An Argumentation System with Indirect Attacks

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Abstract: We discuss argumentation frameworks with indirect attacks, such as why-questions and supports. A why-question is regarded as a kind of attack relation, and a support is an answer to an un-presented why-question. Based on this idea, we construct an argumentation framework with why-questions from a pair of knowledge bases, as an instantiation of Dung's abstract argumentation framework, and show that its extension is consistent. Next, we transform this argumentation framework into an argumentation framework with supports, and discuss its properties. The resulting framework is an instantiation of Bipolar Argumentation Framework (BAF), defined as a triple consisting of arguments, attack relations and support relations. We define an extension of BAF, and show that the framework defined in this paper has some nice properties.

1 INTRODUCTION

Argumentation has long been an object of study in philosophy, but recently has attracted attention in the fields of artificial intelligence and computer science, including multi-agent systems (Bench-Capon and Dunne, 2007; García et al., 2007; Rahwan and Simari, 2009).

Dung proposed an abstract argumentation framework (AF) and expressed semantics in the form of extensions (i.e., a set of accepted arguments) (Dung, 1995). Since then, numerous works have been undertaken based on his framework including extended frameworks (Amgoud et al., 2008; Modgil and Prakken, 2011; Prakken, 2010).

Dung's abstract AF is defined as a pair consisting of arguments and attack relations between arguments. An attack relation is usually instantiated as a counterargument against an opponent's argument that negates a statement (formula) in that argument. However, in actual argumentation, there frequently exist indirect attacks other than counterarguments, such as strengthening the grounds for one's own claim or posing a query when the grounds for the opponent's claim are unacceptable. Such indirect attacks can be considered as a mechanism for expanding or deepening argumentation.

Indirect attacks appear not only when contradictory claims are inferred from the same fact, but also when an agent cannot present a counterargument, and instead questions the opponent's conclusion. By doing so, the agent may obtain new information or discourage the opponent from presenting a counterargument.

Asking for grounds using a why-move is a basic idea in argumentation systems (Walton and Krabbe, 1995), and is effective for legal reasoning. Prakken pointed out that why-moves should be introduced in AFs (Prakken, 2011), but neither an abstract AF with why-moves nor its instantiation has thus far been proposed.

Bipolar Argumentation System (BAF) is an abstract AF in which support relations as well as attack relations are regarded as binary relations between arguments (Amgoud et al., 2008). Although the concept of acceptable set obtained as a result of an argumentation is defined in BAF (Cayrol and Lagasquie-Shiex, 2010), the definition is complicated and does not successfully relate to Dung's semantics. A different approach is proposed to prevent these drawbacks by introducing support meta-arguments (Boella et al., 2010). However, the instantiation of BAF has not been presented, and which formulae are contained in an acceptable set is not discussed.

In this paper, we propose a method of constructing an AF with indirect attacks, such as why-questions or supports, from given knowledge bases.

We regard two agents as having independent knowledge bases, construct an AF with why-questions AF_{AS} from this pair of knowledge bases, and show that its extension is consistent. Next, we transform AF_{AS} into an AF with supports by replacing the pair consisting of a why-question and its answer with a support relation. The resulting framework

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BAF_{AS} is an instantiation of the existing BAF. We define an extension of BAF using the relationship with AF_{AS} , and show that BAF_{AS} is a subset of BAF with nice properties.

The remainder of this paper is organized as follows. In Section 2, we introduce Dung's abstract AF and describe basic concepts. In Section 3, we define our AF with why-questions from given knowledge bases, and discuss its properties. In Section 4, we describe the transformation of the above AF into an AF with support relations, and discuss its properties. Finally, in Section 5 we present our conclusions.

