max(\omega(A) - \omega(B),0)$
  \item $\text{Vdef}_2^\omega(A,B) = 1 - \max(\omega(B) - \omega(A),0)$
\end{itemize}

Note that $\text{Vdef}_\text{bool}^\omega$ exactly corresponds to $\text{Vdef}_1$, when $\succ$ is built from $\omega$ as in Def.3.

Similarly, $\text{Vdef}_2^\omega$ could be built from a WAF by:

$\text{Vdef}_2^\omega(A,B) = 0$ if $\omega(B) > \omega(A)$, 1 if $\omega(A) = \omega(B)$, 1/2 otherwise.

These instantiations of an AFV have been extensively studied in [20] and interesting properties have been provided.

\textsuperscript{5}def stands for defeat.

\textsuperscript{6}In [20], these instantiations have been built using an intermediary argumentation framework, called a VPAF. Nevertheless, due to lack of place, here we only give the last step of this process.
particularly for \( \text{Vdef}^p_2 \). However, most of the definitions for \( \text{Vdef} \) lead to suppress the attacks \((A, B)\) for which \( B \) is strictly preferred to \( A \). With \( \text{Vdef}^p_2 \), an attack from \( A \) to \( B \) is removed when \( (\omega(B) - \omega(A)) = 1 \).

This point is problematic to us. Moreover, our idea is to investigate the instantiation process in the qualitative setting.

### III. FROM PREFERENCES OVER ARGUMENTS TO PREFERENCES OVER ATTACKS

Our purpose is to investigate different ways by which preferences over attacks are computed from preferences over arguments. In the qualitative setting (Sect. III-A), we start by laying down some principles which should govern the instantiation of an \( \text{AF}_{\text{VS}} \) by a \( \text{PAF} \) and we propose examples of such an instantiation. The partial preordering and the attack relation available in a \( \text{PAF} \) serve to compute a particular \( \text{AF}_{\text{VS}} \) in which the relative strength of attacks is represented by a preordering on the attacks. A particular case is to start from a \( \text{WAF} \) and to construct the associated \( \text{PAF} \) according to Def.3. Then, we consider a quantitative setting (Sect. III-B) and follow the same methodology. We propose some principles and take advantage of weights over settings (Sect. III-B) and follow the same methodology. We introduce some conditions on the relationship between preferences over attacks are computed from preferences over arguments. In the qualitative setting (Sect. III-A), we start by laying down some principles which should govern the instantiation of an \( \text{AF}_{\text{VS}} \) by a \( \text{PAF} \) and we propose examples of such an instantiation. The partial preordering and the attack relation available in a \( \text{PAF} \) serve to compute a particular \( \text{AF}_{\text{VS}} \) in which the relative strength of attacks is represented by a preordering on the attacks. A particular case is to start from a \( \text{WAF} \) and to construct the associated \( \text{PAF} \) according to Def.3. Then, we consider a quantitative setting (Sect. III-B) and follow the same methodology. We propose some principles and take advantage of weights over arguments in order to define a value-based preference on the attacks. An important result is that we can provide a construction of a valued \( \text{AF}_{\text{VS}} \) in which the preference over attacks refines the preference obtained in the qualitative setting (see Sect. III-C).

### A. \( \text{AF}_{\text{VS}} \) induced by a \( \text{PAF} \)

We introduce some conditions on the relationship between 
\[ \text{PAF} = \langle A, R, \geq \rangle \text{ and } \text{AF}_{\text{VS}} = \langle A, \text{ATT}, \geq \rangle \text{ when } \text{ATT} \text{ and } \geq \text{ are built from } R \text{ and } \geq. \]
These conditions are expressed under the form of principles:

- **P1** The initial set of conflicts between arguments must not be modified (no attack disappears, no attack appears).
- **P2** An attack from \( A \) to \( B \) with \( A \) strictly preferred to \( B \) must be strictly stronger than an attack between two equivalent or incomparable arguments; in the same way, an attack from \( A \) to \( B \) with \( B \) strictly preferred to \( A \) must be strictly weaker than an attack between two equivalent or incomparable arguments; this principle induces a partition into at least 3 classes of attacks.
- **P3** An attack between two equivalent arguments must be strictly stronger than an attack between two incomparable arguments; this principle associated with \( P2 \) induces a partition into at least 4 classes of attacks.

