Attack Relations among Dynamic Coalitions

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Abstract

In this paper we introduce a formal argumentation framework to reason about the evolution of coalitions. We extend Amgoud's preference-based argumentation framework for coalition formation to an argumentation framework with nested attack relations along the lines proposed by Modgil, and we define an instance of the argumentation framework for reasoning about coalitions based on a new dynamic extension of Conte and Sichman's static dependence networks. We show how this new approach covers a wider range of attacks than Amgoud's task based coalition formation, including attacks weakening the stability of the coalition by removing dependencies. Moreover, we show how it can be used not only for coalition formation, but also for coalitions which evolve due to the addition of dependencies.

1 Introduction

Dung's argumentation theory [11] may be seen as a formal framework for nonmonotonic logic and logic programming, and has been applied to many domains in which non-monotonic reasoning plays a role, such as decision making or coalition formation [4].

Amgoud [1] proposes to use Dung's argumentation theory and associated dialogue theories as a formal framework for coalition formation, and she illustrates this idea by formalizing a task based theory of coalition formation as in instance of Dung's argumentation theory. In this formalization, an argument is a set of agents together with a task, and an argument attacks another one if the two coalitions share an agent, or when they contain the same task. It is therefore based on strong assumptions, for example that an agent cannot be part of two coalitions at the same time. Since the attack relation is symmetric, also preferences are introduced to resolve conflicts.

In this paper, we are interested in a generalization of Amgoud's argumentation based coalition theory, covering a wider range of attacks, and a broader range of reasoning about coalitions. In particular, we would like to cover not only coalition formation but also the dynamics of coalitions, whose stability can be attacked and which can evolve by adding new dependencies among agents in the coalition. In this paper we address the following questions:

1. How to model preferences among coalitions? In particular, how can a global preference relation among coalitions be defined, or derived from the preference relations on coalitions of individual agents?
2. In which ways can a coalition attack another one, including attacks on the stability of coalitions? What kind of coalition formation theory should we use in the argumentation theory to cover a wider range of attacks among coalitions?
3. In which ways can a coalition evolve in time by adding new dependencies among agents in the coalition? How to cover not only coalition formation but also coalition evolution?

To represent preferences among coalitions in terms of attacks of attack relations, we use Modgil's argumentation theory [13]. Modgil has introduced an extension of Dung's framework in which arguments can be given why one argument is preferred to another one. In particular, he proposes an argumentation framework in which an argument can attack an attack relation, and illustrates how this can be used to represent arguments for preferences. In this paper we show how such attacks of attack relations can be modeled as an instance of Dung's theory.

To represent attacks on stability of coalitions and their evolution, we argue that instead of a task based coalition theory as used by Amgoud, a wider range of attacks can be defined using Sichman and Conte's dependence network theory. We extend their theory for conditional dependencies, in which agents can create or destroy dependencies by introducing or removing powers and goals of agents. Goals can be introduced if goals are conditional, or when the agent can create normative goals by creating obligations for the other agents.

The layout of this paper is as follows. In Section 2 we introduce Amgoud's argumentation theory for coalition formation, which is equivalent to Dung's abstract argumentation theory in which arguments are about coalitions, and we introduce our representation of Modgil's argumentation framework with nested attack relations as an instance of Dung's framework. In Section 3 we introduce a dynamic version of Conte and Sichman's dependence networks, following Caire et al [9] we introduce conditional dependencies, but we distinguish among adding powers and goals, and removing them. Finally, in Section 4 we illustrate the framework with examples concerning the deletion and addition of dependencies in coalitions using the argumentation theory. Related work and conclusions end the paper.

2 Arguing about coalitions

Argumentation is a reasoning model based on constructing arguments, identifying potential conflicts between arguments and determining acceptable arguments. Amgoud [1] proposes to use it to construct arguments to form coalitions, identify potential conflicts among coalitions, and determine the acceptable coalitions. Dung's framework [11] is based on a binary attack relation among arguments. In Dung's framework, an argument is an abstract entity whose role is determined only by its relation to other arguments. Its structure and its origin are not known. In this section, following Amgoud, we assume that each argument proposes to form a coalition, but we do not specify the structure of such coalitions yet. We represent the attacks among arguments by $\#$.

