ARGUMENTATION TO COMPOSE SERVICES[1]

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Abstract

We propose in this paper a framework for inter-agents dialogue on actions, which formalize a deliberative process. This framework bounds a dialectical system in which argumentative agents arbitrate and play to reach a practical agreement. For this purpose, we propose an argumentation-based reasoning to manage the conflicts between plans having different strengths for different agents. Moreover, we propose a model of agents which justify the plans to which they commit and take into account the plans of their interlocutors. In the scope of our dialectical system, an agent is responsible of the final decision outcome which is taken according to the autority of the players, the uttered plans and her own rules and priorities. We illustrate this paper with a services composition.

1 Introduction

The collaboration between autonomous and social agents to solve complex tasks is an open problem with many application areas such as cooperative robotics or services composition. The conflicts in the interests and perspectives of agents is the main characteristic of such systems. In this paper, we aim at formalizing a deliberative process with a formal framework for inter-agents interaction. For this purpose, argumentation is a promising approach for reasoning with inconsistent information and conflicting objectives. In this paper, we extend [8] such as arguments are plans and we focus on a dialogical mechanism between software agents to reason, exchange and compose them.

Paper overview. In section 1, we provide the syntax and the semantics of the planning language. Section 3 presents the argumentation framework which manages the interaction between conflicting plans. In accordance with this background, we describe in section 4 our model of agents. In section 5, we define the formal area in which the agents deliberate. Section 6 presents the protocol used to reach a pratical agreement. This paper closes with discussion about related works in section 7.

2 Planning language

In this section, we present the syntax and the semantics of the formal language that we use to express automated planning problem instance : the Action Description Language (ADL). This is an extension of the STRIPS language (*STanford Research Institute Problem Solver*),

The classical planning environments are fully observable, deterministic (the result of actions are foreseeable), discrete (the environment states are finite) and static (changes happens only when the agents acts). Planners decompose the world into logical conditions and represent a state. For example, $\mathrm{Rich} \wedge \mathrm{Famous}$ represents the state of an *happy* agent. Literals in first-order state descriptions must be ground and function-free. Contrary to $\mathrm{in}(\mathrm{a}_1, \mathrm{Ottawa})$, literals such as $\mathrm{in}(\mathrm{a}_x, y)$ or $\mathrm{in}(\mathrm{Daughter}(\mathrm{a}_x), \mathrm{Lille})$ are not allowed.

A planning problem instance is composed of an initial state, the specification of the goal which the planner is trying to reach, and a set of possible actions. Each action is defined in terms of preconditions and postconditions.

Definition 1 *An* ***instance*** *is defined by an ordered pair* $\mathcal{I} = \langle \mathcal{L}, C \rangle$ *where:*

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- *$\mathcal{L}$ is the first-order logic language. We call **condition** a conjunction of literals. The empty conjunction (denoted $\emptyset$) is true;*
- *$C = A \cup \{i, g\}$ is a **competence**, i.e. a set of rule where:*
  - *A is a set of action. Each action a is a 4-tuple of conditions $a : \langle\gamma, \delta\rangle \leftarrow \langle\alpha, \beta\rangle$, where α must be true for the action to be executable, β must be false, γ is made true by the action and δ ones is made false. The empty action is denoted $\epsilon : \langle\emptyset, \emptyset\rangle \leftarrow \langle\emptyset, \emptyset\rangle$;*
  - *$i : \langle\gamma_i, \delta_i\rangle \leftarrow$ is the initial state, given as the pair of conditions, which are respectively true and false ;*
  - *$g : \langle\gamma_g, \delta_g\rangle \leftarrow$ is the specification of the goal state given as a pair, which specify that the condition α_g (resp. β_g) is true (resp. false), in order for a state to be considered as a goal.*

