Social Viewpoints for Arguing about Coalitions

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Abstract. Frameworks for arguing about coalitions are based on non-monotonic logic and are therefore formal and abstract, whereas social theories about agent coalitions typically are based on conceptual modeling languages and therefore semi-formal and detailed. In this paper we bridge the gap between these two research areas such that social viewpoints can be used to argue about coalitions. We formally define three social viewpoints with abstraction and refinement relations among them, and we adapt an existing coalition argumentation theory to reason about the coalitions defined in the most abstract social viewpoint.

1 Introduction

Dung's argumentation theory [13] 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 [3]. 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 paper we develop social viewpoints for arguing about coalitions. Social viewpoints become more popular in multiagent systems, since the representation of multiagent systems as, for example, social networks, dependence networks, organizations, or normative systems, focuses on the interactions among the agents and facilitates the development of interaction mechanisms, agreement technologies or electronic institutions. Castelfranchi [12] offers a general and influential framework for many social-cognitive concepts and their relations, but due to the large number of concepts and their detailed descriptions, this framework is only semi-formal. Consequently, it can be used for conceptual modeling and conceptual analysis, but not for formal analysis or as the basis of formal ontologies or argumentation frameworks. In general, the problem with applying most existing social viewpoints is that they are often only semi-formal and relatively detailed, whereas the argumentation models of Dung and Amgoud are formal and abstract.

We therefor take our approach in [5] as a starting point, which not only defines social viewpoints on MAS, but also relates views of these viewpoints to each other using abstraction and refinement relations. For example, a detailed BDI model can be abstracted to a dependence network as used in early requirements analysis in Tropos [7].

In related work we show how to use these formal representations to define criteria for coalition formation [6], or measures for multiagent systems inspired by social network analysis, such as the social importance of an agent in a system [4]. However, the social viewpoints and the abstraction and refinement relations have been sketched only semi-formally in a two page paper, and moreover we consider only absolute goals and static dependence networks. In many agent programming languages, e.g. [14], and agent architectures, e.g. [9], goals can be derived from the agent's desires and beliefs, and in Castelfranchi's conceptual model, dependence relations can change over time.

In this paper we therefore address the following problems to increase the application of our social viewpoints on multiagent systems:

1. How to develop social viewpoints which can be used in arguing about coalitions? How to define a dynamic dependence network for agents with conditional goals? How to define coalitions for dynamic dependence networks? How to pass from the dynamic dependence networks view to the coalition view?
2. How to argue about coalitions using these social viewpoints? How to reason about attack relations among coalitions?

While the agent view represents the agents of the systems, their goals and the actions that they can perform to achieve these goals, the power view introduces conditional goals, such as those goals that can be added by an agent to another one. We define the dynamic dependence view as an abstraction of the power view, defined as a set of dependencies that can be added thanks to existence of conditional goals. Abstracting from the dynamic dependence view, we define the coalition view representing a coalition as a set of dynamic dependencies where each agent either creates a dependency or fulfills a goal.

In Amgoud's 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. We need to use different viewpoints to describe coalitions since dynamic dependencies have two different roles. From the internal point of view, an agent inside a coalition can be described by viewpoints and this means that we can describe the coalition describing the agents and their goals and capabilities to achieve the goals (agent view) or we can describe the agents inside the coalition as a set of agents and the power relations that link these agents to each other (power view) or, finally, we can describe a coalition as a set of dynamic dependencies where an agent is made dependent on another one for a particular goal by means of the addition of a new dependence by a third agent. From the external point of view, instead, the addition of a new dependence can be represented as an attack relation from a coalition to another one at coalitional view level. In this paper we describe and reason about these attacks using argumentation theory.

The layout of this paper is as follows. In Section 2 we introduce the social viewpoints, and relate them to each other by abstraction and refinement relations. In Section 3 we introduce a modification of Amgoud's argumentation theory to use the social viewpoints.

2 Social viewpoints

In classical planners, goals are unconditional. Therefore, many models of goal based reasoners including our earlier model [5] define the goals of a set of agents A by a function $goals : A \rightarrow 2^G$, where G is the complete set of goals. However, in many agent programming languages and architectures, goals are conditional and can be generated. We therefore extend the agent view with conditional goals.