So, starting from 
\[ \text{PAF} = \langle A, R, \geq \rangle, \] the following definitions give the way for building an \( \text{AF}_{\text{VS}} \) respecting **P1** to **P3**.

**Def. 10:** The partition of \( R \) induced by \( \text{PAF} \), denoted by \( \text{Part}(R) \), is defined as the set \( \{1, 2, 3, 4\} \) with:
- \( 1 = \{(A, B) \in R \text{ such that } A \succ B\} \)
- \( 2 = \{(A, B) \in R \text{ such that } A \sim B\} \)
- \( 3 = \{(A, B) \in R \text{ such that } A \preceq B\} \)
- \( 4 = \{(A, B) \in R \text{ such that } B \succ A\} \)

**Def. 11:** The \( \text{AF}_{\text{VS}} \) induced by \( \text{PAF} \) is the triplet \( \langle A, \text{ATT}, \geq \rangle \) where \( \text{ATT} = \text{Part}(R) \) and \( \geq \text{ is the reflexive transitive closure of the binary relation over } \text{Part}(R) \text{ defined by: } \frac{1}{2} \geq \frac{1}{2} \geq \frac{3}{4} \geq \frac{4}{3} \).

Note that the relation \( \geq \) is a total ordering over \( \text{ATT} \). From the above definitions, it follows easily that \( \geq \) enables to define preorderings on \( R \) that satisfy \( \text{P1}, \text{P2}, \text{P3}. \)

It may be a total preordering such that two attacks of the same class are equivalent, or a partial preordering such that two attacks of the same class are incomparable.

Two other principles may be introduced in the qualitative setting for taking into account the following cases:

- **P4** Consider an attack from \( A \) to \( C \) and an attack from \( B \) to \( C \) of the same class. If \( A \) is strictly stronger than \( B \), the attack \( (A, C) \) must be strictly stronger than the attack \( (B, C) \).
- **P5** Consider an attack from \( A \) to \( C \) and an attack from \( A \) to \( B \) of the same class. If \( B \) is strictly stronger than \( C \), the attack \( (A, C) \) must be strictly stronger than the attack \( (A, B) \).

So, starting from \( \text{PAF} = \langle A, R, \geq \rangle \), we define a new relation over \( R \), which is only a partial preordering:

**Def. 12:** Given \( \text{Part}(R) \), the partial ordering \( \geq \) over \( R \) induced by \( \text{P1} \) to \( \text{P5} \) is the reflexive transitive closure of the binary relation over \( R \) defined by:

- Let \( (A, B), (C, D) \in R \) such that \((A, B) \in 1 \) and \((C, D) \in 1\). Then \((A, B) \geq (C, D)\) iff \( i = j\).
- Let \( (A, B), (C, D) \in 2 \), then \((A, B) \geq (C, D)\).
- Let \( (A, C), (B, C) \in 1 \) (resp. \( 3, 4 \)). If \( A \succ B \) then \((A, C) \geq (B, C)\), and if \( A \sim B \) then \((A, C) \geq (B, C)\).
- Let \( (A, C), (A, B) \in 2 \) (resp. \( 3, 4 \)). If \( B \succ C \) then \((A, C) \geq (A, B)\), and if \( B \sim C \) then \((A, C) \geq (A, B)\).

Now, using this relation \( \geq \) on \( R \), we can define an \( \text{AF}_{\text{VS}} \) respecting \( \text{P1} \) to \( \text{P5} \).