2 AUGUMENTATION FRAMEWORK

Definition 1 (Dung's AF (Dung, 1995)). *An AF is defined as a pair $\langle \mathcal{A}, \mathcal{R} \rangle$, where $\mathcal{A}$ is a set of arguments and $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$ is a set of attacks.*

Definition 2 (conflict-free,admissible,extension). *Let $\langle \mathcal{A}, \mathcal{R} \rangle$ be an AF. For $A, B \in \mathcal{A}$, and $\mathcal{E} \subseteq \mathcal{A}$,*
(1) $\mathcal{E}$ is conflict-free *in $\langle \mathcal{A}, \mathcal{R} \rangle$ iff there are no elements $A, B \in \mathcal{E}$ such that A attacks B.*
(2) $\mathcal{E}$ defends *A in $\langle \mathcal{A}, \mathcal{R} \rangle$ iff there exists an element of $\mathcal{E}$ attacking each argument that attacks A.*
(3) $\mathcal{E}$ is admissible *in $\langle \mathcal{A}, \mathcal{R} \rangle$ iff $\mathcal{E}$ is conflict-free and defends all of its elements.*
(4) $\mathcal{E}$ is a preferred extension *of $\langle \mathcal{A}, \mathcal{R} \rangle$ iff $\mathcal{E}$ is maximal w.r.t. $\subseteq$ admissible set.*

Several extensions are defined as acceptable sets of arguments within a given AF. Here we focus on preferred extensions, and hereafter the word "extension" will mean "preferred extension." Similar discussions are available for other extensions.

Example 1. *For an AF = $\langle \{A, B, C, D\}, \{(A, B), (A, C), (B, D), (C, A), (D, A)\} \rangle$. the preferred extension is $\{B, C\}$.*

We instantiate AF with a logical theory.

Definition 3 (consistent,c-consistent (Modgil and Prakken, 2011)). *Let* **L** *be a set of propositional logic formulae. If no formula ψ exists that satisfies both $\psi \in \mathbf{L}$ and $\neg\psi \in \mathbf{L}$,* **L** *is said to be* consistent. *If no pair of ϕ and ψ exists that satisfies both $\phi \Rightarrow \psi \in \mathbf{L}$ and $\phi \Rightarrow \neg\psi \in \mathbf{L}$,* **L** *is said to be* c-consistent, *where $\Rightarrow$ is a logical implication.*

Let **L** be a set of propositional logic formulae. A knowledge base $\mathbf{K} \subseteq \mathbf{L}$ is a finite, consistent and c-consistent set of propositional formulae. Each agent has its own knowledge base, and uses its elements to participate in argumentation. Note that **K** may not be deductively closed; i.e., there may be a case in which $\phi, \phi \Rightarrow \psi \in \mathbf{K}$ and $\psi \notin \mathbf{K}$ hold. Also note that $\neg\neg\psi$ is considered to be ψ. $\sim$ is introduced in order to make extensions c-consistent by setting $\phi \Rightarrow \neg\psi$ can attack $\phi \Rightarrow \psi$. Let α be a formula $\phi \Rightarrow \psi$, where ϕ may be $\top$. Then $\sim\alpha$ denotes either $\neg(\phi \Rightarrow \psi)$ or $\phi \Rightarrow \neg\psi$.

3 AF WITH WHY-QUESTIONS

A why-question cannot occur arbitrarily, but occurs only when an argument exists that it can attack. Therefore, after constructing the usual arguments and attack relations from the given pair of knowledge bases, we construct arguments and attack relations corresponding to why-questions.

Each agent p has its own knowledge base $\mathbf{K}_\text{p}$.

Definition 4 (argument). *Let $\phi_1, \ldots, \phi_n$ and ψ be formulae in $\mathbf{K}_\text{p}$. An argument on $\mathbf{K}_\text{p}$ is a triple $(Data, Warrant, Claim)$, where $Data = \phi_1, \ldots, \phi_n$, $Warrant = \phi_1 \wedge \ldots \wedge \phi_n \Rightarrow \psi$ and $Claim = \psi$.*

For an argument $P = (Data, Warrant, Claim)$ on $\mathbf{K}_\text{p}$, $Data, Warrant$ and $Claim$ are denoted by $Dat(P), Wrr(P)$ and $Clm(P)$, respectively. $Fml(P)$ is defined to be the set $\{Dat(P)\} \cup \{Wrr(P)\} \cup \{Clm(P)\}$. To simplify the problem, we consider only the case where $n = 1$ in every argument; i.e., an argument is denoted by $(\phi, \phi \Rightarrow \psi, \psi)$, where $\phi, \phi \Rightarrow \psi, \psi \in \mathbf{K}_\text{p}$, and denoted by (ψ) in case $\phi = \top$.