Definition 1 (Agent view). *The Agent view is represented by the tuple $\langle A, G, X, \mathit{goals}, \mathit{skills}, R \rangle$, where:*

- *A, G, X are disjoint sets of agents, goals, and decision variables,*
- *$\mathit{goals} : A \times 2^X \rightarrow 2^G$ is a function associating with an agent its conditional goals,*
- *$\mathit{skills} : A \rightarrow 2^X$ is a function associating with agents their possible decisions, and*
- *$R : 2^X \rightarrow 2^G$ is a function associating with decisions the goals they achieve.*

Example 1.

- $A = \{a, b, c, d\}$, $G = \{g_1, g_2, g_3, g_4\}$, $X = \{x_1, x_2, x_3, x_4, x_5\}$.
- $\mathit{goals}(a, \{\}) = \{g_4\}$, $\mathit{goals}(b, \{x_5\}) = \{g_3\}$, $\mathit{goals}(c, \{\}) = \{g_1\}$, $\mathit{goals}(d, \{\}) = \{g_2\}$.
- $\mathit{skills}(a) = \{x_5\}$, $\mathit{skills}(b) = \{x_1\}$, $\mathit{skills}(c) = \{x_2\}$, $\mathit{skills}(d) = \{x_3, x_4\}$.
- $R(\{x_1\}) = \{g_1\}$, $R(\{x_2\}) = \{g_2\}$, $R(\{x_3\}) = \{g_3\}$, $R(\{x_4\}) = \{g_4\}$.

The power to trigger a goal is distinguished from the power to fulfill a goal.

Definition 2 (Power view). *The Power view is represented by the tuple $\langle A, G, X, \mathit{goals}, power\text{-}goals, \mathit{power} \rangle$, where A, G and X are sets of agents, goals, and decision variables (as before), $\mathit{goals} : A \times 2^X \rightarrow 2^G$ is a function (as before), and:*

- *$power\text{-}goals : 2^A \rightarrow 2^{(A \times G)}$ is a function associating with each set of agents the goals they can create for agents, and*
- *$\mathit{power} : 2^A \rightarrow 2^G$ is a function associating with agents the goals they can achieve.*

The power view can be defined as an abstraction of the agent view, in other words, the agent view is a refinement of the power view. A set of agents B has the power to see to it that agent a has the goal g, written as $(a, g) \in power\text{-}goals(B)$, if and only if there is a set of decisions of B such that g becomes a goal of a. A set of agents B has the power to see to goal g if and only if there is a set of decisions of B such that g is a consequence of it.

Definition 3. *$\langle A, G, \mathit{goals}, power\text{-}goals, power \rangle$ is an abstraction from $\langle A, G, X, \mathit{goals}, \mathit{skills}, R \rangle$ if and only if:*

- *$(a, g) \in power\text{-}goals(B)$ if and only if $\exists Y \subseteq \mathit{skills}(B)$ with $\mathit{skills}(B) = \cup\{skills(b) \mid b \in B\}$ such that $g \in \mathit{goals}(a, Y)$, and*
- *$g \in \mathit{power}(B)$ if and only if $\exists Y \subseteq \mathit{skills}(B)$ such that $g \in R(Y)$.*

Example 2 (Continued). Agent a has no power to fulfill goals, but he can create a goal of agent d.

– $power\text{-}goals(\{a\}) = (\{d\}, \{g_3\})$
– $power(\{b\}) = \{g_1, g_3\}, power(\{c\}) = \{g_2\}, power(\{d\}) = \{g_4\}$.

Due to the power to create goals, dependence relations are no longer static, but they can be created by agents. We therefore have to extend the dependence networks developed by Conte and Sichman [23] and used in multiagent systems methodologies like Tropos [7]. Dynamic dependence networks can be defined as follows [11].

Definition 4 (Dynamic dependence view). *A dynamic dependence network is a tuple $\langle A, G, dyndep\rangle$ where A and G are disjoint sets of agents and goals (as before), and:*

– *dyndep* $: A \times 2^A \times 2^A \to 2^{2^G}$ *is a function that relates with each triple of sets of agents all the sets of goals on which the first depends on the second, if the third creates the dependency.*

We write $dep(a, B, G)$ for dyndep$(a, B, \emptyset) = G$.