On one hand, a state *a fortiori* the initial state i is a totally specified state represented as a conjunction of positive ground literals (γ_i) and a conjunction of negative ground literals (δ_i). On the other hand, the specification of a goal g is a partially specified state represented as a conjunction of positive ground literals (α_g) and a conjunction of negative ground literals (β_g). A state ($s : \langle\gamma_s, \delta_s\rangle \leftarrow$) satisfies a goal ($g : \langle\alpha_g, \beta_g\rangle \leftarrow$) if s contains all the atoms in g and possibly others ($\alpha_g \subseteq \gamma_s$ and $\beta_g \subseteq \delta_s$). An action a is specified in terms of positive preconditions (α) and negative preconditions (β) that must hold before it can be executed, the positive effects (γ) and the negative effects (δ) that ensure when it is executed. For example, an action for flying a plane from one location to another is: $\text{fly}(\text{from}, \text{to}) : \langle\text{in}(\text{buyer}, \text{to}), \text{in}(\text{buyer}, \text{from})\rangle \leftarrow \langle\text{in}(\text{buyer}, \text{from}), \emptyset\rangle$. This rule is also called action schema, meaning that it represents a number of differents actions that can be derived by instantiating the variables *from*, and *to* to different constants. The action name $\text{fly}(\text{from}, \text{to})$ serves to identify the action, Any variables in the preconditions or in the postconditions must also appear in the action's parameter list. One of the most important restrictions is that literals be function-free. With this restriction, we can be sure that any action schema can be propositionalized, so turned into a finite collection of purely propositional action representations with no variables. Since the preconditions expressing the facts that a flight cannot be made from an airport to itself, cannot be expressed sunccintly in STRIPS, we prefer the Action Description Language to the STRIPS language. To improve readibility, we have divided the preconditions and the effects into lists for positive and negative literals. In ADL, the fly action could be written as : $\text{fly}(\text{from}, \text{to}) : \langle\text{in}(\text{buyer}, \text{to}), \text{in}(\text{buyer}, \text{from})\rangle \leftarrow \langle\text{in}(\text{buyer}, \text{from}), \text{from} = \text{to}\rangle$.

Having defined the syntax for the representation of planning problems, we can now define the semantics. For this purpose, we specify a direct transition from a state ($s : \langle\alpha_s, \beta_s\rangle \leftarrow$) into successor-state axioms whose semantics come from first order logic. An action ($a : \langle\gamma_a, \delta_a\rangle \leftarrow \langle\alpha_a, \beta_a\rangle$) is applicable in any state that satisfies the preconditions. More formally:

$$s, a \vdash \begin{cases} \langle(\alpha_s \cup \gamma_a) - \delta_a, (\beta_s \cup \delta_a) - \gamma_a\rangle & \text{if } \alpha_a \subseteq \alpha_s \text{and} \beta_a \subseteq \beta_s \\ \langle\alpha_s, \beta_s\rangle & \text{else} \end{cases}$$

Starting in a state s, the result of executing an **applicable action** a is a state s' such that any positive literals in the effect are added to s' and any negative literals are removed from s'. For example, suppose the current state is described by: $s : \langle\text{in}(\text{buyer}, \text{Paris}), \text{in}(\text{buyer}, \text{Lille})\rangle$. This state satisfies the precondition: $\langle\text{in}(buyer, \text{from}), \text{from} = \text{to}\rangle$ with substitution $\{\text{Paris}/\text{from}, \text{Montreal}/\text{to}\}$. Thus, after the concrete action $\text{fly}(\text{Paris}, \text{Montreal})$ the current state becomes $s' : \langle\text{in}(\text{buyer}, \text{Montreal}), \text{in}(\text{buyer}, \text{Paris}) \wedge \text{in}(\text{buyer}, \text{Lille})\rangle \leftarrow$. Note that if a positive effect is already in s it is not added twice, and if a negative effect is not in a, then that part of the effect is ignored. This definition embodies the assumption that every literal not mentionned in the effects remains unchanged. In this way, we avoid the frame problem. Since the states could be represented by a pair of conditions, two (totally or partially specified) states $s_1 : \langle\alpha_1, \beta_1\rangle \leftarrow$ and $s_2 : \langle\alpha_2, \beta_2\rangle \leftarrow$ are **incompatible** (denoted $s_1 \perp s_2$) iff: $(\alpha_1 \cap \beta_2) \cup (\alpha_2 \cap \beta_1) \neq \emptyset$.