Definition 1 (Argumentation framework) *An argumentation framework is a pair $\langle \mathcal{A}, \# \rangle$, where $\mathcal{A}$ is a set (of arguments to form coalitions), and $\# \subseteq \mathcal{A} \times \mathcal{A}$ is a binary relation over $\mathcal{A}$ representing a notion of* attack *between arguments.*

The various semantics of an argumentation framework are all based on the notion of defense. A set of arguments $\mathcal{S}$ defends an argument a when for each attacker b of a, there is an argument in $\mathcal{S}$ that attacks b. A set of acceptable arguments is called an *extension*.

Definition 2 (Acceptable arguments)

- *$\mathcal{S} \subseteq A$ is attack free if and only if there are no arguments $a_1, a_2 \in \mathcal{S}$ such that a_1 attacks a_2.*
- *$\mathcal{S}$ defends a if and only if for all $a_1 \in \mathcal{A}$ such that a_1 attacks a, there is an alternative $a_2 \in \mathcal{S}$ such that a_2 attacks a_1.*
- *$\mathcal{S}$ is a preferred extension if and only if $\mathcal{S}$ is maximal w.r.t. set inclusion among the subsets of $\mathcal{A}$ that are attack free and that defend all their elements.*
- *$\mathcal{S}$ is a basic extension if and only if it is a least fixpoint of the function $F(\mathcal{S}) = \{a | a$ is defended by $\mathcal{S}\}$.*

The following example illustrates argumentation theory.

Example 1 *Let $AF = \langle \mathcal{A}, \# \rangle$ be an argumentation framework, where $\mathcal{A} = \{C_1, C_2, C_3\}$ is the set (of arguments or coalitions), and $\{C_1 \# C_2, C_2 \# C_3\}$ is the binary relation over $\mathcal{A}$ representing a notion of* attack *between arguments. Due to the so-called reinstatement principle of argumentation theory, the acceptable arguments are C_1 and C_3, for any kind of semantics. C_1 is accepted because it is not attacked by any other argument, and C_3 is accepted because its only attacker C_2 is attacked by an accepted argument.*

Amgoud [1] proposes to use preference-based argumentation theory for coalition formation, in which the attack relation is replaced by a binary relation $\mathcal{R}$, which she calls a defeat relation, together with a (partial) preordering on the coalitions. Each preference-based argumentation framework represents an argumentation framework, and the acceptable arguments of a preference-based argumentation framework are simply the acceptable arguments of the represented argumentation framework.

Definition 3 (Preference-based argumentation framework) *A preference-based argumentation framework is a tuple $\langle \mathcal{A}, \mathcal{R}, \succeq \rangle$ where $\mathcal{A}$ is a set of arguments or coalitions, $\mathcal{R}$ is a binary defeat relation defined on $\mathcal{A} \times \mathcal{A}$ and $\succeq$ is a (total or partial) pre-order (preference relation) defined on $\mathcal{A} \times \mathcal{A}$. A preference-based argumentation framework $\langle \mathcal{A}, \mathcal{R}, \succ \rangle$ represents $\langle \mathcal{A}, \# \rangle$ if and only if $\forall a, b \in \mathcal{A}$, we have $a \# b$ if and only if $a \mathcal{R} b$ and it is not the case that $b \succ a$ (i.e., $b \succeq a$ without $a \succeq b$). The extensions of $\langle \mathcal{A}, \mathcal{R}, \succ \rangle$ are the extensions of the represented argumentation framework.*

The following example illustrates the preference based argumentation theory.

