Approximating agreements in argumentation dialogues

Juan Carlos Nieves

Department of Computing Science
Umeå University
SE-901 87, Umeå, Sweden
jcnieves@cs.umu.se

Abstract. In many real applications, to reach an agreement between the participants of a dialogue, which can be for instance a negotiation, is not easy. Indeed, there are application domains such as the medical domain where to have a consensus among medical professionals is not feasible and might even be regarded as counterproductive. In this paper, we introduce an approach for expressing goals of a dialogue considering ordered disjunction rules. By applying argumentation semantics and degrees of satisfaction of goals, we introduce the so-called *dialogue agreement degree*. Moreover, by considering sets of dialogue agreement degrees, we define a *lattice of agreement degrees*. We argue that a lattice of agreement degrees suggests different approximations between the current state of a dialogue and its aimed goals. Indeed, a lattice of agreement degrees can show evidence about whether or not it is acceptable to dismiss goals in order to maximize agreements regarding other goals.

1 Introduction

Formal argumentation has been revealed as a powerful conceptual tool for exploring the theoretical foundations of reasoning and interaction in autonomous systems and multiagent systems [1, 27]. Different dialogue frameworks have been proposed by considering formal argumentation. Indeed, by considering formal argumentation, the so-called *Agreement Technologies* have been introduced in order to deal with the new requirement of interaction between autonomous systems and multiagent systems [22].

Formal argumentation dialogues have been intensively explored in the last years [5, 10, 17, 23, 25] by the community of formal argumentation theory. Most current approaches have been suggested as general frameworks for setting up different kinds of dialogues. Roughly speaking, we can understand a dialogue as a finite sequence of utterances: $[u_1, \dots, u_n]$. Depending on the followed dialogue approach [5, 10, 17, 23, 25], the sequence of utterances follows a protocol of valid moves performed by the participants of a dialogue. Moreover, these approaches are mainly oriented to a particular topic/goal that is usually denoted by a logical formula. Hence, these dialogue approaches are only concerned about validating a particular goal, *i.e.* a given logical formula. Therefore, we can say that these approaches were defined for validating only static goals. This means that there is an agreement at the end of a dialogue upon whether the given goal holds true in the outcomes of the dialogue; otherwise, there is no agreement at the end of the dialogue.

In many real applications, to reach an agreement between the participants of a dialogue is not easy [28, 29]. Indeed, there are application domains such as the medical domain where to have a consensus among medical professionals is not feasible and might even be regarded as counterproductive [16]. In order to illustrate this situation, let us consider a hypothetical scenario from the medical domain in the field of human organ transplanting (the scenario is reported from [21, 29]):

Scenario 1
Let us assume that we have two transplant coordinators, one which is against the viability of the organ (TCA_D) and one which is in favour of the viability of the organ (TCA_R). TCA_D argues that the organ is not viable since the donor had endocarditis due to Streptococcus viridans*, then the recipient could be infected by the same microorganism. In contrast, TCA_R argues that the organ is viable because the organ presents correct function and correct structure and the infection could be prevented with post-treatment with penicillin, even if the recipient is allergic to penicillin, there is the option of post-treatment with teicoplanin.*

In the settings of the aforementioned scenario, one can argue that the main goal is to keep alive the recipient; however, finding safe-organs is an issue for a discussion since there are not unique criteria for selecting safe-organs [29].

We argue that managing *dynamic degrees of agreement* during a dialogue can help with the management of disagreements during a dialogue. These dynamic degrees of agreement can be defined by considering preferences between the goals of a dialogue. Currently, dialogue systems manage mainly static goals that usually are introduced as the topic of a dialogue [5, 10, 17, 23, 25]. Hence, these approaches do not allow the specification of preferences between goals of a given dialogue.

Depending on the application domain, we can argue that there are *static* and *dynamic goals* during a dialogue. A static goal is a goal that cannot be skipped during a dialogue and a dynamic goal is a goal that can change during a dialogue, *e.g.,* a goal that can be skipped during a dialogue. These assumptions suggest a need for defining methods that can manage *degrees of agreement* on an ongoing dialogue *w.r.t.* each intended goal of a dialogue. In these settings, some research questions arise:

Q1: Given a dialogue, is there *a partial degree of agreement* between the participants of a dialogue?

Q2: Given a dialogue, can we *dismiss goals* in order to maximize agreements *w.r.t.* other goals?

In this paper, we address the aforementioned questions. To this end, we follow Dung style [8] for selecting arguments from a set of arguments with disagreements. We consider structured arguments, which are constructed from extended logic programs. Moreover, logic programs with ordered disjunctions [7] are considered for expressing preferences between the goals of a dialogue. For instance, a possible representation of the dialogue of Scenario 1 is:

$$D = \langle Participants, Goals, Utterances \rangle$$

in which $Participants = \{TCA_D, TCA_R\}$, $Goals = \{keep\_alive\_recipient \leftarrow \top; healthy\_donor \leftarrow \top; safe\_organs \times managed\_disease \leftarrow \top\}$. Let us observe that the rule $safe\_organs \times managed\_disease \leftarrow \top$ suggests that the dialogue looks for safe organs for being transplanted; however, if not possible, the doctors will argue for organs that can be treated post-transplanting. $Utterances = [u_1, \ldots, u_n]$ in which each $u_i (1 \leq i \leq n)$ is an utterance from either TCA_D, TCA_R.