Abstracting power view to a dynamic dependence network can be done as follows. Note that in this abstraction, the creation of a dynamic dependency is based only on the power to create goals. In other models, creating a dependency can also be due to creation of new skills of agents.

Definition 5. *$\langle A, G, dyndep\rangle$ is an abstraction of $\langle A, G, power\text{-}goals, power\rangle$, if we have $H \in dyndep(a, B, C)$ if and only if*

1. *$\forall g \in H : (a, g) \in power\text{-}goals(C)$, and*
2. *$H \subseteq power(B)$*

Example 3 (Continued). Agent b depends on agent d for goal g_3, if agent a creates this dependency: $dep(a, d, g_4), dep(d, c, g_2), dep(c, b, g_1), dyndep(b, \{d\}, \{a\}) = \{\{g_3\}\}$.

Combining these two abstractions, abstracting agent view to a dynamic dependence network can be done as follows.

Proposition 1. *$\langle A, G, dyndep\rangle$ is an abstraction of $\langle A, G, X, goals, skills, R\rangle$, if we have $H \in dyndep(a, B, C)$ if and only if*

1. *$\exists Y \subseteq skills(C)$ such that $H \subseteq goals(a, Y)$, and*
2. *$\exists Y \subseteq skills(B)$ such that $H \subseteq R(Y)$*

Finally, we define reciprocity based coalitions for dynamic dependence networks. We represent the coalition not only by a set of agents, as in game theory, but as a set of agents together with a partial dynamic dependence relation. Intuitively, the dynamic dependence relation represents the "contract" of the coalition: if $H \in dyndep(a, B, D)$, then the set of agents D is committed to create the dependency, and the set of agents B is committed to see to the goals H of agent a. The rationality constraints on such reciprocity based coalitions are that each agent contributes something, and receives something back.

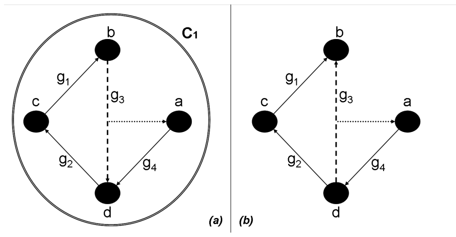

Fig. 1. (a) - The coalition C_1 of Example 4, (b) - Example of a set of agents that is not a coalition.

Definition 6 (Reciprocity based Coalition). *Given a dynamic dependence network $\langle A, G, \mathit{dyndep} \rangle$, a reciprocity based coalition is represented by coalition $C \subseteq A$ together with dynamic dependencies dyndep$'$ $\subseteq$ dyndep, such that*

- *if $\exists b, B, D, H$ with $H \in$ dyndep$'(a, B, D)$ then $a \in C$, $B \subseteq C$ and $D \subseteq C$ (the domain of dyndep$'$ contains only agents in coalition C), and*
- *for each agent $a \in C$ we have $\exists b, B, D, H$ with $H \in$ dyndep$'(b, B, D)$ such that $a \in B \cup D$ (agent a contributes something, either creating a dependency or fulfilling a goal), and*
- *for each agent $a \in C$ $\exists B, D, H$ with $H \in$ dyndep(a, B, D) (agent a receives something from the coalition).*

The following example illustrates that dependencies will be created by agents only if the new dependencies work out in their advantage.

Example 4 (Continued). Each agent of $C_1 = \{a, b, c, d\}$ creates a dependency or fulfills a goal. In Figure 1, conditional goals are represented with dashed arrows while the creation of new dependencies is represented with dotted ones. The arrows go from the agent having the goal put as label of the arrow to the agent that has the power to fullfil this goal. Figure 1 - (a) represents a set of agents composing a coalition in accordance with Definition 6 while Figure 1 - (b) represents the same set of agents not forming a coalition. The difference among the two figures is in the direction of the arrow joining agents b and d.