Example 2 (Continued) *Let $PAF = \langle \mathcal{A}, \mathcal{R}, \succeq \rangle$ be a preference-based argumentation framework, where $\mathcal{A} = \{C_1, C_2, C_3\}$ is a set of arguments to form coalitions, $\{C_1 \mathcal{R} C_2, C_2 \mathcal{R} C_1, C_2 \mathcal{R} C_3, C_3 \mathcal{R} C_2\}$ a binary defeat relation defined on $\mathcal{A} \times \mathcal{A}$ and $\{C_1 \succ C_2, C_2 \succ C_3\}$ a total order (preference relation) defined on $\mathcal{A} \times \mathcal{A}$. PAF represents AF, so the acceptable arguments are again C_1 and C_3, for any kind of semantics.*

In general, preference-based argumentation frameworks are a useful and intuitive representation for argumentation frameworks, but for the application of coalition formation it is less clear where the preferences among coalitions come from. Moreover, when the defeat relation is symmetric, as in Amgoud's task based coalition theory, then it leads to a lack of expressive power, because some attack cycles can no longer be represented (see [12] for details).

Modgil [13] relates preferences to second-order attacks. Suppose that arguments a and b attack each other, and that argument a is preferred to argument b. Modgil observes that we can then say that the preference attacks the attack relation from b to a. The advantage of this perspective is that Modgil introduces also arguments which attack attack relations, which he uses to represent non-monotonic logics in which the priorities among the rules are represented in the formalism itself, rather than being given a priori (such as Brewka's theory [7], or Prakken and Sartor's theory [14]). Whereas Modgil presents his theory as an extension of Dung, such that he has to define new semantics for it, we define a version of second order attacks as an instance of Dung's theory. Each second order argumentation framework represents an argumentation framework, and the acceptable arguments of the second order argumentation framework are simply the acceptable arguments of the represented argumentation framework.

Definition 4 *A second order argumentation framework is a tuple $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, not, \mathcal{A}_\#, \# \rangle$, where $\mathcal{A}_\mathcal{C}$ is a set of coalition arguments, $\overline{\mathcal{A}}$ is a set of arguments such that $|\overline{\mathcal{A}}| = |\mathcal{A}_\mathcal{C}|$, not is a bijection from $\mathcal{A}$ to $|\overline{\mathcal{A}}|$, $\mathcal{A}_\#$ is a set of arguments that coalitions attack each other, and $\# \subseteq (\mathcal{A}_\mathcal{C} \times \overline{\mathcal{A}}) \cup (\overline{\mathcal{A}} \times \mathcal{A}_\#) \cup (\mathcal{A}_\# \times \mathcal{A}_\mathcal{C}) \cup (\mathcal{A}_\mathcal{C} \times \mathcal{A}_\#)$ is a binary relation on the set of arguments such that for $a \in \mathcal{A}_\mathcal{C}$ and $b \in \overline{\mathcal{A}}$ we have $a \# b$ if and only if $b = not(a)$, and for each $a \in \mathcal{A}_\#$, there is precisely one $b \in \overline{\mathcal{A}}$ such that $b \# a$ and precisely one $c \in \mathcal{A}_\mathcal{C}$ such that $a \# c$. A second order argumentation framework $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, \mathcal{A}_\#, \# \rangle$ represents $\langle \mathcal{A}, \# \rangle$ if and only if $\mathcal{A} = \mathcal{A}_\mathcal{C} \cup \overline{\mathcal{A}} \cup \mathcal{A}_\#$. The extensions of $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, \mathcal{A}_\#, \# \rangle$ are the extensions of the represented argumentation framework.*

The following example illustrates the second order argumentation theory. The main feature of $not(C)$ arguments is just to ensure that if an argument is not accepted, then it cannot attack other arguments. The argument C_0 is a dummy argument to represent the preferences, here used to map the second order framework to the preference-based one. This example is showed in Figure 1.

Example 3 (Continued) *Let $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, not, \mathcal{A}_\#, \# \rangle$ be a second order argumentation framework, where $\mathcal{A}_\mathcal{C} = \{C_1, C_2, C_3, C_0\}$ is a set of coalition arguments, $\overline{\mathcal{A}} = \{C'_1, C'_2, C'_3, C'_0\}$, not is the bijection $not(C_i) = C'_i$, $\mathcal{A}_\# = \{C_{1,2}, C_{2,1}, C_{2,3}, C_{3,2}\}$ is a set of arguments that coalitions attack each other, and*