By considering dialogues, argumentation semantics and subsets of goals, we introduce the so-called *dialogue agreement degree*. This dialogue agreement degree considers different sets of goals such that each goal has a satisfaction agreement degree in terms of satisfaction degrees of ordered-disjunction rules. Considering sets of dialogue agreement degrees, we define a *lattice of agreement degrees*. We consider that both dialogue agreement degrees and lattices of agreement degrees are novel ideas that have not been explored in the settings of formal argumentation dialogue before. Indeed, to the best of our knowledge, we are introducing the first argumentation dialogue system that considers degrees of agreements based on preferences among the goals of a dialogue. We argue that a lattice of agreement degrees suggests different approximations between the current state of a dialogue and its aimed goals. Indeed, a lattice of agreement degrees can show evidence about whether or not it is acceptable to dismiss goals in order to maximize agreements regarding other goals.

The rest of the paper is split as follows: In section 2, basic concepts of logic programming are introduced. Moreover, an approach for building arguments from logic programs is presented. In Section 3, we introduce our approach for defining dialogues considering preferences between the goals of a dialogue. In Section 4, the concepts of dialogue agreement degree and lattice of agreement degrees are introduced. In the last section, our conclusions and future work are outlined.

2 Background

In this section, a basic background in logic programming is presented. Mainly, extended logic programs and logic programs with ordered disjunctions are presented. We are assuming that the reader is familiar with basic concepts of Answer Set Programming (ASP). A good introduction to ASP is presented in [2]. In terms of argumentation, we present an approach for building arguments from an extended logic program.

2.1 Extended logic programs

Let us introduce the language of a propositional logic, which consists of propositional symbols: $p_0, p_1, \ldots$; connectives: $\leftarrow, \neg, \ not, \top$; and auxiliary symbols: (,), in which $\wedge, \leftarrow$ are 2-place connectives, $\neg, \ not$ are 1-place connectives and $\top$ is a 0-place connective. The propositional symbols, the 0-place connective $\top$ and the propositional symbols of the form $\neg p_i \ (i \geq 0)$ stand for the indecomposable propositions, which we call *atoms*, or *atomic propositions*. The atoms of the form $\neg a$ are also called *extended atoms* in the literature. In order to simplify the presentation, we call them atoms as well. The negation symbol $\neg$ is regarded as the so-called *strong negation* in the Answer Set Programming literature [2], and the negation symbol *not* as *negation as failure*.

A literal is an atom, *a* (called a positive literal), or the negation of an atom *not a* (called a negative literal). A (propositional) extended normal clause, *C*, is denoted:

$$a \leftarrow b_1, \ldots, b_j, \textit{not}\ b_{j+1}, \ldots, \textit{not}\ b_{j+n} \tag{1}$$

in which $j+n \geq 0$, *a* is an atom, and each b_i ($1 \leq i \leq j+n$) is an atom. We use the term *rule* as a synonym of *clause* indistinctly. When $j+n=0$, the clause is an abbreviation of $a \leftarrow \top$ (a *fact*), such that $\top$ is the propositional atom that always evaluates to true. In a slight abuse of notation, we sometimes write a clause $C = a \leftarrow \mathcal{B}^+ \wedge \textit{not}\ \mathcal{B}^-$, in which $\mathcal{B}^+ := \{b_1, \ldots, b_j\}$ and $\mathcal{B}^- := \{b_{j+1}, \ldots, b_{j+n}\}$. We denote by $head(C)$ the head atom a of clause C.

An extended logic program *P* is a finite set of extended normal clauses. When $n = 0$, the clause is called an *extended definite clause*. By $\mathcal{L}_P$, we denote the set of atoms that appear in *P*.

Let A be a set of atoms and P be an extended (definite or normal) logic program. $r = a_0 \leftarrow \mathcal{B}^+,\ not\ \mathcal{B}^- \in P$ is applicable in A if $\mathcal{B}^+ \subseteq A$. $App(A, P)$ denotes the subset of rules of P which are applicable in A. $C = a_0 \leftarrow \mathcal{B}^+,\ not\ \mathcal{B}^- \in P$ is closed in A if C is applicable in A and $head(C) \in A$.

Since we are using a comma for denoting the $\wedge$ binary connective in the body of the rules, we will use semicolon for separating elements in sets of rules.

2.2 Logic Programs with Ordered Disjunction

The formalism of *Logic Programs with Ordered Disjunction* (LPODs) was created with the idea of expressing explicit context-dependent preference rules, which select the most plausible atoms to be used in a reasoning process and to order answer sets [7].

Technically speaking, LPODs are based on extended logic programs augmented by an ordered disjunction connector $\times$ which allows for the expression of qualitative preferences in the head of rules [7]. An LPOD is a finite collection of rules of the form:

$$r = c_1 \times \ldots \times c_k \leftarrow b_1, \ldots, b_m,\ not\ b_{m+1}, \ldots,\ not\ b_{m+n} \tag{2}$$

where c_i's ($1 \leq i \leq k$) and b_j's ($1 \leq j \leq m+n$) are atoms. The intuitive reading behind a rule like (2) is that if the body of r is satisfied, then some c_i must be true in an answer set, if possible c_1, if c_1 is not possible then c_2, and so on. As previously stated, from a nonmonotonic reasoning point, each of the c_i's can represent alternative ranked options for selecting the most plausible (default) rules of an LPOD.