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 7. *Coalition $\langle C_1, \mathit{dyndep}_1 \rangle$ attacks coalition $\langle C_2, \mathit{dyndep}_2 \rangle$ if and only if there exists $a_1, a_2, B_1, B_2, D_1, D_2, G_1, G_2$, such that $G_1 \in \mathit{dyndep}_1(a_1, B_1, D_1)$, $G_2 \in \mathit{dyndep}_2(a_2, B_2, G_2)$ and $G_1 \cap G_2 \neq \emptyset$.*

The simplest kind of attack on an attack relation is to remove or add one of the dependencies of the attacker.

Definition 8. *Coalition $\langle C, \mathit{dyndep} \rangle$ attacks the attack from coalition $\langle C_1, \mathit{dyndep}_1 \rangle$ on coalition $\langle C_2, \mathit{dyndep}_2 \rangle$ 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 $G \in \mathit{dyndep}(a, B, D)$.*

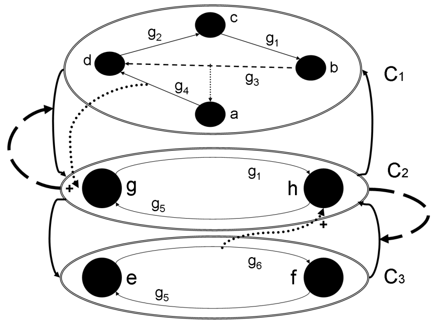

Fig. 2. Dynamic dependence view and coalition view.

Example 5. Assume we have eight agents, a, b, c, d, e, f, g, h and the dependencies of Example 3: $dep(a, \{d\}, \{\{g_4\}\})$, $dep(d, \{c\}, \{\{g_2\}\})$, $dep(c, \{b\}, \{\{g_1\}\})$, *dyndep*$(b, \{d\}, \{a\}, \{\{g_3\}\})$,

plus the following ones:

$dep(e, \{f\}, \{\{g_6\}\})$, $dep(f, \{e\}, \{\{g_5\}\})$, $dep(g, \{h\}, \{\{g_1\}\})$, $dep(h, \{g\}, \{\{g_5\}\})$, $dep(c, \{h\}, \{\{g_1\}\})$, $dep(g, \{b\}, \{\{g_1\}\})$, $dep(h, \{e\}, \{\{g_5\}\})$, $dep(f, \{g\}, \{\{g_5\}\})$.

The possible coalitions are C_1, C_2 and C_3 where:

$C_1 = \{dep(a, \{d\}, \{\{g_4\}\}), dep(d, \{c\}, \{\{g_2\}\}), dep(c, \{b\}, \{\{g_1\}\}),$
dyndep$(b, \{d\}, \{a\}, \{\{g_3\}\})\}$,
$C_2 = \{dep(e, \{f\}, \{\{g_6\}\}), dep(f, \{e\}, \{\{g_5\}\})\}$,
$C_3 = \{dep(g, \{h\}, \{\{g_1\}\}), dep(h, \{g\}, \{\{g_5\}\})\}$.

Note that some of the dependencies remain outside all coalitions (e.g., $dep(c, \{h\}, \{\{g_1\}\})$, $dep(g, \{b\}, \{\{g_1\}\})$, $dep(h, \{e\}, \{\{g_5\}\})$, $dep(f, \{g\}, \{\{g_5\}\})$, not reported in Figure 2). 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_5 respectively. Note that these attacks are reciprocal.

The coalitions attack each other since agents b and h on which respectively c and g 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_3 achieved by d and g_5 by g.

We depict this situation in Figure 2: 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 (dashed bold arrows are explained in the subsequent example).

3 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, identifying potential conflicts among coalitions, and determine the acceptable coalitions. Dung's framework [13] 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 9 (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 10 (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 with respect to 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 fix point of the function $F(\mathcal{S}) = \{a | a \text{ is defended by } \mathcal{S}\}$.*

The following example illustrates argumentation theory.

Example 6. Let $AF = \langle \mathcal{A}, \# \rangle$ be an argumentation framework, where the set (of arguments or coalitions) is $\mathcal{A} = \{C_1, C_2, C_3\}$, 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 11 (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 to form 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 7 (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 [17] for details).