Finaly we can define the solution for a planning problem. The transition relation can be extended such that: $c, \epsilon \vdash c$ and $c, (a_1, a_2, \ldots, a_n) \vdash (c, a_1 \vdash), (a_2, \ldots, a_n)$. A plan for an instance is a sequence of actions such that the state that results from executing the actions from the initial state satisfies the goal conditions. A **plan** $P = \langle(a_1, a_2, \ldots, a_n), i_P, g_P\rangle$ is a triple where:

- i_P is a totally specified state;
- g_P is a partially specified state;
- $(a_1, a_2, \ldots, a_n)$ is a sequence of actions ($\forall i\ a_i \in A$) such as $i_P, (a_1, a_2, \ldots, a_n) \vdash g_P$.

P **satisfies** S iff $\gamma_i \subseteq \gamma_{i_P}, \delta_i \subseteq \delta_{i_P}, \alpha_g \subseteq \alpha_{g_P}, \beta_g \subseteq \beta_{g_P}$. In other words, a solution for a planning problem is just a plan that, when excecuted in the initial state, results in a state that satisfies the goal. Below we will use this planning language within our argumentation framework.

3 Argumentation-based plan

We present in this section an argumentation framework built around the previous language, which manage the interaction between plans. In order to deliberate, we considers a set of audiences ($a_1, \ldots, a_n \in \mho_A$) which adhere to different plans with a variable intensity. These audiences consider the same instance (denoted $\mathcal{I} = \langle \mathcal{L}, C \rangle$) and the same transition rule (denoted $\vdash$). At first, we consider that the audiences share an value-based competence, *i.e.* a set of rules promoting values:

Definition 2 *The* ***value-based competence*** $AC = \langle \mathcal{C}, V, promote \rangle$ *is defined by a triple where:*

- $\mathcal{C}$ *is a competence, i.e. a finite set of rules;*
- V *is a non-empty finite set of values* $\{v_1, \ldots, v_t\}$*;*
- *promote* : $\mathcal{C} \to V$ *maps from the rules to the values.*

We say that the rule c *relates to the value* v *if* c *promotes* v*. For every* $c \in \mathcal{C}$*, promote*$(c) \in V$*.*

To distinguish different audiences, values, both concrete and abstract, constitute starting points [2]. Values are arranged in hierarchies. For instance, an audience will value both justice and utility but an argument may require the determination of a strict preference between the two. Since audiences are individuated by their hierarchies of values, the values have different priorities for different audiences. The **value-based competence of the audience** $\mathbf{a}_i$ is a 4-tuple $AC_i = \langle \mathcal{C}, V, \text{promote}, \ll_i \rangle$ where $AC = \langle \mathcal{C}, V, \text{promote} \rangle$ is a value-based competence as previously defined and $\ll_i$ is the priority relation of the audience a_i, *i.e.* a strict complete ordering relation on V.

A priority relation is a transitive, irreflexive, asymmetric, and complete relation on V. It stratifies the competence into finite non-overlapping sets. The priority level of a non-empty competence $C \subseteq \mathcal{C}$ (written $\text{level}_i(C)$) is the least important value promoted by one element in C. On one hand, a priority relation captures the value hierarchy of a particular audience. On the other hand, the competence gathers the rules shared by the audiences. Plans are built upon this competence. Since the plans can be conflictual, *i.e.* leads to incompatible goals, plans can be considered as arguments.