$$\{C_1 \# C'_1, C_2 \# C'_2, C_3 \# C'_3, C_0 \# C'_0, C'_1 \# C_{1,2}, C'_2 \# C_{2,1}, C'_2 \# C_{2,3}, C'_3 \# C_{3,2},$$

$$C_{1,2} \# C_2, C_{2,1} \# C_1, C_{2,3} \# C_3, C_{3,2} \# C_2, C_0 \# C_{2,1}, C_0 \# C_{3,2}\}$$

is a binary relation on the set of arguments. For the nested attack relations, we also write $C_0 \# (C_2 \# C_1)$ and $C_0 \# (C_3 \# C_2)$. The acceptable arguments are C_1 and C_3, together with C_0, C'_2, $C_{1,2}$, $C_{2,3}$, for any kind of semantics.

We use the same example in Section 4 using coalitions defined by dynamic dependence networks.

We can visualize second order argumentation frameworks by not visualizing $\overline{\mathcal{A}}$ or $\mathcal{A}_\#$, and visualizing an indirect attack from an element of $\mathcal{A}_\mathcal{C}$ to $\mathcal{A}_\mathcal{C}$ via an element of $\mathcal{A}_\#$ as an arrow, and an attack of an element

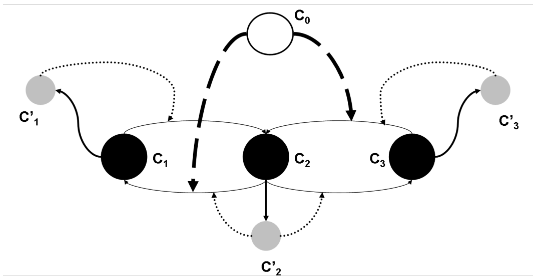

Figure 1: Graphical representation of Example 3.

of $\mathcal{A}_\mathcal{C}$ to an element of $\mathcal{A}_\#$ as an attack on an attack relation, see [13] for examples of such a visualization. Example 3 shows that arguments that attack attack relations do that directly. However, Barringer, Gabbay and Woods [3] argue that such attack relations can themselves also be attacked, leading to a notion of higher order attacks.

Definition 5 *A higher order argumentation framework is a tuple $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, not, \mathcal{A}_\#, \# \rangle$, where $\mathcal{A}_\mathcal{C}$ is a set of coalition arguments, $\overline{\mathcal{A}}$ is a set of arguments such that $|\overline{\mathcal{A}}| = |\mathcal{A}_\mathcal{C}|$, not is a bijection from $\mathcal{A}$ to $|\overline{\mathcal{A}}|$, $\mathcal{A}_\#$ is a set of arguments that coalitions attacks attack each other, and $\# \subseteq (\mathcal{A}_\mathcal{C} \times \overline{\mathcal{A}}) \cup (\overline{\mathcal{A}} \times \mathcal{A}_\#) \cup (\mathcal{A}_\# \times \mathcal{A}_\mathcal{C}) \cup (\mathcal{A}_\# \times \mathcal{A}_\#)$ is a binary relation on the set of arguments such that for $a \in \mathcal{A}_\mathcal{C}$ and $b \in \overline{\mathcal{A}}$ we have $a\#b$ if and only if $b = not(a)$, and for each $a \in \mathcal{A}_\#$, there is precisely one $b \in \overline{\mathcal{A}}$ such that $b\#a$ and precisely one $c \in \mathcal{A}_\mathcal{C} \cup \mathcal{A}_\#$ such that $a\#c$. A higher order argumentation framework $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, \mathcal{A}_\#, \# \rangle$ represents $\langle \mathcal{A}, \# \rangle$ if and only if $\mathcal{A} = \mathcal{A}_\mathcal{C} \cup \overline{\mathcal{A}} \cup \mathcal{A}_\#$. The extensions of $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, \mathcal{A}_\#, \# \rangle$ are the extensions of the represented argumentation framework.*

3 Coalition formation

Coalitions can be defined in so-called dependence networks, based on the idea that to be part of a coalition, every agent has to contribute something, and has to get something out of it. Dependence networks are a kind of social network introduced by Sichman and Conte, representing how each agent depends on other agents to achieve the goals he cannot achieve himself. They are used to specify early requirements in the Tropos agent methodology [6], and to model and reason interactions among agents in multiagent systems. Roughly, a coalition can be formed when there is a cycle of dependencies (the definition of coalitions is more complicated due to the fact that an agent can depend on a set of agents, see below).