Modgil [18] 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 [8], or Prakken and Sartor's theory [20]). Whereas Modgil presents his theory as an extension of Dung, such that he has to define new semantics for it, in this paper we show how to define 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 12. *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 intuition behind second order argumentation is the following. Attack relations are substituted by arguments $\mathcal{A}_\#$ representing attacks, so that these can be attacked in turn by further arguments. However, the arguments $\mathcal{A}_\#$ differently from the original attack relations have an existence which is more independent from the arguments which they stem from. E.g., the attack of C_1 to C_2 is substituted by an argument $C_{1,2}$. If C_1 is attacked, then its attack relations should not be considered anymore. Instead, if

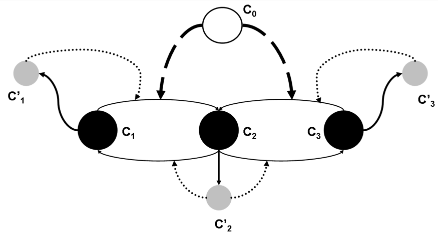

Fig. 3. Graphical representation of Example 7.

the attack relation is substituted by an argument in $\mathcal{A}_{\#}$, this argument continues to attack other arguments even when the argument it stems from is attacked: e.g., if C_1 is attacked, $C_{1,2}$ continues to attack C_2. Thus, to avoid this problem, for each argument in $\mathcal{A}_{\mathcal{C}}$ a new argument C_1' in $\overline{\mathcal{A}}$ is created. This argument is created such that it attacks all the arguments of $\mathcal{A}_{\#}$ representing the attack relations of C_1 against other arguments. Besides C_1, C_1' is added, attacking $C_{1,2}$. C_1' however should not attack $C_{1,2}$ at any moment, but only when C_1 is attacked: for this reason, an attack relation between C_1 and C_1' is added, so that C_1' attacks the attack relations stemming from C_1 only when C_1 is attacked.

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 visualized in Figure 3.

Example 8 (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

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

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

is a binary relation on the set of arguments. For the nested attack relations, we also write $C_0 \#(C_1 \# C_2)$ and $C_0 \#(C_3 \# C_2)$. The acceptable argument is C_2, together with C_0, C_1', C_3', $C_{2,1}$, $C_{2,3}$, for any kind of semantics. 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 of $\mathcal{A}_{\mathcal{C}}$ to an element of $\mathcal{A}_{\#}$ as an attack on an attack relation, see [18] for examples of such a visualization. This example shows that arguments that attack attack relations do that directly.

Example 9 (Continues Example 5 - See Figure 2). Assume instead that $dep(a, \{d\}, \{\{g_4\}\})$ is not present since the beginning and it happens that agent g of C_2

has the power to create it: i.e., it is substituted by *dyndep*$(a, \{d\}, \{g\}, \{\{g_4\}\})$. Thus, C_2 attacks the attack relation between C_1 and C_2, $C_2\#(C_1\#C_2)$ by Definition 8: if coalition C_1 remains potential, since nothing guarantees that g will create goal g_4 of agent a without receiving anything in exchange, then it cannot attack any other coalition. Moreover, assume that $dep(e, \{f\}, \{\{g_6\}\})$ is not present since the beginning and it happens that agent h of C_2 has the power to create it and, thus, the dependency is substituted by *dyndep*$(e, \{f\}, \{h\}, \{\{g_6\}\})$. Thus, C_2 attacks the attack relation between C_2 and C_3, $C_2\#(C_3\#C_2)$ by Definition 8. The only extension is $\{C_2\}$.

We illustrate this situation in Figure 2: the attack relation on attack relations is depicted as bold dashed arrows pointing on other arrows.

Note that if in Example 8 argument C_0 is identified with C_2 (and C_0' with C_2'), a second order argumentation framework for the current example is obtained.

Finally, we show how to relate the argumentation frameworks. We illustrate how second order argumentation frameworks can be seen as an extension of Dung's argumentation framework.