The LPODs semantics was defined in terms of split programs. Split programs are a way to represent every option of ordered disjunction rules with the property that the set of all answer sets of an LPOD corresponds exactly to the answer sets of the split programs. An alternative and more straightforward characterization of the LPODs semantics was also given in terms of a program reduction defined as follows:

Definition 1 ($\times$-reduction). [7] *Let $r = c_1 \times \ldots \times c_k \leftarrow b_1, \ldots, b_m,\ not\ b_{m+1}, \ldots,\ not\ b_{m+n}$ be an ordered disjunction rule and M be a set of atoms. The $\times$-reduction of a rule r is defined as:*

$$r_\times^M = \{c_i \leftarrow b_1, \ldots, b_m | c_i \in M \wedge M \cap (\{c_1, \ldots, c_{i-1}\} \cup \{b_{m+1}, \ldots, b_{m+n}\}) = \emptyset\}$$

The $\times$-reduction is generalized to an LPOD P in the following way:

$$P_{\times}^{M} = \bigcup_{r \in P} r_{\times}^{M}$$

Based on the $\times$-reduction, the LPODs semantics is defined by the following definition:

Definition 2 (SEM_{LPOD}). [7] *Let P be an LPOD and M be a set of atoms. Then, M is an answer set of P if and only if M is closed under all the rules in P and M is the minimal model of $P_{\times}^{M}$. We denote by $SEM_{LPOD}(P)$ the set of answer sets of P.*

One interesting characteristic of LPODs is that they provide a means to represent preferences among answer sets by considering the satisfaction degree of an answer set *w.r.t.* a rule [7].

Definition 3 (Rule Satisfaction Degree). [7] *Let M be an answer set of an LPOD P. The satisfaction degree M w.r.t. a rule $r = c_1 \times \ldots \times c_k \leftarrow b_1, \ldots, b_m, not\ b_{m+1} \ldots,\ not\ b_{m+n}$, denoted by $deg_M(r)$, is*

- *1 if $b_j \notin M$ for some j ($1 \leq j \leq m$), or $b_i \in M$ for some i ($m+1 \leq i \leq m+n$),*
- *j ($1 \leq j \leq k$) if all $b_l \in M$ ($1 \leq l \leq m$), $b_i \notin M$ ($m+1 \leq i \leq m+n$), and $j = min\{r \mid c_r \in M, 1 \leq r \leq k\}$.*

The degrees can be viewed as penalties, as a higher degree expresses a lesser degree of satisfaction. Therefore, if the body of a rule is not satisfied, then there is no reason to be dissatisfied and the best possible degree 1 is obtained [7]. A preference order on the answer sets of an LPOD can be obtained by means of the following preference relation.

Definition 4. [7] *Let P be an LPOD, and M_1 and M_2 be two answers of P. M_1 is preferred to M_2 (denoted by $M_1 >_p M_2$) if and only if $\exists\, r \in P$ such that $deg_{M_1}(r) < deg_{M_2}(r)$ and $\nexists r' \in P$ such that $deg_{M_2}(r') < deg_{M_1}(r')$.*

2.3 Constructing arguments from extended logic programs

In this section, an approach for building arguments from a logic program is presented [14]. In the construction of these arguments, the well-founded semantics (WFS) is used [12]. By lack of space, the definition of WFS is not presented, see [12] for the formal definition of WFS. We just mention that WFS is a three-valued semantics that infers a unique partial interpretation of a given logic program. Hence, given a logic program P, $WFS(P) = \langle T, F \rangle$ such that the atoms that appear in T are considered true, the atoms that appear in F are considered false, and the atoms that are neither in T nor in F are considered undefined.

The following definition introduces an approach for constructing arguments from an extended normal logic program.

Definition 5. *[14] Given an extended logic program P and $S \subseteq P$, $Arg_P = \langle S,\ g \rangle$ is an **argument** under WFS, if the following conditions hold:*

1. $WFS(S) = \langle T, F \rangle$ *such that* $g \in T$.
2. S *is minimal w.r.t. the set inclusion satisfying 1.*
3. $\nexists\, g \in \mathcal{L}_P$ *such that* $\{g, \neg g\} \subseteq T$ *and* $WFS(S) = \langle T, F \rangle$.

By $\mathcal{A}rg(P)$ *we denote the set of all of the arguments built from* P.

Given an argument $A = \langle S,\ g \rangle$, S is usually called the *support* of A, g the *conclusion* of A, $Cl(A) = g$ and $Sp(A) = S$. Given a set of arguments Ag, Δ_{Ag} denotes $\{Cl(A) | A \in Ag\}$.

Let us mention that there are other approaches for constructing arguments from a logic program [6, 8, 11, 26]. We are considering an approach that has shown to be a conservative approach since it does not allow problematic arguments such as the self-attacked arguments. For instance, the construction of arguments suggested by Definition 5 will not construct arguments such as the argument $arg_1 = \langle \{a \leftarrow \ \ not\ a\},\ a \rangle$; nevertheless, arg_1 can be constructed by other approaches for constructing arguments [26]. arg_1 can be understood as a self-attacked argument.

Formally attacks between arguments are binary relations between arguments; moreover, these binary relations express disagreements between arguments. Intuitively, an attack between two arguments emerges whenever there is a *disagreement* between these arguments. Attacks between arguments can be identified by the following definition:

Definition 6 (Attack relationship between arguments). *[14] Let* $A = \langle S_A, g_A \rangle$, $B = \langle S_B, g_B \rangle$ *be two arguments such that* $WFS(S_A) = \langle T_A, F_A \rangle$ *and* $WFS(S_B) = \langle T_B, F_B \rangle$. *We say that* A *attacks* B*, denoted by* (A, B)*, if one of the following conditions holds:*

1. $a \in T_A$ *and* $\neg a \in T_B$.
2. $a \in T_A$ *and* $a \in F_B$.

$At(\mathcal{A}rg)$ *denotes the set of attack relationships between the arguments belonging to the set of arguments* $\mathcal{A}rg$.

It has been shown that this definition of attack between arguments generalizes other definitions of attacks between arguments based on logic programs [19]. Like Dung's style, we define the resulting argumentation framework from a logic program as follows:

Definition 7. *Let* P *be an extended logic program. The resulting argumentation framework w.r.t.* P *is the tuple:* $AF_P = \langle \mathcal{A}rg_P, At(\mathcal{A}rg_P) \rangle$.