Dynamic dependence networks have been introduced by Caire et al. [9], in which a dependency between agents can depend on the interaction of other agents. Here we distinguish "negative" dynamic dependencies where a dependency exists unless it is removed by a set of agents, due to removal of a goal or ability of an agent, and "positive" dynamic dependencies where a dependency may be added due to the power of a third set of agents. As explained in the following section, these two dynamic dependencies can be used to reason about the evolution of coalitions.

Definition 6 (Dynamic Dependence Networks) *A dynamic dependence network is a tuple $\langle A, G, dyndep^-, dyndep^+ \rangle$ where:*

- *A is a set of agents and G is a set of goals.*
- *$dyndep^- : A \times 2^A \times 2^A \rightarrow 2^{2^G}$ is a function that relates with each triple of a agent and two sets of agents all the sets of goals in which the first depends on the second, unless the third deletes the dependency. The static dependencies are defined by $dep(a, B) = dyndep^-(a, B, \emptyset)$.*
- *$dyndep^+ : A \times 2^A \times 2^A \rightarrow 2^{2^G}$ is a function that relates with each triple of a agent and two sets of agents all the sets of goals on which the first depends on the second, if the third creates the dependency.*

A coalition can be represented by a set of dependencies, represented by $C(a, B, G)$ where a is an agent, B is a set of agents and G is a set of goals. Intuitively, the coalition agrees that for each $C(a, B, G)$ part of the coalition, the set of agents B will see to the goal G of agent a. Otherwise, the set of agents B may be removed from the coalition or be sanctioned.

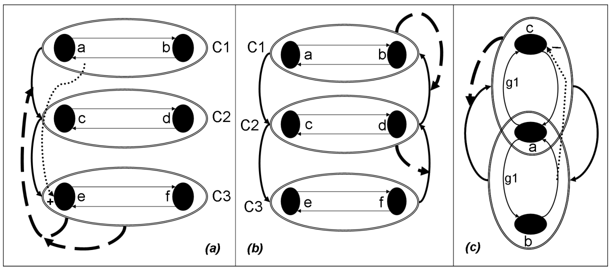

Figure 2: (a) - (b) - Three coalitions attacking each other, (c) - Vulnerable coalitions

Definition 7 *Let A be a set of agents and G be a set of goals. A coalition function is a partial function $C : A \times 2^A \times 2^G$ such that $\{a \mid C(a, B, G)\} = \{b \mid b \in B, C(a, B, G)\}$, the set of agents profiting from the coalition is the set of agents contributing to it. Let $\langle A, G, dyndep^-, dyndep^+\rangle$ be a dynamic dependence network, and dep the associated static dependencies.*

1. *A coalition function C is a coalition if $\exists a \in A, B \subseteq A, G' \subseteq G$ such that $C(a, B, G')$ implies $G' \in dep(a, B)$. These coalitions which cannot be destroyed by addition or deletion of dependencies by agents in other coalitions.*
2. *A coalition function C is a vulnerable coalition if it is not a coalition and $\exists a \in A, B \subseteq A, G' \subseteq G$ such that $C(a, B, G')$ implies $G' \in \cup_D dyndep^-(a, B, D)$. Coalitions which do not need new goals or abilities, but whose stability can be destroyed by removing dependencies.*
3. *A coalition function C is a potential coalition if it is not a coalition or a vulnerable coalition and $\exists a \in A, B \subseteq A, G' \subseteq G$ such that $C(a, B, G')$ implies $G' \in \cup_D (dyndep^-(a, B, D) \cup G' \in dyndep^+(a, B, D))$ Coalitions which could be created or which could evolve if new abilities or goals would be created by agents of other coalitions on which they dynamically depend.*

In this paper we do not consider further refinements of the notion of coalition as in [5], but focus on the use of argumentation theory to reason about coalitions.