Definition 3 *Let* C *be a competence. An* ***argumentative plan*** *is a triple* $A = \langle s_P, i_P, g_P \rangle$ *where* i_P *(resp.* g_P*) is an initial state (resp. the specification of a goal) and* $s_P = (a_1, \ldots, a_n)$ *a sequence of actions in* C *such as:* $i_P, (a_1, \ldots, a_n) \vdash g_P$*.* (i_P, s_P) *is the premise of* A*, denoted premise*(A)*.* g_P *is the conclusion of* A*, denoted conclusion*(A)*. The argumentative plan* A' *is a* ***sub-plan*** *of* A *iff its sequence of actions is a subsequence of* s_p*. A plan is* ***trivial*** *iff the sequence of actions is empty.*

In other words, argumentative plans (plans for short) are relations of consequence between a premise and a conclusion. Since the competence C can be conflictual, the set of plans (denoted $\mathcal{P}(C)$) will conflict. The relation of attack between plans is built upon the incompatibility between their conclusions.

Definition 4 *Let* C *be a competence and* $A, B \in \mathcal{P}(C)$ *two plans.* A ***attacks*** B *iff :* $\exists A_1 = \langle s_1, i_1, g_1 \rangle, B_2 = \langle s_2, i_2, g_2 \rangle \in \mathcal{P}(C)$ *respectively sub-plan of* A *and* B *such as* $g_1 \bot g_2$*.*

Because each audience is associated with a particular priority relation, the audiences individually evaluate the strength of plans. According to the audience a_i, the **strength** of A (written $\text{strength}_i(A)$) is the least important value promoted by one rule in the premise. In other words, the strength of plans depends on the priority relation. Since the audiences individually evaluate the strength of plans, an audience can ignore the attack of a plan over another plan.

Definition 5 *Let* $AC_i = \langle \mathcal{C}, V, promote, \ll_i \rangle$ *be the value-based competence of the audience* a_i *and* $A = \langle s, i, g \rangle, B = \langle s', i', g' \rangle \in \mathcal{P}(\mathcal{C})$ *two plans.* A ***defeats*** B ***for the audience*** a_i *iff* $\exists A_1 = \langle s_1, i_1, g_1 \rangle, B_2 = \langle s_2, i_2, g_2 \rangle \in \mathcal{P}(C)$ *respectively sub-plan of* A *and* B *such as: i)* $g_1 \bot g_2$*; ii)* $\neg(\mathit{strength}_i(A_1) \ll_i \mathit{strength}_i(B_2))$*. Similarly, we say that a set* S *of plans defeats* B *if* B *is defeated by a plan in* S*.*

Contrary to the relation of attack, the relation of defeat is asymmetric and subjective. Considering the individuated viewpoint of each audience, we focus on the subjective acceptance.

Definition 6 *Let $AC_i = \langle \mathcal{C}, V, promote, \ll_i \rangle$ be the value-based competence of the audience a_i. Let $A \in \mathcal{P}(\mathcal{C})$ be a plan and $S \subseteq \mathcal{P}(\mathcal{C})$ a set of plans. A* ***is subjectively acceptable by the audience*** *a_i* ***with respect to S*** *iff $\forall B \in \mathcal{P}(\mathcal{C})$ $defeats_i(B, A) \Rightarrow defeats_i(S, B)$.*

The set of subjectively acceptable plans consists of a consistent position, also called preferred extension, which is a maximal set of acceptable plans [6]. In other words, this set defends itself from all attacks, and cannot be extended without introducing a conflict. Since the priority relation is an ordering relation, the set of acceptable plans is unique and non-empty [4]. The following example illustrate this argumentation-based reasoning framework for plans.