**Def. 13:** The \( \text{AF}_{\text{VS}} \) induced by \( \text{PAF} \) is the triplet \( \langle A, \text{ATT}, \geq \rangle \) where \( \text{ATT} \) is the set of singletons \( \{(A, B)\} \) s.t. \((A, B) \in R \) and \( \geq \) as defined in Def.12.

Note that these principles do not apply to the class \( 2 \), since all tracks in this class are arguments which are equivalent.

\( \geq \) is partial since, considering \((A, B)\) and \((C, D)\) in \( 2, \forall i = 1, 3, 4, \) with \( A \neq C \) and \( B \neq D \), there is no reason for deciding either that \((A, B) \geq (C, D)\) or that \((A, B) \geq (C, D)\).
Note that a particular case of the construction provided by Def.11 (resp. Def.13) occurs when the PAF is obtained from a WAF according to Def.3.

In the following, we give some properties of $\text{AF}_{\text{vs}}$ induced by a PAF. First, it is worth noticing that an $\text{AF}_{\text{vs}}$ is a strict extension of a classical Dung’s framework.

Let $\text{AF}_{\text{vs}} = \langle \text{A}, \{ \frac{1}{\text{vs}} , \ldots , \frac{n}{\text{vs}} \} \rangle$, $\text{AF} = \langle \text{A}, \cup \frac{1}{\text{ vs}} \rangle$ denotes the classical Dung’s argumentation framework associated with $\text{AF}_{\text{vs}}$. It has been shown in [18], [19] that if a set of arguments $S$ is vs-admissible in $\text{AF}_{\text{vs}}$, it is also admissible in $\text{AF}$. However, there does not exist a formal compilation of an $\text{AF}_{\text{vs}}$ (even obtained from a PAF) into a classical Dung argumentation framework over the same set of arguments, which would be equivalent; i.e. such that the vs-admissible sets of $\text{AF}_{\text{vs}}$ would exactly coincide with the admissible sets of $\text{AF}$ (see the following example).

Ex. 1: Consider the $\text{AF}_{\text{vs}}$ represented by:

```
A 2
\downarrow
D
\downarrow
B
\downarrow
C
\downarrow
E
```

Assuming that $\text{AF}_{\text{vs}}$ can be compiled into an equivalent classical $\langle \text{A}, \text{R} \rangle$, the following constraints hold:

- \{A, C, D, E\} is vs-admissible, so \{A, C, D, E\} must be admissible in $\langle \text{A}, \text{R} \rangle$, and so \{A, C, D, E\} must be conflict-free in $\langle \text{A}, \text{R} \rangle$.
- \{E\} is not vs-admissible, so \{E\} should not be admissible in $\langle \text{A}, \text{R} \rangle$. So, E must be attacked and since \{A, C, D, E\} is conflict-free, E is attacked by B in $\langle \text{A}, \text{R} \rangle$, and B is the only attacker of E in $\langle \text{A}, \text{R} \rangle$.
- And similarly, B is the only attacker of C in $\langle \text{A}, \text{R} \rangle$.
- \{A, E\} is vs-admissible, so \{A, E\} must be admissible in $\langle \text{A}, \text{R} \rangle$. So, A must attack B in $\langle \text{A}, \text{R} \rangle$.
- \{A, C\} is not a vs-admissible set, so \{A, C\} should not be admissible in $\langle \text{A}, \text{R} \rangle$.

As A attacks B, which is the only attacker of C, and due to the fact that \{A, C, D, E\} is conflict-free, it must be the case that \{A, C\} does not defend A. The only possibility is that A is attacked by B (since \{A, C, D, E\} is conflict-free). But then, the set \{A, C\} would still be admissible (since A attacks B). So, in conclusion, it is not possible to turn the above $\text{AF}_{\text{vs}}$ into an equivalent classical system.

Nevertheless, there exist at least two cases in which the vs-defence in $\text{AF}_{\text{vs}}$ and the defence in $\text{AF}$ coincide:

- If all arguments are equivalent (resp. incomparable) then $\text{AF}_{\text{vs}} = \text{AF}$.
- If any attack from A to B is such that A $\triangleright$ B and if the preordering between arguments is a total one then $\text{AF}_{\text{vs}} = \text{AF}$.