The basic attack relations between coalitions are due to the fact that they are based on the same goals. This is analogous to the conflicts between coalitions in Amgoud's coalition theory where two coalitions are based on the same tasks.

Definition 8 *Coalition C_1 attacks coalition C_2 if and only if there exists a, a', B, B', G, G', such that $C_1(a, B, G)$, $C_2(a', B', G')$ and $G \cap G' \neq \emptyset$.*

We illustrate the conflict among coalitions with an example:

Example 4 *Assume we have three agents, a, b, c and the dependencies (we write $C(a, b, g_1)$ for $C(a, \{b\}, \{g_1\})$ and $dep(a, b, g_1)$ for $dep(a, \{b\}, \{g_1\})$): $dep(a, b, g_1), dep(a, c, g_1), dep(b, a, g_2), dep(c, a, g_3)$. So there are two coalitions: $C_1 = \{(a, b, g_1), (b, a, g_2)\}, C_2 = \{(a, c, g_1), (c, a, g_3)\}$. They will not create both since one is enough for agent a to have someone look after his goal g_1: $C_1 \# C_2$ and $C_2 \# C_1$.*

We now go beyond Amgoud's approach by defining the second order attacks. The simplest kind of attack on an attack relation is to remove or add one of the dependencies of the attacker.

Definition 9 *Coalition C attacks the attack from coalition C_1 on coalition C_2 if and only if there exists a set of agents $D \subseteq \{a \mid \exists E, H C(a, E, H)\}$ such that $\exists a, B, G' C_1(a, B, G')$ and $G \in dyndep^{\{+,-\}}(a, B, D)$.*

On the one hand, this definition reflects the idea that the stability of a vulnerable coalition $C1$ can be endangered by agents of another coalition C if they decide to remove a dependency of $C1$ due to the dynamic dependency *dyndep*$^-(a, B, D)$. On the other hand that a potential coalition $C1$ can never materialize or evolve if the agents of $C1$ do not create the dependency denoted by *dyndep*$^+(a, B, D)$.

The effect of making a vulnerable coalition unstable or of leaving a potential coalition immaterial is represented by the fact that all the attack relations which stem from it are attacked by the coalition C on which $C1$ dynamically depend. The next section will discuss these two possibilities thanks to some examples.

4 Examples

In this section we illustrate by means of examples how to reason about coalitions in the argumentation framework. The first example shows three coalitions which attack each other since they share some goals. Attacks on attacks relations allow to define asymmetric attacks.

Example 5 *Assume we have six agents, a, b, c, d, e, f and the following dependencies:*

$dep(a, b, g_1)$, $dep(b, a, g_2)$, $dep(c, d, g_1)$, $dep(d, c, g_3)$, $dep(e, f, g_4)$, $dep(f, e, g_3)$, $dep(a, d, g_1)$, $dep(c, b, g_1)$, $dep(d, e, g_3)$, $dep(f, c, g_3)$.

The possible coalitions are C_1, C_2 and C_3 where $C_1 = \{(a, b, g_1), (b, a, g_2)\}$, $C_2 = \{(c, d, g_1), (d, c, g_3)\}$, $C_3 = \{(e, f, g_4), (f, e, g_3)\}$.

Note that some of the dependencies remain outside all coalitions (e.g., $dep(a, d, g_1)$, $dep(c, b, g_1)$). Thus, $C_1 \# C_2$, $C_2 \# C_1$, $C_2 \# C_3$ and $C_3 \# C_2$ due to the fact that they share goals g_1 and g_3 respectively. Note that these attacks are reciprocal.

The coalitions attack each other since, for example, agents b and d on which respectively a and c depend for g_1 would not make their part hoping that the other one will do that, so to have a free ride and get respectively g_2 achieved by a and g_3 by c.

To model the fact that C_1 is more important than C_2 and C_2 of C_3 we add an attack on the attack relation: $C_1 \# (C_2 \# C_1)$ and $C_2 \# (C_3 \# C_2)$. Thus the only possible extension is $\{C_1, C_3\}$.