Following Dung's style [8], argumentation semantics are used for selecting arguments from the resulting argumentation frameworks from logic programs. An argumentation semantics σ is a function that assigns to an argumentation framework AF_P *w.r.t.* P a set of sets of arguments denoted by $\mathcal{E}_\sigma(AF_P)$. Each set of $\mathcal{E}_\sigma(AF)$ is called σ-extension. Let us observe that σ can be instantiated with any of the argumentation semantics that has been defined in terms of abstract arguments [3].

3 Dialogues and relations between them

In this section, we introduce an approach for defining dialogues between agents. These dialogues will have the property of expressing preferences between their goals by using ordered disjunction programs. As was argued in Section 1, the main aim of this paper is to study the outcomes (*i.e. agreements*) of an ongoing dialogue by considering the current *active knowledge* of a dialogue and the set of goals of this dialogue. Hence, we put less attention to the protocols that lead the moves of the participants of a dialogue. The protocols that lead the moves of the participants of a dialogue mainly depend on the kind of dialogue that a dialogue-based system aims to implement [23, 24].

Let us start by introducing the basic piece of a dialogue that is called *utterance*.

Definition 8. *An utterance of a given agent a is a tuple of the form $\langle a, A\rangle$ in which A is an argument according to Definition 5.*

For the sake of simplicity of presentation, the following notation is introduced. Given an utterance $u = \langle a, A\rangle$, $u^* = A$. Given a set of utterances $\mathcal{U}$, $\mathcal{U}^* = \{u^* | \, u \in \mathcal{U}\}$.

An utterance is a suggested argument by an agent a in an ongoing dialogue. Considering utterances, dialogues between a set of agents are defined as follows:

Definition 9. *A dialogue is a tuple of the form $\langle \mathcal{I}, G, D_r^t\rangle$ in which G is a logic program with ordered disjunction and D_r^t is a finite sequence of utterances $[u_r, \ldots, u_t]$ involving a set of participating agents $\mathcal{I}$, where $r, t \in \mathbb{N}$ and $r \leq t$, such that:*

1. *$Sender(u_s) \in \mathcal{I}$ $(r \leq s \leq t)$,*

in which $Sender : \mathcal{U} \longmapsto \mathcal{I}$ is a function such that $Sender(\langle Agent, Argument\rangle) = Agent$ and $\mathcal{U}$ denotes the set of all the possible utterances of the participating agents $\mathcal{I}$.

Given a dialogue, $D = \langle \mathcal{I}, G, [u_r, \ldots, u_t]\rangle, \mathcal{U}_D = \{u_i | r \leq i \leq t, [u_r, \ldots, u_t]\}$.

Let us illustrate Definition 9 considering the following simple abstract example.

Example 1. Let $D_1 = \langle \mathcal{I}, G, D_1^2\rangle$ such that $\mathcal{I} = \{1, 2\}$, $G = \{a \times c \leftarrow \top; b \leftarrow \top\}$, $D_1^2 = [u_1, u_2]$, $u_1 = \langle 1, \langle \{a \leftarrow \;\; not \; b\}, a\rangle\rangle$ and $u_2 = \langle 2, \langle \{c \leftarrow \top; b \leftarrow c\}, b\rangle\rangle$. Hence, D_1 is a dialogue between two agents. D_1 has as goals the topics expressed in terms of two ordered disjunction rules: $a \times c \leftarrow \top$ and $b \leftarrow \top$. D_1 has two utterances: u_1, u_2. We can see that $\mathcal{U}_{D_1} = \{u_1, u_2\}$.

Let us observe that given a dialogue D, we can get an *active knowledge base*, *i.e.* an extended logic program, *w.r.t.* D. Moreover, we can get the set of conclusions of the utterances *w.r.t.* D.

Definition 10. *Let $D = \langle \mathcal{I}, G, U_r^t\rangle$ be a dialogue.*

- *The active knowledge base w.r.t. D, denoted by $\mathcal{A}_D$, is $\mathcal{A}_D = \bigcup_{u \in \mathcal{U}_D} Sp(u^*)$.*
- *The argument-conclusions of the utterances w.r.t. D, denoted by $\mathcal{C}_D$, is: $\mathcal{C}_D = \bigcup_{u \in \mathcal{U}_D} Cl(u^*)$.*

The active knowledge of a dialogue is the information that the participating agents of a dialogue have shared by means of arguments.

Example 2. Considering the dialogue D_1 introduced by Example 1, we can see that:
$\mathcal{A}_{D_1} = \{a \leftarrow \ not\ b; c \leftarrow \top; b \leftarrow c\}$
$\mathcal{C}_{D_1} = \{a, b\}$

Considering the information of a dialogue in terms of utterances, active knowledge and arguments, we define four kinds of sub-dialogues.

Definition 11. *Let $D = \langle \mathcal{I}, G, U_r^t \rangle$, $D' = \langle \mathcal{I}', G', U_i^j \rangle$ be two dialogues.*

- *D' is a sub-dialogue w.r.t. utterances of D ($D' \sqsubseteq_u D$) iff $\mathcal{U}_{D'}^* \subseteq \mathcal{U}_D^*$.*
- *D' is a sub-dialogue w.r.t. active-knowledge of D ($D' \sqsubseteq_{ak} D$) iff $\mathcal{A}_{D'} \subseteq \mathcal{A}_D$.*
- *D' is a sub-dialogue w.r.t. argument-conclusions of D ($D' \sqsubseteq_{ac} D$) iff $\mathcal{C}_{D'} \subseteq \mathcal{C}_D$.*
- *D' is a sub-dialogue w.r.t. goals of D ($D' \sqsubseteq_g D$) iff $G' \subseteq G$.*

We illustrate Definition 11 in the following example.