Example 1 *Let us consider a_1, a service provider which wants to sell transport tickets. The value-based argumentative competence of the audience a_1 is represented in the table 1. This audience is associated with*

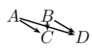
$\ll_1$	V	$\mathcal{C}$	
↑	$\mathbf{v_1}$	$\mathbf{g}(\text{price}) : \langle \text{in}(\text{buyer}, \text{Ottawa}) \wedge \text{paid}(\text{price}), \emptyset \rangle \leftarrow$ $\mathbf{i} : \langle \text{in}(\mathbf{buyer}, \text{Lille}) \wedge, \text{budget}(> \mathbf{2000}) \rangle \leftarrow$	
	$\mathbf{v_2}$	$\text{fly}(\text{from}, \text{to}, \text{price}) : \langle \text{in}(\text{buyer}, \text{to}) \wedge \text{paid}(\text{price}), \text{in}(\text{buyer}, \text{from}) \rangle \leftarrow \langle \text{greater}(\text{budget}, \text{price}) \wedge \text{in}(\text{buyer}, \text{from}), \text{from} = \text{to} \rangle$ $\text{bus}(\text{from}, \text{to}, \text{price}) : \langle \text{in}(\text{buyer}, \text{to}) \wedge \text{paid}(\text{price}), \text{in}(\text{buyer}, \text{from}) \rangle \leftarrow \langle \text{greater}(\text{budget}, \text{price}) \wedge \text{in}(\text{buyer}, \text{from}), \text{from} = \text{to} \rangle$ $\text{train}(\text{from}, \text{to}, \text{price}) : \langle \text{in}(\text{buyer}, \text{to}) \wedge \text{paid}(\text{price}), \text{in}(\text{buyer}, \text{from}) \rangle \leftarrow \langle \text{greater}(\text{budget}, \text{price}) \wedge \text{in}(\text{buyer}, \text{from}), \text{from} = \text{to} \rangle$	
	v_3	$\text{fly}(\text{Paris}, \text{Montreal}, 800)$	
	v_4	$\text{fly}(\text{Bruxelles}, \text{Montreal}, 650)$	
	v_5	$\text{bus}(\text{Montreal}, \text{Ottawa}, 50)$	
	v_6	$\text{bus}(\text{Montreal}, \text{Ottawa}, 100)$	
	v_7	$\text{train}(\text{Lille}, \text{Bruxelles}, 100)$	
	v_8	$\text{train}(\text{buyer}, \text{Lille}, \text{Paris}, 150)$	

Table 1: Argumentative competence of the service provider a_1.

a competence, i.e. a set of rules ($g(price), i, \ldots$) and a set of values ($v_1, \ldots, v_8$). The rules corresponding to the goal specification ($g(price)$) and the initial situation (i) promote the value v_1. The rules of common sense promote the value v_2 : "take a flight" ($fly(from, to, price)$), "take a train" ($train(from, to, price)$) and "take a bus" ($bus(from, to, price)$). The other particular rules such as"take TGV" ($train((Lille, Paris, 150)$) promote the values $v_3, \ldots, v_8$. According to an audience, a value above another one in the figure has priority over it. a_1 prefers Air France to Air Canada and the cheapest connexion. The four following plans conflict:
$A = (i, (train(Lille, Paris, 150), fly(Paris, Montreal, 800), bus(Montreal, Ottawa, 50))$
$B = (i, (train(Lille, Paris, 150), fly(Paris, Montreal, 800), bus(Montreal, Ottawa, 100))$
$C = (i, (train(Lille, Bruxelles, 100), fly(Bruxelles, Montreal, 650) bus(Montreal, Ottawa, 50))$
$D = (i, (train(Lille, Bruxelles, 100), fly(Bruxelles, Montreal, 650), bus(Montreal, Ottawa, 100))$
The strength of A and B is v_7 and the strength of C and D is v_8. Therefore, A and B defeats C and D but C and D does not defeat A and B. The set $\{A, B\}$ is subjectively acceptable for AC_1 with respect to $\mathcal{P}(\mathcal{C})$.

In the next section, we shift from the zero-agent notion of acceptability to the one-agent notion of conviction in order to take into account not only plans shared by different audiences but also plans exchanged by agents.