We depict this situation in Figure 2 - (b): normal arrows connecting the agents represent the dependencies among these agents (they can be labeled with the goal on which the dependence is based), coalitions are represented by the ovals containing the agents of the coalition, bold arrows indicate the attack relations among the coalitions and the attack relation on attack relations is depicted as bold dashed arrows pointing on other arrows. Using the terminology of argumentation theory, coalition C_1 attacks coalition C_2 but not vice versa, and C_2 attacks C_3 but not vice versa. Therefore C_1 becomes an acceptable coalition since it is not attacked, and C_3 is attacked only by a coalition which will not be accepted, and therefore it is reinstated as an acceptable coalition. This can be explained as follows. Since an agent of coalition C_1 has the power to destroy the coalition C_2 by removing a dependency, it will not be realized. The agents involved will prefer coalition C_1, which cannot be attacked by removing a dependency, and which is therefore more stable. Note that for this reasoning, the coalitions do not have to be constructed. It is assumed that all the agents know the dependencies, and they therefore realize that coalition C_2 is not viable. For coalition C_3, the situation is more complicated. Though it can be attacked by coalition C_2, the agents realize following the argumentation above that C_2 will never be realized, and therefore they realize that the agents in coalition C_2 who could attack the coalition, will not do so, because they have nothing to win by attacking the coalition. So despite the fact that it is a vulnerable coalition, it will be accepted by the agents involved. This follows by hypothetical reasoning using the dynamic dependence network, formalized in the argumentation theory based on the reinstatement principle.

The following example illustrates how the deletion of a dependency can be used to attack an attack relation (see Figure 2 - (c), dotted arrows characterized by a label + or - links a dependency with an agent and it indicates that the dependency can be added (+) or deleted (-)).

Example 6 (Continues Example 4) *Now, assume agent c can destroy the dependency $dep(b, a, g_2)$, i.e., we substitute it with dyndep$^-(b, a, c, g_2)$, for example by removing the power of a to see to goal g_2, or by removing the goal g_2 of agent b. This deletion allows agent c to ensure himself the dependence on himself of agent a on goal g_1. This deletion sets a preference relation of the coalition C_2, represented here with the attack of coalition C_2 to the attack relation of coalition C_1 to coalition C_2. In this case, the coalition $C_2 = \{(a, c, g_1), (c, a, g_3)\}$ will become the only possible extension, since $C_2 \# (C_1 \# C_2)$ by Definition 9.*

Whereas the previous example illustrates the role of dynamic dependencies which can delete existing dependencies, in the next example we consider the role of adding dependencies (see Figure 2 - (a)).

Example 7 (Continues Example 5) *Assume instead that $dep(b, a, g_2)$ is not present since the beginning and it happens that agent e of C_3 has the power to create it: i.e., it is substituted by dyndep$^+(b, a, e, g_2)$. Thus, C_3 attacks the attack relation between C_1 and C_1, $C_3 \# (C_1 \# C_2)$ by Definition 9: if coalition C_1 remains potential, then it cannot attack any other coalition. Thus, the only extension is $\{C_2\}$.*

However this dependence network does not capture the fact that agent e should be able to understand that it is better off in a situation where he actually creates the dependency $dep(b, a, g_2)$. We can represent *this situation by adding an attack relation between coalition C_3 which e belongs to and the attack relation between introduced by Definition 9: $C_3\#(C_3\#(C_1\#C_2))$. Note that this requires an higher order argumentation framework, like the one of Definition 5, where arguments can attack attack relations against other attack relations. This means that agent e exercises his option to add the dependency $dep(b, a, g_2)$ to C_1. The extension in this case would be $\{C_1, C_3\}$.*

5 Related work

Although there were many approaches defining coalition formation, two represents different perspectives: the model of Shehory and Kraus [15] and the one of Sichman [16]. The approach of Shehory and Kraus [15] is based on the assumption that autonomous agents in the multiagent environments may need to cooperate in order to fulfill tasks. They present algorithms that enable the agents to form groups and assign a task to each group, calling these groups coalitions. The paper presents coalition formation algorithms which are appropriate for Distributed Problem Solving cases where agents cooperate in order to increase the overall outcome of the system and are not concerned with their personal payoffs as they are in MAS.