Definition 5 (attack). *Let A and B be arguments on $\mathbf{K}_\text{a}$ and $\mathbf{K}_\text{b}$, respectively.*

If $Clm(A) \Leftrightarrow \sim Clm(B)$, then (A, B) is said to be a rebut *from A to B. If $Clm(A) \Leftrightarrow \sim Dat(B)$ or $Clm(A) \Leftrightarrow \sim Wrr(B)$, then (A, B) is said to be* an undercut *from A to B. If (A, B) is a rebut or an undercut from A to B, then (A, B) is an attack from A to B.*

Let $\mathbf{K}_\text{a}$ and $\mathbf{K}_\text{b}$ be knowledge bases for agents a and b, respectively. Let $\mathcal{A}_a$ and $\mathcal{A}_b$ be sets of arguments on $\mathbf{K}_\text{a}$ and $\mathbf{K}_\text{b}$, respectively. Also, let $\mathcal{R}_a$ and $\mathcal{R}_b$ be sets of attacks from A to B and B to A, respectively. Then, we introduce why-questions and their answers.

Let p be agent a or b, and q its opponent. and let WB denote either Wrr or Dat. For $Q \in \mathcal{A}_q$, if $WB(Q) \notin \mathbf{K}_\text{p}$, create a new argument called *why-argument* $A_{whyp} = (\neg WB(Q))$ for p, and a new attack called *why-question* (A_{whyp}, Q). Moreover, if there exists an argument $Q' \in \mathcal{A}_q$ such that $Clm(Q') \Leftrightarrow \neg WB(A_{whyp})$, create a new attack *why-answer* (Q', A_{whyp}) corresponding to the answer to the why-question.

Example 2. *Figure 1 shows an example of why-arguments and why-attacks. Assume that*

$F, G, H, F \Rightarrow G, H \Rightarrow (F \Rightarrow G) \in \mathbf{K}_q$ *and* $F \Rightarrow G \notin \mathbf{K}_p$. *First, two arguments* Q, Q' *are constructed. Then, a why-argument* A_{whyp} *is created, and a why-question* (A_{whyp}, Q) *and a why-answer* (Q', A_{whyp}) *are added.*

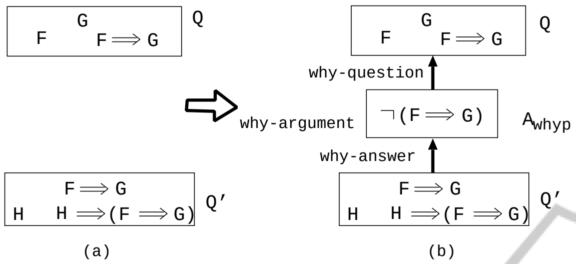


Figure 1: Example of why-arguments and why-attacks.

Why-questions from p to q and why-answers from p to q are called *why-attacks from p to q*.

Let $\mathcal{A}_{whya}$ and $\mathcal{R}_{whya}$ be a set of why-arguments for a and a set of why-attacks from a to b, respectively. Let $\mathcal{A}_{whyb}$ and $\mathcal{R}_{whyb}$ be a set of why-arguments for b and a set of why-attacks from b to a, respectively.

Definition 6 (AF with why-questions on knowledge bases (AF_{AS}))**.** *Let* $\mathcal{A}$ *be* $\mathcal{A}_a \cup \mathcal{A}_{whya} \cup \mathcal{A}_b \cup \mathcal{A}_{whyb}$ *and* $\mathcal{R}$ *be* $\mathcal{R}_a \cup \mathcal{R}_{whya} \cup \mathcal{R}_b \cup \mathcal{R}_{whyb}$. *Then* $\langle \mathcal{A}, \mathcal{R} \rangle$ *is said to be* an AF with why-questions on $\mathbf{K}_a$ and $\mathbf{K}_b$, *denoted by* AF_{AS} *.*

In AF_{AS} , an attack is either a rebut, an undercut or a why-attack. Note that AF_{AS} is an instantiation of AF.