Depending on the properties of the relations $\text{R}$ and $\triangleright$ over arguments, particular cases of Def.10 can be identified:

- If $\triangleright$ is a total preordering then there are only 3 classes of attacks in $\text{Part}(\text{R})$: $\frac{1}{\text{ vs}}$, $\frac{2}{\text{ vs}}$ and $\frac{3}{\text{ vs}}$ (for instance, if the PAF is obtained from a WAF).
- If there is no \{(A, B) $\in$ \text{R} such that B $\triangleright$ A then there are only 3 classes of attacks in $\text{Part}(\text{R})$: $\frac{1}{\text{ vs}}$ and $\frac{2}{\text{ vs}}$.
- If there is no \{(A, B) $\in$ \text{R} such that B $\triangleright$ A and if $\triangleright$ is a total preordering then there are only 2 classes of attacks in $\text{Part}(\text{R})$: $\frac{1}{\text{ vs}}$ and $\frac{3}{\text{ vs}}$.

Finally, we establish links between our construction and other approaches based on a framework close to $\text{AF}_{\text{vs}}$. The first one [13] starts from a PAF where the attack relation $\text{R}$ is supposed symmetric. So, 3 classes of attack are obtained:

- $\text{ATT}_1 = \{(A, B) \text{ in conflict, with } A \triangleright B\}$ (A is a “proper defeater” of B),
- $\text{ATT}_2 = \{(A, B) \text{ in conflict, with } A \sim B\}$ (A is a “blocking defeater” of B and vice-versa),
- $\text{ATT}_3 = \{(A, B) \text{ in conflict, with } A \not\sim B\}$ (A is a “blocking defeiter” of B and vice-versa).

The correspondence with our $\text{AF}_{\text{vs}}$ follows easily: let \{(A, B) \text{ such that } A \text{ attacks } B\},

- \{(A, B) \in \text{ATT}_1 \text{ iff } (A, B) \in \frac{1}{\text{ vs}}\} and \{(B, A) \in \frac{2}{\text{ vs}}\}.
- \{(A, B) \in \text{ATT}_2 \text{ iff } (A, B) \in \frac{2}{\text{ vs}}\} and \{(B, A) \in \frac{3}{\text{ vs}}\}.

Note that a constraint analogous to P4 was added in [13] in order to compare two vs-defenders of a same argument. Another approach given in [17] aims at defining four notions of defence in an $\text{AF}_{\text{vs}}$: let $C \triangleright B \triangleright A$.

- C is a strong defender of A against B iff $\frac{3}{\text{ vs}} \sim \frac{2}{\text{ vs}}$.
- C is a weak defender of A against B iff $\frac{4}{\text{ vs}} \sim \frac{2}{\text{ vs}}$.
- C is a normal defender of A against B iff $\frac{3}{\text{ vs}} \sim \frac{3}{\text{ vs}}$.
- C is an unqualified defender of A against B iff $\frac{4}{\text{ vs}} \sim \frac{3}{\text{ vs}}$.

It is easy to see that our notion of vs-defence corresponds to a defence which is either strong or normal or unqualified. Moreover, if we consider an $\text{AF}_{\text{vs}}$ built from a PAF obtained with a WAF, the vs-defence corresponds to strong or normal defence.

B. Valued $\text{AF}_{\text{vs}}$ induced by a WAF

In this section, we turn to the qualitative setting. Starting from a WAF, our purpose is to take advantage of the weights over arguments to define an $\text{AF}_{\text{vs}}$ with a value-based preference over attacks. For simplicity, we assume that $\omega : \text{A} \rightarrow [0, 1]$, but any linearly ordered scale with top and bottom could be used as well.