4 Model of agents

In multi-agent setting it is natural to assume that the agents do not all have exactly the same beliefs and capacities. Since the competences of agents can be common, complementary or contradictory, agents exchange their plans and argue. For this purpose, our agents individually valuate the perceived commitments with respect to the estimated reputation of the agents from whom the plan is obtained. The agent a_i, which has a personal competence $\mathcal{C}_i$, a set of personal values V_i and a priority relation $\ll_i$, record in the commitment store CS^i_j which contains the rules taken before or at time t by the agent a_j. Moreover, the agent a_i individually valuates the reputation of their interlocutors with her reputation relation $\prec_i$, *i.e.* a strict complete ordering relation on $\mho_A$. The rules in the commitment store CS^i_j relate to the reputation value v^i_j.

The personal competences of agents are not necessarily disjoint. We call **common competence** the set of rules explicitly shared by the agents: $\mathcal{C}_{\Omega_A} \subseteq \cap_{a_i \in \mho_A} \mathcal{C}_i$. Similarly, we call **common values** the values explicitly shared by the agents: $V_{\Omega_A} \subseteq \cap_{\mathrm{a}_i \in \mho_A} V_i$. The common rules relate to the common values. For every $c \in \mathcal{C}_{\Omega_A}$, $\mathrm{promote}(c) = v \in V_{\Omega_A}$. The personal rules can be complementary or contradictory. We call **joint competence** the set of rules distributed in the system: $\mathcal{C}_{\mho_A} = \cup_{\mathrm{a}_i \in \mho_A} \mathcal{C}_i$. The agent own rules relate to the agent own values. For every $c \in \mathcal{C}_i - \mathcal{C}_{\Omega_A}$, $\mathrm{promote}_i(c) = v \in V_i - V_{\Omega_A}$.

Reputation is a social concept that links an agent to her interlocutors. It is also a leveled relation [9]. The individuated reputation relations, which are transitive, irreflexive, asymmetric, and complete relations on $\mho_A$, preserve these properties. $\mathrm{a}_j \prec_i \mathrm{a}_k$ denotes that an agent a_i trusts an agent a_k more than another agent a_j. In order to take into account the rules notified in the commitment stores, each agent is associated with the following **extended competence**: $\mathrm{AC}_i^* = \langle \mathcal{C}_i^*, V_i^*, \mathrm{promote}_i^*, \ll_i^* \rangle$, which is a value-based competence where:

- $\mathcal{C}_i^* = \mathcal{C}_i \cup [\bigcup_{j \neq i} \mathrm{CS}_j^i]$ is the extended personal competence of the agent composed of the personal competence and the set of perceived commitments;
- $V_i^* = V_i \cup [\bigcup_{j \neq i} \{v_j^i\}]$ is the extended set of personal values of the agent composed of the set of personal values and the reputation values associated with her interlocutors;
- $\mathrm{promote}_i^* : \mathcal{C}_i^* \rightarrow V_i^*$ is the extension of the function $\mathrm{promote}_i$ which maps from the rules in the extended personal competences to the extended set of personal values. On the one hand, the personal rules relate to the personal values. On other hand, the rules in the commitment store CS_j^i relate to the reputation value v_j^i;
- $\ll_i^*$ is the extended priority relation of the agent, *i.e.* an ordering relation on V_i^*.

Since the deliberation is a collaborative social process, the agents share common rules (common goal, common initial situation, common sense, ...) of prime importance. That is the reason why the common values have priority over the other values. Since the agents argue, they estimate themselves more authoritative than their interlocutors. That is the reason why the personal values have priority over the reputation values. In other words, the extended priority relation of the agent is constrained as follows: $\forall \mathrm{a}_j \in \mho_A\ \forall v_\omega \in V_{\Omega_A} \forall v \in V_i - V_{\Omega_A}\ (v_j^i \ll_i^* v \ll_i^* v_\omega)$. We can easily demonstrate that the extended priority relation is a strict complete ordering relation. The **agent a_i is convinced by the rule** c iff c is the conclusion of an acceptable argument by the audience a_i with respect to $\mathcal{P}(\mathcal{C}_i^*)$.