Proposition 1. AF_{AS} *does not have an odd loop; i.e., if* (A_{i-1}, A_i) $(\forall i.\ 1 \leq i \leq n;\ A_n = A_0)$ *are attacks, then n is an even number.*

Proposition 2. *Let* $\mathcal{E}$ *be an extension of* AF_{AS} *. Then,* $\cup_{A \in \mathcal{E}} \{Clm(A)\}$ *is consistent and c-consistent, and* $\cup_{A \in \mathcal{E}} Fml(A)$ *is consistent and c-consistent.*

4 AN INSTANTIATION OF THE BIPOLAR AF

4.1 Transformation from AF_{AS} to BAF_{AS}

A support is an argument that strengthens another argument. It is considered as a why-answer presented without a why-question. Based on this idea, we present a transformation $\mathcal{T}$ from AF_{AS} to an AF with support BAF_{AS} .

Let AF_{AS} be an AF with why-questions on $\mathbf{K}_a$ and $\mathbf{K}_b$. We define a set of supports for a and a set of supports for b, denoted by $\mathcal{S}_a$ and $\mathcal{S}_b$, respectively.

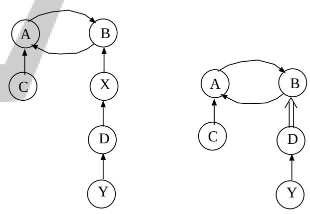
[Transformation from AF_{AS} to BAF_{AS}]

Set $\mathcal{S}_a$ and $\mathcal{S}_b$ equal to $\emptyset$. Let p be agent a or b, and q its opponent. For each why-argument $Q \in \mathcal{A}_{whyq}$ and an argument P' such that $(P', Q) \in \mathcal{R}_{whyp}$ and $(Q, P) \in \mathcal{R}_{whyq}$, (i) (P', P) is added to $\mathcal{S}_p$, (ii) (P', Q) is deleted from $\mathcal{R}_{whyp}$ for each P', (iii) (Q, P) is deleted from $\mathcal{R}_{whyq}$ for each Q. Finally, we obtain the AF with supports on the knowledge bases.

Definition 7 (AF with supports on the knowledge bases (BAF_{AS}))**.** *Let* $\mathcal{A}$ *be* $\mathcal{A}_a \cup \mathcal{A}_{whya} \cup \mathcal{A}_b \cup \mathcal{A}_{whyb}$, $\mathcal{R}$ *be* $\mathcal{R}_a \cup \mathcal{R}_{whya} \cup \mathcal{R}_b \cup \mathcal{R}_{whyb}$, *and* $\mathcal{S}$ *be* $\mathcal{S}_a \cup \mathcal{S}_b$, *where each set is the end result of the transformation procedure. Then* $\langle \mathcal{A}, \mathcal{R}, \mathcal{S} \rangle$ *is said to be* an AF with supports on $\mathbf{K}_a$ and $\mathbf{K}_b$, *denoted by* BAF_{AS} *.*

In this transformation $\mathcal{T}$, why-questions with their answers are replaced by supports, while the other ones without their answers remain. Note that there is a one-to-one relationship between AF_{AS} and BAF_{AS} . Therefore, we can define $\mathcal{T}^{-1}$.

Example 3. *Figure 2(a) shows* AF_{AS} *. In this figure, X and Y are why-arguments and the edges connected from/to them are why-attacks. Figure 2(b) shows* BAF_{AS} *obtained via* $\mathcal{T}$ *. In the figure,* $\rightarrow$ *represents an attack, and* $\Rightarrow$ *represents a support.*



(a) AF_{AS} (b) BAF_{AS}

Figure 2: A transformation from AF_{AS} to BAF_{AS} .

4.2 Bipolar AF

An abstract bipolar AF (BAF) includes a support relationship. We transform this framework to AF via $\mathcal{T}^{-1}$, and define an extension of BAF using the corresponding AF.

Definition 8 (BAF (Amgoud et al., 2008))**.** A BAF *is defined as a triple* $\langle \mathcal{A}, \mathcal{R}, \mathcal{S} \rangle$, *where* $\mathcal{A}$ *is a set of arguments,* $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$ *is a set of attack relations, and* $\mathcal{S} \subseteq \mathcal{A} \times \mathcal{A}$ *is a set of support relations.*

Example 4. *Figure 2(b) shows BAF* $= \langle \{A, B, C, D, Y\}, \{(A, B), (B, A), (C, A), (Y, D)\}, \{(D, B)\} \rangle$.