Given $\omega$, we define the strength of an attack from A to B from $\omega$ and a function $f : [0, 1] \times [0, 1] \rightarrow \text{R}$. Formally, let $A, B \in \text{A}$, such that A attacks B. We assume that the strength of the attack from A to B is quantified by $f(\omega(A), \omega(B))$. As for the construction of an $\text{AF}_{\text{vs}}$ induced by a PAF, we want to impose conditions on the relationship between the weights on arguments and the strength on
attacks. We keep Principles P1 and P2. Principle P3 becomes of interest since there are no more incomparable arguments. Then we strengthen Principles P4 and P5 and reformulate them in terms of weights: let \((A, B) \in \mathbb{R}\).

- **P4'** If the weight of \(A\) is greater than the weight of \(B\), then the higher the difference of the weights, the stronger the attack from \(A\) to \(B\).

- **P5'** If the weight of \(A\) is lower than the weight of \(B\), then the higher the difference of the weights, the weaker the attack from \(A\) to \(B\).

In order to build a valued AF_{vs} satisfying P1, P2, P4', P5', we assume some conditions on the function \(f\).

**Def. 14:** A weighting translation function is a function \(f : [0, 1] \times [0, 1] \rightarrow \mathbb{R}\) such that: \(\forall x, y, z, t \in [0, 1],\)

- if \(x > y\) and \(t > z\) then \(f(x, y) > f(y, y) > f(z, t)\).
- \(f(x, x) = f(y, y)\).
- if \(x - y > z - t > 0\) then \(f(x, y) > f(z, t)\).
- \(f(x, x) = f(z, t)\).

First and second items of the previous definition allow the respect of P2. The other items correspond to P4' and P5'.

An example of such a weighting translation function is:

**Def. 15:** \(\forall x, y \in [0, 1], f_{\alpha, \beta}(x, y) = \alpha(x - y) + \beta, \) with \(\alpha > 0\) and \(\beta > 0\).

The following definition gives the way for building an AF_{vs} respecting P1, P2, P4', P5' (due to the conditions assumed for the weighting translation function \(f\) in Def.14):

**Def. 16:** Let WAF = \(\langle A, \mathbb{R}, \omega \rangle\). Let \(f\) be a weighting translation function. An AF_{vs} induced by WAF using \(f\) is a triplet \(\langle A, \text{ATT}, \rhd \rangle\) where ATT is the set of attack relations over \(A\) \(\langle \rhd _1, \ldots, \rhd _n \rangle\) defined by:

- \(\rhd _i = \{(A, B) \in \mathbb{R} \text{ such that } f(\omega(A), \omega(B)) = i\}\) and
- \(\rhd \) is the reflexive transitive closure of the binary relation on ATT defined by: \(\rhd_i \rhd_j \iff i > j\).

**C. Qualitative vs quantitative setting**

So far we have two ways for building an AF_{vs} from a given WAF:

- either applying Def.3 and then using Def.13 (which offers a more interesting ordering than Def.11),
- or using Def.16.

There is an important difference between these two constructions: in the first case, the resulting preference over attacks is a partial preordering, whereas, in the second case, it is a total one. Hopefully, these two ways are coherent, in the following sense: the second construction provides a valued AF_{vs} in which the preference over attacks refines the preference obtained by the first construction.

**Prop. 1:** Let WAF = \(\langle A, \mathbb{R}, \omega \rangle\) be a weighted argumentation framework. Let PAF be the corresponding preference argumentation framework obtained from WAF using Def.3. Let AF_{vs} (resp. AF_{vs}) be the argumentation system with attacks of various strength obtained from PAF (resp. WAF) using Def.13 (resp. Def.16). \(\rhd \geq_1\) (resp. \(\rhd \geq_2\)) denotes the associated preference relation between attacks. We have:

- \(\forall (A, B), (C, D) \in \mathbb{R}, \text{ if } (A, B) \rhd 1 (C, D) \text{ then } (A, B) \rhd 2 (C, D)\).
- \(\forall (A, B), (C, D) \in \mathbb{R}, \text{ if } (A, B) \sim_1 (C, D) \text{ then } (A, B) \sim_2 (C, D)\).
- \(\forall (A, B), (C, D) \in \mathbb{R}, \text{ if } (A, B) \rhd_2 (C, D) \text{ then } (A, B) \rhd_1 (C, D) \text{ or } (A, B) \not\rhd_1 (C, D)\).