The agents utter messages to exchange their rules. The syntax of messages is in conformance with the common **communication language**, $\mathcal{CL}_\mho$. A message $M_k = \langle S_k, H_k, A_k \rangle \in \mathcal{CL}_\mho$ has an identifier M_k. It is uttered by a speaker ($S_k = \mathrm{speaker}(M_k)$) and addressed to a hearer ($H_k = \mathrm{hearer}(M_k)$) $A_k = \mathrm{act}(M_k)$ is the speech act of the message. It is composed of a locution and a content. The locution is one of the following: `question`, `assert`, `unknow`, `concede`, `challenge`, `withdraw`. The content, also called **hypothesis**, is a rule or a set of rules. As in [8] the speech acts have an argumentative and public semantics. We have presented here a model of agents who exchange hypothesis and argue. In the next section, we bound a formal area to shift from the one-agent notion of conviction to the n-agent notion of provability.

5 Dialectical system

When a set of social and autonomous agents deliberate, they reply each other in order to reach the goal of the interaction. Since we want to warrant that a practical agreement will be reached, we need to bound a formal area, called dialectical system, in which agents play and arbitrate. Moreover, we add a third agent who arbitrates in accordance with the estimated authority of the players, the uttered plans and her own rules and priorities.

During exchanges, the speech acts are not isolated but they respond each other. The syntax of moves is in conformance with the common **moves language**. A move $\mathrm{move}_k = \langle M_k, R_k, P_k \rangle \in \mathcal{ML}_\mho$ has an identifier move_k. It contains a message M_k as defined before. The moves are messages with some attributes to control the sequence. $R_k = \mathrm{reply}(\mathrm{move}_k)$ is the identifier of the move to which move_k responds. A move (move_k) is either an initial move ($\mathrm{reply}(\mathrm{move}_k) = \mathrm{nil}$) or a replying move ($\mathrm{reply}(\mathrm{move}_k) \neq \mathrm{nil}$). $\mathrm{P}_k = \mathrm{protocol}(\mathrm{move}_k)$ is the name of the protocol which is used. A dialectical system is composed of three agents. In this formal area, two agents play moves in front of a third agent to check that the initial hypothesis, *i.e.* the topic, can be reached.

Definition 7 *Let* $AC_{\Omega_A} = \langle \mathcal{C}_{\Omega_A}, V_{\Omega_A}, promote_{\Omega_A} \rangle$ *be a common value-based competence and* g_0 *a rule (the specification of a goal). The* ***dialectical system*** *on the topic* g_0 *is a 7-tuple* $DS_{\Omega_M}(c_0, AC_{\Omega_A}) = \langle N, judge, H, T, protocol, Z, (u_p)_{p \in N} \rangle$ *where:*

- $N = \{init, part\} \subset \mho_A$ *is a set of two agents called players: the initiator and the partner;*
- $judge \in \mho_A$ *is a third agent with a personal competence which contains the common competence* ($\mathcal{C}_{judge} \supseteq \mathcal{C}_{\Omega_A}$)*;*
- $\Omega_M \subseteq \mathcal{ML}_{\mho}$ *is a set of well-formed moves;*
- H *is the set of histories, i.e. the sequences of well-formed moves;*
- $T : H \to N$ *is the turn-taking function determining the speaker of a move;*
- *protocol* $: H \to \Omega_M$ *is the function determining the moves which are allowed or not to expand an history;*
- Z *is the set of deliberation, i.e. the terminal histories which consist of maximally long histories.*

In order to be well-formed, the initial move is a question about the topic from the judge to the initiator and the partner and a replying move from a player references an earlier move uttered by one of the other players. Obviously, all moves should contain the same value for the protocol parameter. The judge computes the final practical agreement. At the history h, the judge is associated to the extended competence $\text{AC}^*_{judge}(h) = \langle \mathcal{C}^*_{judge}(h), V^*_{judge}, \text{promote}^*_{judge}, \ll^*_{judge} \rangle$ where:

- the extended personal competence contains the common competence and the commitments of players: $\mathcal{C}^*_{judge}(h) \supseteq \mathcal{C}_{\Omega_A} \cup \text{CS}^{judge}_{init}(h) \cup \text{CS}^{judge}_{part}(h)$;
- the extended set of values is composed of the common values and the reputation values of the two players: $V^*_{judge} = V_{\Omega_A} \cup \{v^{judge}_{init}, v^{judge}_{part}\}$.