Example 3. Let D_1 be the dialogue introduced by Example 1 and $D_2 = \langle \mathcal{I}_2, G_2, D_1^1 \rangle$ such that $\mathcal{I}_2 = \{1, 2\}$, $G_2 = \{a \times c \leftarrow \top; b \leftarrow \top\}$, $D_1^1 = [u_1]$ and $u_1 = \langle 1, \langle \{a \leftarrow not\ b\}, a \rangle \rangle$.

We are assuming that D_1 and D_2 have the same participating agents. Following Definition 11, the following sub-dialogue relations hold: $D_2 \sqsubseteq_u D_1$, $D_2 \sqsubseteq_{ak} D_1$, $D_2 \sqsubseteq_{ac} D_1$, $D_2 \sqsubseteq_g D_1$ and $D_1 \sqsubseteq_g D_2$

Given that the definitions of sub-dialogues, introduced by Definition 11, are basically defined in terms of subsets, the equality between dialogues is defined by the classical definition of set-equality.

Definition 12. *Let $D = \langle \mathcal{I}, G, U_r^t \rangle$, $D' = \langle \mathcal{I}', G', U_i^j \rangle$ be two dialogues and $\epsilon \in \{u, ak, ac, g\}$. D and D' are ϵ-equal ($D' =_\epsilon D$) iff $D' \sqsubseteq_\epsilon D$ and $D \sqsubseteq_\epsilon D'$ holds.*

It is easy to see that if two dialogues are utterances-equal, then they are active-knowledge and argument-conclusions equal. However, if two dialogues are active-knowledge equal, it does not imply that they are utterances-equal and argument-conclusions-equal. The main reason for this is because one can construct two arguments with same conclusions but with different supports. This property is quite common in different approaches for constructing arguments from a knowledge base [26, 18, 6].

Considering a dialogue, two argumentation frameworks can be derived from it.

Definition 13. *Let $D = \langle \mathcal{I}, G, U_r^t \rangle$ be a dialogue.*

- *The resulting argumentation framework AF_D^u w.r.t. D and its utterances is $\langle \mathcal{U}_D^*, At(\mathcal{U}_D^*) \rangle$.*
- *The resulting argumentation framework AF_D^{ak} w.r.t. D and its active-knowledge is $\langle \mathcal{A}rg(\mathcal{A}_D), At(\mathcal{A}rg(\mathcal{A}_D)) \rangle$.*

AF_D refers to either AF_D^u or AF_D^{ak}.

We can illustrate Definition 13 with the following simple example:

Example 4. Let D_1 be the dialogue introduced by Example 1.

$AF^{u}_{D_1}$ *w.r.t.* D_1 is $\langle\{arg_1, arg_2\}, \{(arg_2, arg_1)\}\rangle$

$AF^{ak}_{D_1}$ *w.r.t.* D_1 is $\langle\{arg_1, arg_2, arg_3\}, \{(arg_2, arg_1)\}\rangle$

in which $arg_1 = \langle\{a \leftarrow \ not\ b\}, a\rangle$, $arg_2 = \langle\{c \leftarrow \top; b \leftarrow c\}, b\rangle$ and $arg_3 = \langle\{c \leftarrow \top\}, c\rangle$.

Let us observe that the arguments of AF^u_D are the arguments that the participating agents of D have explicitly shared by means of utterances in the dialogue. However, considering the active-knowledge of a dialogue new both arguments and attacks can emerge; hence, AF^{ak}_D suggests a different view of the shared information in a dialogue. Nevertheless, we can identify a relationship between AF^u_D and AF^{ak}_D.

Proposition 1. *Let $D = \langle\mathcal{I}, G, U^t_r\rangle$ be a dialogue, $AF^u_D = \langle A^u, At^u\rangle$ and $AF^{ak}_D = \langle A^{ak}, At^{ak}\rangle$. It holds the following subset relations: $A^u \subseteq A^{ak}$ and $At^u \subseteq At^{ak}$.*

We consider that AF^u_D and AF^{ak}_D show different perspectives of an ongoing dialogue. Hence, these two views of an ongoing dialogue can be taken in consideration for defining strategic plans of dialogue-moves by the participating agents in a dialogue, *e.g.,* in a negotiation dialogue.

4 Agreement degrees of dialogues

Up to now, we have seen how to deal with the information that has been shared by the participating agents of a dialogue in terms of argumentation frameworks; however, we have not seen how this information can be understood regarding the goals of the dialogue. As was mentioned in the previous section, the shared information in a dialogue can define different argumentation frameworks regarding the active knowledge of a given dialogue. Now in this section, we will use these argumentation frameworks for exploring the satisfiability of the goals of a given dialogue.

The inference from argumentation frameworks is usually led by considering argumentation semantics. Hence, we will use σ-extensions of a σ argumentation semantics for defining answer sets of ordered disjunction rules as follows:

Definition 14. *Let $D = \langle\mathcal{I}, G, U^t_r\rangle$ be a dialogue, $G' \subseteq G$ and σ be an argumentation semantics. A σ-extension $E_\sigma \in \mathcal{E}_\sigma(AF_D)$ is a σ-model of G' iff $M = \mathcal{L}_{G'} \cap \Delta_{E_\sigma}$ is an answer set of G'. $\mathcal{M}_\sigma(AF_D, G')$ denotes the set of all σ-models inferred by the argumentation semantics σ w.r.t. AF_D and G'.*