**Proof**

- Let \(\langle A, B, (C, D) \rangle \in \mathbb{R}\) such that \((A, B) \rhd_1 (C, D)\). Due to Def.12 and 13, it is sufficient to consider three situations:

  1. \((A, B) \rhd i \text{ and } (C, D) \rhd j \text{ with } i < j\). For instance, we have \(\omega(A) > \omega(B) (i = 1) \text{ and } \omega(C) = \omega(D) (j = 2)\). In that case, due to the first and second items of Def.14, we have \(f(\omega(A), \omega(B)) > f(\omega(C), \omega(D))\) and then \((A, B) \rhd_2 (C, D)\). The proof is similar for the other cases \((i = 1 \text{ and } j = 4, i = 2 \text{ and } j = 4)\).

  2. \(B = D, (A, B), (C, D) \rhd (A \succ C) \text{ with } A \succ C \text{ or equivalently } \omega(A) > \omega(C)\). For instance, we have \(\omega(A) > \omega(B) \text{ and } \omega(C) > \omega(B) (i = 1)\). In that case, due to the third item of Def.14, we have \(f(\omega(A), \omega(B)) > f(\omega(C), \omega(B))\) and then \((A, B) \rhd_2 (C, B)\). For the case \(i = 4\), we use the fourth item of Def.14.

  3. \(A = C, (A, B), (A, D) \rhd (A \succ D) \text{ with } D > B \text{ or equivalently } \omega(D) > \omega(B)\). For instance, we have \(\omega(A) > \omega(B) \text{ and } \omega(A) > \omega(D) (i = 1)\). In that case, due to the third item of Def.14, we have \(f(\omega(A), \omega(B)) > f(\omega(A), \omega(D))\) and then \((A, B) \rhd_2 (A, D)\).

**D. Examples**

In this section, our main definitions are illustrated on AF = \(\langle A, \mathbb{R} \rangle\) represented by the following graph:
D. Approach of [20]

In this example, Arguments E and F are not vs-defended by A against C, the attack from A to C being too weak; similarly, H is not vs-defended by F against G, the attack from F to G being too weak. Moreover, following Def.12, (D, I) ∼ (D, J) (and this fact has no impact on the vs-defence). However, with Def.12, (A, B), (C, E) and (D, I) (for instance) are left incomparable.

Now, we consider the WAF = (A, R, ω) with the following weighting function:

- ω(A) = 0.7
- ω(B) = ω(D) = ω(E) = 0.6
- ω(C) = ω(F) = ω(G) = ω(H) = 1
- ω(I) = 0.5
- ω(J) = 0.4
- ω(K) = ω(L) = 0.3

Using Def.15 with α = β = 10, the AFVS obtained with Def.16 is represented by:

Here again, Arguments E and F are not vs-defended by A against C, the attack from A to C being too weak. The case of H is different: H is vs-defended by F against G since Arguments F and G have been made equivalent. Note also that, due to Principles P4' and P5', a difference between K and L appears: L is no longer vs-defended. Moreover, this example illustrates Point 3 of Prop.1: with Def.16, we have (C, E) ∼ (D, I) ∼ (A, B), whereas these attacks were incomparable with Def.12.

IV. A COMPARATIVE STUDY OF SEVERAL PROPOSALS

In this section, we propose a comparative study of the different proposals presented so far for defining preferences over attacks from preferences over arguments. We are interested in two issues: the ordering between the attacks and the notion of defence. Figure 1 gives a synthetic representation of these different proposals.