Sichman [16], instead, introduces a different point of view. He presents coalition formation using a dependence-based approach based on the notion of social dependence introduced by Castelfranchi [10]. Concerning coalition formation, this model introduces the notion of dependence situation, which allows an agent to evaluate the susceptibility of other agents to adopt his goals, since agents not automatically adopt the goals of each other. In this dependence-based model, coalitions can be modeled using dependence networks developed by Sichman and Conte [17] where an agent is described by a set of prioritized goals and a global dependence relation that explicates how an agent depends on other agents for fulfilling its goals. A definition of coalitions inspired by dependence networks is given by Boella et al. [5].

Once represented the internal structure of coalitions, one could study which kind of relations there are among potential coalitions at an higher level of detail disregarding which are the causes for incompatibility. The application of argumentation frameworks to coalition formation has been discussed by Amgoud [1] and by Bulling et al. [8]. Amgoud [1] provides a unified and general formal framework for generating the coalitions structures. The coalition formation problem is represented by Amgoud by means of four steps: constructing the coalitions, defining the defeasibility and preference relations between these coalitions, defining the acceptable coalitions and concluding. In contrast with our approach, a coalition is viewed as an abstract entity whose role is only determined by its relation to other coalitions and its structure is not known. Unlike Amgoud's work [1], we do not provide this paper with a proof theory since it is derivable from the argumentation theory's literature.

Bulling et al. [8], instead, combine the argumentation framework and ATL. They provide a formal extension of ATL in which the actual computation of the coalition is modeled in terms of argumentation semantics. A difference regarding the Amgoud's paper, is the intuition, in accordance with ATL, where larger coalitions are more powerful than smaller ones. Bulling's approach is a generalization of Dung's argumentation framework, extended with a preference relation. The basic notion is that of a coalitional framework containing a set of elements (agents or coalitions), an attack relation for modeling conflicts, and a preference relation between these elements to describe favorite agents/coalitions. The notion of coalitional framework is based on the notion of framework for generating coalition structures presented in [1].

6 Conclusions

We generalize Amgoud's argumentation-based coalition theory, covering a wider range of attacks, and a broader range of reasoning about coalitions.

To represent preferences among coalitions in terms of attacks of attack relations, we use Modgil's argumentation theory [13]. Instead of resolving conflicts among coalitions by preferences among coalitions, we can resolve conflicts by arguments that resolve them. Whereas preferences among coalitions seem a derived notion, we show that attacks of attacks among coalitions can be given a natural interpretation. Instead of a task-based coalition theory as in [1], a wider range of attacks can be defined using Sichman and Contes dependence network theory. The basic attack relations between coalitions are due to the fact that they are based on the same goals. Moreover, we go beyond Amgouds approach by defining a second order attack: the simplest kind of attack on an attack relation is to remove or add one of the dependencies of the attacker. In this way, we cover not only coalition formation but also the evolution of coalitions, whose stability can be attacked by other coalitions. To represent attacks on stability of coalitions and their evolution we use an extension of Sichman and Conte's dependence network theory with dynamic dependencies. A coalition can be attacked by removing a dependency from the coalition, or by introducing new dependencies which create new coalitions.

Concerning future work, we would like to model the argumentation theory in the more general framework introduced recently by Baroni and Giacomin [2]. In their approach, an argumentation framework is interpreted as a set of arguments of a reasoner at a moment in time. Consequently, it can be used to model a dialogue among agents as a sequence or tree of Dung's argumentation frameworks. Deleting a dependency or restraining from creating a dependency can be used to defend a coalition from a direct or indirect attack. Conversely, restraining from deleting a dependency and creating one can be used to avoid attacking a coalition which counter attacks other coalitions. Since dynamic dependencies are mapped on arguments which attack attack relations, this mechanism should be made more flexible to adapt to the context. Moreover, we would like to explain the dynamics of dependence networks using a normative system: in this way it would be possible to sanction agents who do not fulfill their role in a coalition. Further kind of attacks among coalitions may be defined, for example by introducing incompatibilities among dependence relations.

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