Let us observe, in Definition 14, that the σ argumentation semantics is suggesting sets of atoms that can be considered for satisfying the goals of a dialogue. As was mentioned in Section 2.2, an answer set infers a satisfaction degree of an ordered disjunction rule. Hence, considering this satisfaction degree of each goal (an ordered disjunction), we define a satisfaction degree of a set of goals as follows:

Definition 15. *Let $D = \langle \mathcal{I}, G, U_r^t \rangle$ be a dialogue, $G' \subseteq G$, σ be an argumentation semantics. The satisfaction degree of $M \in \mathcal{M}_\sigma(AF_D, G')$ w.r.t. AF_D and G' is:*

$$deg_M(AF_D, G') = max\{deg_M(r) | r \in G'\}$$

Let us observe that $deg_M(AF_D, G')$ is capturing the satisfaction degree of the ordered disjunction rule that was worst satisfied. It is worth mentioning that according to Definition 4, an ordered disjunction rule with higher degree expresses a lesser degree of satisfaction. Hence if a dialogue and an argumentation semantics suggest that the $deg_M(AF_D, G') = 1$ means that all the goals of G' were satisfied in its best case. However, if $deg_M(AF_D, G') = 2$ means that at least one of the decisions (*i.e.* an ordered disjunction rule) of G' took the second option.

We can define preferences between σ models considering the satisfaction degree defined by Definition 15.

Definition 16. *Let $D = \langle \mathcal{I}, G, U_r^t \rangle$ be a dialogue, $G' \subseteq G$ and σ be an argumentation semantics. If $M_1, M_2 \in \mathcal{M}_\sigma(AF_D, G')$, M_1 is preferred to M_2 (denoted by $M_1 >_p M_2$) if and only if $deg_{M_1}(AF_D, G') < deg_{M_2}(AF_D, G')$.*

It easy to see that $>_p$ defines a partial ordered set considering all the σ models suggested by an argumentation semantics σ. Let us denote by $Upp(D, G', \sigma)$ the satisfaction degree of the members of the upper bound of $(\mathcal{M}_\sigma(AF_D, G'), >_p)$.

Now we are ready for defining the dialogue agreement degree suggested by an argumentation semantics σ regarding a given dialogue.

Definition 17 (Dialogue agreement degree). *Let $D = \langle \mathcal{I}, G, U_r^t \rangle$ be a dialogue, $G' \subseteq G$ and σ be an argumentation semantics. The dialogue agreement degree of D w.r.t. AF_D and σ (denoted by D-Deg(D, AF_D, G', σ)) is a tuple of the form $\langle i/n, Upp(D, G', \sigma) \rangle$ such that $i = |G'|$ and $n = |G|$.*

According to Definition 17, a dialogue D reaches *a total agreement* whenever D-Deg$(D, AF_D, \sigma) = \langle 1, 1 \rangle$, which means that all the goals were satisfied and all of them took the best option.

Example 5. Once again, let us consider the dialogue D_1 introduced by Example 1. Hence, $D_1 = \langle \mathcal{I}, G, D_1^2 \rangle$ such that $\mathcal{I} = \{1, 2\}$, $G = \{a \times c \leftarrow \top; b \leftarrow \top\}$, $D_1^2 = [u_1, u_2]$, $u_1 = \langle 1, \langle \{a \leftarrow \ not\ b\}, a \rangle \rangle$ and $u_2 = \langle 2, \langle \{c \leftarrow \top; b \leftarrow c\}, b \rangle \rangle$.

As we saw in Example 4, $AF_{D_1}^{ak}$ *w.r.t.* D_1 is $\langle \{arg_1, arg_2, arg_3\}, \{(arg_2, arg_1)\} \rangle$ in which $arg_1 = \langle \{a \leftarrow \ not\ b\}, a \rangle$, $arg_2 = \langle \{c \leftarrow \top; b \leftarrow c\}, b \rangle$ and $arg_3 = \langle \{c \leftarrow \top\}, c \rangle$.

If we consider the grounded semantics [8], denoted by gs, $\mathcal{E}_{gs}(AF_{D_1}^{ak}) = \{\{arg_2, arg_3\}\}$. We can see that $\Delta_{\{arg_2, arg_3\}} = \{b, c\}$. Moreover, one can see that $M_{gs} = \mathcal{L}_G \cap \Delta_{\{arg_2, arg_3\}}$ is a gs-model of G.

Let us denote by $r_1 = a \times c \leftarrow \top$ and $r_2 = b \leftarrow \top$. We can see that $deg_{M_{gs}}(r_1) = 2$ and $deg_{M_{gs}}(r_2) = 1$. Therefore, $deg_{M_{gs}}(AF_{D_1}^{ak}, G) = 2$.

Since the grounded semantics only infers a unique gs-model, we get a unique element in $\mathcal{M}_{gm}(AF_{D_1}, G)$. One can see that D-Deg$(D_1, AF_{D_1}^{ak}, G, gs) = \langle 1, 2 \rangle$. By removing goals from G, one can get different agrement degrees *w.r.t.* AF_D^{ak} and gs. For instance, by considering the sets $\{a \times c \leftarrow \top\}$ and $\{b \leftarrow \top\}$, we get:

D-Deg$(D_1, AF_{D_1}^{ak}, \{a \times c \leftarrow \top\}, gs) = \langle 0.5, 2\rangle$.
D-Deg$(D_1, AF_{D_1}^{ak}, \{b \leftarrow \top\}, gs) = \langle 0.5, 1\rangle$.

In figure 1, it is depicted the different agreement degrees that can be committed considering the current sequence of utterances of D_1. Let us point out that Figure 1 suggests different readings regarding dismissing some of the goals of the D_1. For instance, D-Deg$(D_1, AF_{D_1}^{ak}, \{b \leftarrow \top\}, gs) = \langle 0.5, 1\rangle$ suggests that one of the goals is satisfied in its optimal value; however, it is skipping other goals of the dialogue.