Proposition 3. *An abstract BAF can be transformed into an abstract AF via* $\mathcal{T}^{-1}$.

An extension of the resulting AF $\mathcal{E}_{AF}$ is defined according to Definition 2. An extension of BAF is defined using $\mathcal{E}_{AF}$.

Definition 9 (extension of BAF)**.** *Let* $\langle \mathcal{A}, \mathcal{R}, \mathcal{S} \rangle$ *be a BAF, and let AF be the corresponding Dung's AF. Let* $\mathcal{E}_{AF}$ *be an extension of AF. Then* $\mathcal{E}_{AF} \cap \mathcal{A}$ *is an extension of BAF.*

From this definition, the following property holds.

Proposition 4. *Let* $\mathcal{E}_{AF}$ *be an extension of* AF_{AS} *on* $\mathbf{K}_a$ *and* $\mathbf{K}_b$*. Then there exists* $\mathcal{E}_{BAF}$ *of* BAF_{AS}*, obtained from* AF_{AS} *by* $\mathcal{T}$*, such that* $\mathcal{E}_{BAF} \subseteq \mathcal{E}_{AF}$ *holds.*

Example 5. *In Figure 2, there is only one extension in both* AF_{AS} *and* BAF_{AS}*. The extension of* AF_{AS} *is* $\{C, X, Y\}$*, while the extension of* BAF_{AS} *is* $\{C, Y\}$*.*

4.3 Properties of BAF_{AS}

BAF itself is defined as an abstract framework. It can include cyclic arguments, and a pair of arguments may be an attack and a support at the same time. Moreover, it is immaterial which agent presents an argument, and the order in which arguments are presented is also irrelevant. Therefore, the internal meaning of an extension of BAF is unclear. On the other hand, BAF_{AS} obtained from AF_{AS} via the transformation $\mathcal{T}^{-1}$ is a subset of BAF that satisfies several nice properties.

First, Propositions 1 and 2 in AF_{AS} are preserved in BAF_{AS}.

In addition, the following properties hold.

Proposition 5. *Let* $\langle \mathcal{A}, \mathcal{R}, \mathcal{S} \rangle$ *be* BAF_{AS}*. If* (A', A) *is in* $\mathcal{S}$*, then* $Clm(A') \Leftrightarrow Wrr(A)$ *or* $Clm(A') \Leftrightarrow Dat(A)$ *holds, and* $Clm(A') \notin \mathbf{K}_a \cap \mathbf{K}_b$*.*

This proposition follows from the definition of a why-question, and shows that we can construct BAF_{AS} directly from $\mathbf{K}_a$ and $\mathbf{K}_b$.

Proposition 6. *Let* $\langle \mathcal{A}, \mathcal{R}, \mathcal{S} \rangle$ *be* BAF_{AS}*.* $\mathcal{R} \cap \mathcal{S} = \emptyset$*.*

This proposition follows from the definition of an attack and a support.

Proposition 7. *Let* $\langle \mathcal{A}, \mathcal{R}, \mathcal{S} \rangle$ *be* BAF_{AS}*. Let* A, A', B *be arguments in* $\mathcal{A}$*. If* (A', A) *is in* $\mathcal{S}$ *and* (B, A) *is in* $\mathcal{R}$*, then* (B, A') *is not in* $\mathcal{S}$*, and* (A', B) *is not in* $\mathcal{S}$*.*

This proposition shows that we need not consider a case against our intuition in which B and A' are in the support relation when B attacks A and A' supports A.

We proved all these properties, although the proofs are not shown here because of the space limit.

5 CONCLUSIONS

We proposed the construction of an AF with why-questions from a pair of knowledge bases, as an instantiation of an abstract AF, and showed that its extension is consistent. Moreover, we transformed this framework into an AF with supports, and discussed its properties.

Our main contributions are as follows. (1) Agents argue using different knowledge bases, whereas a single knowledge base is used in most systems. (2) An AF with why-questions is constructed. (3) A new, simple definition of BAF extension is given, and a subset with some nice properties is presented. The former two points are advantageous for handing actual argumentation.

As future research, we are considering the construction of a system with changing knowledge bases.

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