Proposition 2. *An argumentation framework $\langle \mathcal{A}, \#_1 \rangle$ represents a second order argumentation framework $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, not, \mathcal{A}_\#, \#_2 \rangle$ when*

1. *$\mathcal{A}_\mathcal{C} = \mathcal{A}$, and*
2. *there is an element $a \in \mathcal{A}_\#$ for each pair of arguments $b, c \in \mathcal{A}$ such that $b\#_1c$, with $not(b)\#_2a$ and $a\#_2c$.*
3. *there are no arguments $a \in \mathcal{A}$ and $b \in \mathcal{A}_\#$ such that $a\#_2b$.*

If $\langle \mathcal{A}, \#_1 \rangle$ represents $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, not, \mathcal{A}_\#, \#_2 \rangle$, then the extensions of $\langle \mathcal{A}, \#_1 \rangle$ correspond to the extensions of $\langle \mathcal{A}_\mathcal{C}, \overline{\mathcal{A}}, not, \mathcal{A}_\#, \#_2 \rangle$ intersected with $\mathcal{A}$.

4 Related work

Sichman [22] presents coalition formation using a dependence-based approach based on the notion of social dependence introduced by Castelfranchi [12].

The application of argumentation frameworks to coalition formation has been discussed by Amgoud [1] and by Bulling et al. [10]. In Amgoud's paper, a coalition may have a cost and a profit, so the agents are able to evaluate each coalition. Unlike Amgoud's work [1], we do not provide the present paper with a proof theory since it is derivable from the argumentation theory's literature. Moreover, unlike Amgoud's paper [1], we do not define any kind of dialogue model among the agents involved in coalitions.

Another formal approach to reason about coalitions is coalition logic [19] and Alternating Temporal Logic (ATL), describing how a group of agents can achieve a set of goals, without considering the internal structure of the group of agents [2, 15, 16]. See [21] for a further discussion. Bulling et al. [10], instead, combine the argumentation framework and ATL with the aim to develop a logic through which reasoning at the same time about abilities of coalitions of agents and about coalitions formation. They provide a formal extension of ATL in which the actual computation of the coalition is modeled in terms of argumentation semantics. The key construct in ATL expresses that a coalition of agents can enforce a given formula. [10] presents a first approach towards extending ATL for modeling coalitions through argumentation. A difference regarding Amgoud's paper, is the intuition, in accordance with ATL, where larger coalitions are more powerful than smaller ones. In Bulling's paper, the actual computation of the coalition is modeled in terms of a given argumentation semantics in the context of coalition formation. The paper's approach is a generalization of the framework of Dung for argumentation, extended with a preference relation. The basic notion is that of a coalitional framework containing a set of elements (usually represented as agents or coalitions), an attack relation (for modeling conflicts among these elements), 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 Amgoud's paper.

5 Summary and further research

Frameworks for arguing about coalitions are based on non-monotonic logic and are therefore formal and abstract, whereas social theories about agent coalitions typically are based on conceptual modeling languages and therefore semi-formal and detailed. In this paper we bridge the gap between these two research areas such that social viewpoints can be used to argue about coalitions.

For arguing about coalitions, we define three social viewpoints with abstraction and refinement relations between them, and adapt existing coalition argumentation theory to reason about the coalitions defined in the most abstract viewpoint, the coalition view representing a coalition as a set of dynamic dependencies between agents. We define dynamic dependence networks by making the dependence relation conditional to the agents that have the power to create it, distinguishing two kinds of power, not only to fulfill goals as in static networks but also to create dependencies. Coalitions are defined by a kind of "contracts" in which each agent both contributes to the coalition, and profits from it.

We need to use different viewpoints to argue about coalitions since dynamic dependencies underline two different aspects of coalitions. From an internal point of view, the agents inside a coalition can be described by viewpoints and thus we represent the coalition, depending on the adopted abstraction, as a set of agents with their goals and skills or as a set of agents related due the notion of power or, finally, as a set of dynamic dependencies. From an external point of view, instead, the addition of a new dependence can be represented as an attack relation from a coalition to another one at coalitional view level.

Subjects of further research are the use of our new theory for coalition formation. For example, when two agents can make the other depend on itself and thus create a potential coalition, when will they do so? Do these new ways to create coalitions make the system more efficient, or more convivial? Moreover, new measures have to be defined for the dynamic dependence networks, where we may find inspiration in dynamic social network analysis.

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