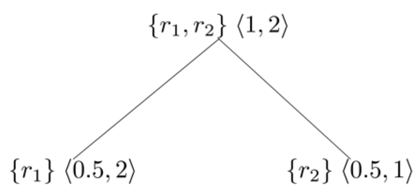

Fig. 1. A lattice of agreement degrees of Example 5.

One can observe that agrement degree values are monotonic regarding the size of the set of goals.

Proposition 2. *Let $D = \langle \mathcal{I}, G, U_r^t\rangle$, $D' = \langle \mathcal{I}', G', U_i^j\rangle$ be two dialogues and σ be an argumentation semantics.*

- *If $D =_u D'$ and $D' \sqsubseteq_g D$, then $j' \leq j$ such that D-Deg$(D, AF_D, G, \sigma) = \langle i, j\rangle$ and D-Deg$(D', AF_{D'}, G', \sigma) = \langle i', j'\rangle$.*

As we can see in Figure 1, if we consider all the possible subsets of the set of goals of a dialogue, we can identify different understanding of an ongoing dialogue in terms of agreement degrees. Therefore, by having a list of utterances U_r^t, we can identify the best possible agreements that are possible to reach by considering different subsets of goals. Hence, a lattice of agreement degrees is defined as follows:

Definition 18 (Lattice of agreement degrees). *Let $D = \langle \mathcal{I}, G, U_r^t\rangle$ be a dialogue, σ be an argumentation semantics. The lattice of agreement degrees w.r.t. D and σ is $\Omega_D^\sigma = (L, \leq_\Omega)$ in which:*

- $L = \{\langle G', Upp(D', G', \sigma)\rangle | G' \in 2^G \setminus \emptyset, D' = \langle \mathcal{I}, G', U_r^t\rangle\}$

– *$\leq_\Omega$ is a lexicographical order considering the $\subseteq$ relation for the first element of the tuple and the numerical relation $\leq$ for the last element of the tuple.*

Let us observe that one can also define a lattice of agreements considering all the possible tuples suggested by Definition 17. The unique difference will be the first element of the tuples.

Let us point out that Ω^σ_D is defined in terms of a particular argumentation semantics σ. Nevertheless, by considering different argumentation semantics, one can identify different evaluations of the elements of Ω^σ_D.

Before ending this section, let us mention that the big issue regarding the construction of Ω^σ_D is the computational complexity of the argumentation semantics σ. An important concern in argumentation semantics is the *computational complexity* of the decision problems that has been shown to range from NP-complete to $\Pi_2^{(p)}$-complete [9].

5 Conclusions and future work

Currently, formal argumentation dialogue systems see the disagreements of a dialogue from the perspective of a unique argumentation framework [5, 20]. However, in open environments of agents, the participating agents of a dialogue can join a dialogue and have different interpretations of the shared knowledge by the participating agents. From this perspective, we consider that a given share knowledge base can give place to different argumentation frameworks. In this paper, we show that the active knowledge of a dialogue at least can give place to two different argumentation frameworks AF^{ak}_D, AF^u_D (see Definition 13). Considering Proposition 1, it is easy to see that AF^{ak}_D is an expansion [4] of AF^u_D. We have considered an approach, for constructing arguments, that does not allow us to construct self-attacked arguments. However, considering other constructions of arguments (*e.g.,* [26]), one can identify different argumentation frameworks from the same active knowledge base of a dialogue. From this perspective, the use of self-attacked arguments can be an interesting topic for defining strategies in order to decide the next moves of an ongoing dialogue.

We show that by considering an argumentation semantics approach we can manage ordered disjunctions rules such that these ordered disjunctions rules capture preferences between goals of a dialogue. We show that argumentation semantics can define different satisfaction degrees of the goals of a dialogue, which are captured by ordered disjunctions rules. Hence, considering the active knowledge of a dialogue and an argumentation semantics, we introduce an approach for measuring an agreement degree of a dialogue. Considering this agreement degree of a dialogue, we introduce an approach for answering the research question **Q1**. It is clear that if we change the argumentation semantics, the dialogue agreement degree can change. Hence, a new research question arises:

Q3: Which argumentation semantics infers the maximum (or minimum) agreement degrees of a dialogue and its goals?

Answering **Q3** will be part of our future work. Let us point out that by considering different argumentation semantics one can define different lattices of agreement degrees. It is known that there are different sub-contention relations between different well-acceptable argumentation semantics [3]. Hence, to see the effect of these sub-contention relations in agreement degrees of dialogues will be also part of our future work.

Considering the lattice of agreement degrees, we introduce an approach for answering **Q2**. Let us observe that $\Omega^{\sigma}_{D} = (L, \leq_{\Omega})$ shows a picture of the pros and the cons of eliminating goals of a dialogue since L is defining different agreement degrees by considering different subset of goals of the initial set of goals of a dialogue.

Let us point out that in this paper we are introducing a novel approach for modeling dialogues with preferences in their goals. Moreover, the satisfaction degree of a dialogue is a novel approach for defining heuristics to decide the next move in an on-going dialogue. In this regard, let us highlight that the process of deciding which set of rules to disclosure from a private knowledge has been shown to be NP-complete even when the problem of deciding whether a given theory entails a literal can be computed in polynomial time [13]. Hence, the suggested lattice of agreement degrees can define heuristics in the settings of strategic argumentation [13].

From our applied research, we have observed that considering only static goals in a dialogue do not work in real applications. For instance, let us consider the case of persuasive software agents. If a given persuasive software agent has as a goal to persuade a given human agent, the persuasive software agent will need take into consideration different possible scenarios of agreement where different user preferences can be partially satisfied during a dialogue. Hence, we consider that by modeling preferences between the goals of a dialogue, one can incorporate user preferences into dialogues between software agents and human agents [15].