A. Proposals issued from a PAF

Starting from a PAF, we compare the approach proposed by [20] given in Def.8 with our approach given in Def.11. Table I shows how the set of attacks is partitioned.

<table>
<thead>
<tr>
<th>Our approach</th>
<th>Approach of [20]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A → B</td>
<td>V defenses (A, B)</td>
</tr>
<tr>
<td>A ∼ B</td>
<td>V defenses (A, B)</td>
</tr>
<tr>
<td>A ≈ B</td>
<td>V defenses (A, B)</td>
</tr>
<tr>
<td>B ≻ A</td>
<td>V defenses (A, B)</td>
</tr>
</tbody>
</table>

Table I

CLASSES OF ATTACKS IN THE CASE OF PAF

The main difference lies in the treatment of attacks (A, B) such that B ≻ A. With the weighted attacks of [20], all these attacks are removed (since the weight equals to 0), whereas we keep these attacks. Moreover, our approach enables to distinguish the attacks between equivalent arguments with those between incomparable arguments.

Then we are interested in the defence provided by C for A against B. Table II shows the different cases. Three situations are worth-noticing (in bold in the table). They highlight the fact that our approach provides a finer partition of the set of attacks.

Note that considering Def.13 instead of Def.11 would not modify the comparison, since applying Def.13 does not modify the hierarchy of the classes of attacks. It only adds preferences between attacks of the same class. Moreover, the ordering defined by Def.13 has no impact on the vs-defence.

B. Proposals issued from a WAF

Starting from a WAF, we compare the approach proposed by [20] given in Def.9 with our proposal for building an AFVS. As said in Section III-C, we can apply either Def.3 and then Def.13, or Def.16. We successively consider both

10So, the weighting translation function will be defined by f11 : [0, 1] × [0, 1] → [0, 2] with f11(x, y) = (x - y) + 1.
Approach of [20]

<table>
<thead>
<tr>
<th></th>
<th>Our approach vs-defence</th>
<th>Approach of [20] Vdef\textsubscript{1}\textsuperscript{#}-defence</th>
<th>Vdef\textsubscript{2}-defence</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C \succ B \succ A )</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>( C \succ B \sim A )</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>( C \succ B \not\sim A )</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>( C \sim B \not\succ A )</td>
<td>yes, since no attack on ( A )</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>( C \sim B \succ A )</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>( C \sim B \not\sim A )</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
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<td>( C \sim B \not\succ A )</td>
<td>yes, since no attack on ( A )</td>
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<td>no</td>
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<td>( C \not\succ B \not\sim A )</td>
<td>yes</td>
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<td>yes</td>
</tr>
<tr>
<td>( C \not\succ B \not\succ A )</td>
<td>no, since no attack on ( A )</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

Note also that, as in the case of PAF, some attacks are removed in [20] (particularly with Vdef\textsubscript{2}e).

Table II
DEFENCE IN THE CASE OF PAF: Let \( (C, B), (B, A) \in \mathbb{R} \), is \( C \) a defender of \( A \) against \( B \)?

<table>
<thead>
<tr>
<th></th>
<th>Vdef\textsubscript{1}\textsuperscript{#}-defence</th>
<th>Vdef\textsubscript{2}-defence</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \omega(C) &gt; \omega(B) )</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>( \omega(B) &gt; \omega(A) )</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>( \omega(C) = \omega(B) )</td>
<td>yes</td>
<td>yes (Note 1)</td>
</tr>
<tr>
<td>( \omega(C) &gt; \omega(B) )</td>
<td>yes</td>
<td>yes (Note 1)</td>
</tr>
<tr>
<td>( \omega(B) = \omega(A) )</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>( \omega(C) = \omega(B) )</td>
<td>yes</td>
<td>yes (Note 1)</td>
</tr>
<tr>
<td>( \omega(C) &lt; \omega(B) )</td>
<td>yes</td>
<td>yes (Note 1)</td>
</tr>
<tr>
<td>( \omega(B) &lt; \omega(A) )</td>
<td>yes</td>
<td>yes (Note 1)</td>
</tr>
<tr>
<td>( \omega(C) &lt; \omega(B) )</td>
<td>yes</td>
<td>yes (Note 1)</td>
</tr>
<tr>
<td>( \omega(B) &lt; \omega(A) )</td>
<td>yes</td>
<td>yes (Note 1)</td>
</tr>
</tbody>
</table>