Acknowledgements

The author is very grateful to the anonymous referees for their useful comments.

References

1. K. Atkinson, P. Baroni, M. Giacomin, A. Hunter, H. Prakken, C. Reed, G. R. Simari, M. Thimm, and S. Villata. Towards artificial argumentation. *AI Magazine*, 38(3):25–36, 2017.
2. C. Baral. *Knowledge Representation, Reasoning and Declarative Problem Solving*. Cambridge University Press, Cambridge, 2003.
3. P. Baroni, M. Caminada, and M. Giacomin. An introduction to argumentation semantics. *Knowledge Eng. Review*, 26(4):365–410, 2011.
4. R. Baumann and S. Woltran. The role of self-attacking arguments in characterizations of equivalence notions. *Journal of Logic and Computation*, 2014.
5. E. Black and A. Hunter. An inquiry dialogue system. *Autonomous Agents and Multi-Agent Systems*, 19(2):173–209, 2009.
6. A. Bondarenko, P. M. Dung, R. A. Kowalski, and F. Toni. An abstract, argumentation-theoretic approach to default reasoning. *Artificial Intelligence*, 93:63–101, 1997.
7. G. Brewka, I. Niemelä, and T. Syrjänen. Logic programs with ordered disjunction. *Computational Intelligence*, 20(2):335–357, 2004.

8. P. M. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial Intelligence*, 77(2):321–358, 1995.
9. P. E. Dunne. Computational properties of argument systems satisfying graph-theoretic constraints. *Artificial Intelligence*, 171(10-15):701–729, 2007.
10. X. Fan and F. Toni. A general framework for sound assumption-based argumentation dialogues. *Artif. Intell.*, 216:20–54, 2014.
11. A. J. García and G. R. Simari. Defeasible logic programming: An argumentative approach. *Theory and Practice of Logic Programming*, 4(1-2):95–138, 2004.
12. A. V. Gelder, K. A. Ross, and J. S. Schlipf. The well-founded semantics for general logic programs. *Journal of the ACM*, 38(3):620–650, 1991.
13. G. Governatori, F. Olivieri, S. Scannapieco, A. Rotolo, and M. Cristani. Strategic argumentation is np-complete. In *ECAI 2014 - 21st European Conference on Artificial Intelligence*, volume 263 of *Frontiers in Artificial Intelligence and Applications*, pages 399–404. IOS Press, 2014.
14. E. Guerrero, J. C. Nieves, and H. Lindgren. Semantic-based Construction of Arguments: an Answer Set Programming Approach. *International Journal of Approximate Reasoning*, 64:54–74, 2015.
15. E. Guerrero, J. C. Nieves, and H. Lindgren. An activity-centric argumentation framework for assistive technology aimed at improving health. *Argument and Computation*, 7(1):5–33, 2016.
16. M. Kljakovic. Clinical disagreement: A silent topic in general practice. *New Zealand Family Physician*, 30(5):358–360, 2003.
17. S. Kraus, K. P. Sycara, and A. Evenchik. Reaching agreements through argumentation: A logical model and implementation. *Artif. Intell.*, 104(1-2):1–69, 1998.
18. S. Modgil and H. Prakken. The $ASPIC^+$ framework for structured argumentation: a tutorial. *Argument & Computation*, 5(1):31–62, 2014.
19. J. C. Nieves. Expansion and equivalence relations on argumentation frameworks based on logic programs. In *the 14th European Conference on Multi-Agent Systems (EUMAS 2016)*, volume IN PRESS of *LNCS*, 2017.
20. J. C. Nieves and H. Lindgren. Deliberative argumentation for service provision in smart environments. In *12th European Conference on Multi-Agent Systems (EUMAS 2014)*, LNCS, pages 388–397. Springer, 2015.
21. J. C. Nieves, M. Osorio, and U. Cortés. Supporting decision making in organ transplating using argumentation theory. In *LANMR 2006: 2nd Latin American Non-Monotonic Reasoning Workshop*, pages 9–14, 2006.
22. S. Ossowski. *Agreement technologies*. Springer, 2013.
23. S. Parsons, M. Wooldridge, and L. Amgoud. Properties and complexity of some formal inter-agent dialogues. *Journal of Logic and Computation*, 13(3):347–376, 2003.
24. H. Prakken. Coherence and flexibility in dialogue games for argumentation. *Journal of Logic and Computation*, 15(6):1009–1040, 2005.
25. H. Prakken. Formal systems for persuasion dialogue. *Knowledge Eng. Review*, 21(2):163–188, 2006.
26. H. Prakken and G. Sartor. Argument-based extended logic programming with defeasible priorities. *Journal of Applied Non-Classical Logics*, 7(1), 1997.
27. I. Rahwan and G. R. Simari, editors. *Argumentation in Artificial Intelligence*. Springer, 2009.
28. C. Sierra, S. Simoff, and R. López de Màntaras. The argumentative mediator. In *Multi-Agent Systems and Agreement Technologies - 14th European Conference, EUMAS 2016,*

and 4th International Conference, AT 2016, Valencia, Spain, December 15-16, 2016, Revised Selected Papers, volume 10207 of *Lecture Notes in Computer Science*, pages 439–454. Springer, 2017.

29. P. Tolchinsky, U. Cortés, J. C. Nieves, A. López-Navidad, and F. Caballero. Using arguing agents to increase the human organ pool for transplantation. In *Proc. of the Third Workshop on Agents Applied in Health Care (IJCAI 2005)*, 2005.