Note 1: With Vdef\textsubscript{1}\textsuperscript{\#}, attacks \( (D, E) \) such that \( \omega(D) \not\succ \omega(E) \) are not considered. So in many cases, either \( A \) is defended since the attack from \( B \) to \( A \) does not exist or \( A \) cannot be defended since the attack from \( C \) to \( B \) does not exist.

Case 1: In this case, \( C \) vdef\textsubscript{1}\textsuperscript{\#}-defends \( A \) against \( B \) except if \( (\omega(B) - \omega(A)) > (\omega(C) - \omega(B)) \). In contrast, \( C \) always vs-defends \( A \) against \( B \).

Case 2: In this case, \( C \) vdef\textsubscript{2}-defends \( A \) against \( B \) except if \( (\omega(B) - \omega(C)) > (\omega(A) - \omega(B)) \). In contrast, \( C \) always vs-defends \( A \) against \( B \).

Case 3: As Vdef\textsubscript{2} does not discriminate between an attack \( (A, B) \) with \( A \succ B \) and an attack \( (A, B) \) with \( A \not\succ B \), if \( (\omega(B) = \omega(C)) > (\omega(A) - \omega(B)) \), then \( C \) vdef\textsubscript{2}-defends \( A \) against \( B \). In contrast, we have \( B \sim A \) and \( C \not\succ B \), so \( C \) does not vs-defend \( A \) against \( B \).

Finally, let us consider the valued AF\textsubscript{VS} obtained with
Def.16. Due to the conditions stated in Def.14, and the definition of $\text{Vdef}_1^\omega$ and $\text{Vdef}_2^\omega$, it is easy to see that:

- With $\omega(A) > \omega(B)$ and $\omega(C) > \omega(D)$, if $\text{Vdef}_1^\omega(A, B) > \text{Vdef}_1^\omega(C, D)$, then $f(\omega(A), \omega(B)) > f(\omega(C), \omega(D))$.
- With $\omega(A) < \omega(B)$ and $\omega(C) < \omega(D)$, if $\text{Vdef}_2^\omega(A, B) > \text{Vdef}_2^\omega(C, D)$, then $f(\omega(A), \omega(B)) > f(\omega(C), \omega(D))$.

In other words, the valued $\text{AF}_{\text{VS}}$ obtained with Def.16 allows for a total preordering on $R$ that extends the $\text{Vdef}_1^\omega$-based ordering on the attacks $(A, B)$ such that $A \succ B$ and the $\text{Vdef}_2^\omega$-based ordering on the attacks $(A, B)$ such that $B \succ A$:

- Ordering given by Def.16 $\Rightarrow$ Ordering given by Def.13.

V. CONCLUSION

In this paper, we have investigated the relationships between preferences over arguments and preferences over attacks in abstract argumentation. We have laid down some principles which should govern the definition of preferences over attacks from preferences over arguments. Following these principles, we have proposed different instantiations of an $\text{AF}_{\text{VS}}$ (argumentation framework with attacks of various strength), when preferences over arguments are available. We have considered qualitative as well as quantitative approaches for expressing preferences. Then, we have compared our proposal with related works, particularly regarding the conditions in which the defense holds. This work is a first contribution towards a better handling of preferences in argumentation. The proposed principles will have to be validated by considering how preferences over arguments can be obtained, when arguments have an internal structure (for instance, when they are built from pieces of knowledge). Another issue for future work concerns the computation of acceptable sets of arguments, when arguing with preferences.

REFERENCES