The set of convincing plans for the judge depends on the history, the reputation of players and her own rules and priorities. The reputation relation of the judge corresponds to the global social order. s_1 is **provable at the history** h (written $\text{provable}^h(s_1)$) if $s_1, \epsilon \vdash g_0$ and the judge is convinced by s_1 at the history h. The deliberation computes the n-agent notion of provability. In this way, the arbitrage of the judge depends on the plans exchanged and the estimated authority of the players and her own rules and priorities.

We have bound here the area in which the deliberations take place to define the n-agent notion of provability. In order to deliberate, we formalize in the next section a protocol.

6 Protocol

When a set of social and autonomous agents deliberate, they collaborate to confront their convictions. In this section we illustrate our dialectical system with a protocol where agents reach a practical agreement by verbal means [1]. In this paper, we formalize this protocol. The protocol consists of the sequence rules represented in the table 2. Each rule specifies the authorized replying moves. For example, the rule of "Assertion/Refutation" (written $\text{sr}_{A/R}$) specifies the authorized moves replying to the previous assertion ($\texttt{assert}(H)$). The speech acts resist or surrender to the previous one. Contrary to the resisting acts, the surrendering acts close the deliberation. A concession ($\texttt{concede}(H)$) surrenders to the previous assertion. A challenge (challenge(h)) and a refutation ($\texttt{assert}(h_2)$) resist to the previous assertion. As previously said, the speech acts $\texttt{question}(h)$, $\texttt{challenge}(h)$, $\texttt{unknow}(h)$, and $\texttt{withdraw}(h)$ are used to manage the sequence of moves. On one side, a question initiates the deliberation. On the other side, a plea of ignorance and a withdrawal close the deliberation. A challenge is a request for a plan.

In order to confront her conviction with the partner, an agent initiates a deliberation. If the partner has no plan for the topic, she pleads ignorance and closes the deliberation. If the players have the same convictions, the judge is convinced and the deliberation closes. Otherwise, the goal of the deliberation is to reach a pratical agreement by verbal means. The following example illustrates such a protocol.

Sequences rules	Speech acts	Resisting replies	Surrendering replies
$\text{sr}_{Q/A}$	question(g_0)	assert$(s_1), s_1, \epsilon \vdash g_0$	unknow(g_0)
$\text{sr}_{A/R}$	assert(H)	challenge(h), $h \in H$ assert(h_2), $\exists h_1 \in H\ h_1 \bot h_2$	concede(H)
$\text{sr}_{C/A}$	challenge(h)	assert(H), $H, \epsilon \vdash h$	withdraw(h)
sr_T	unknow(H)	$\emptyset$	$\emptyset$
	concede(H)	$\emptyset$	$\emptyset$
	withdraw(H)	$\emptyset$	$\emptyset$

Table 2: Set of speech acts and the potential answers.

$\mathcal{C}_1^* - \mathcal{C}_{\Omega_A}$		$\mathcal{C}_{\Omega_A}$ $c_{11}, c_{12}, c_{21}, c_{22}, c_{23}$	$\mathcal{C}_2^* - \mathcal{C}_{\Omega_A}$	
$\mathcal{C}_1$	CS_2^1	Game situation	CS_1^2	$\mathcal{C}_2$
premise(B)	$\emptyset$	0	$\emptyset$	premise(C)
		$\leftarrow$ buyer question$(g(\text{price}))$ $\rightarrow$		
premise(B)	$\emptyset$	1	$\emptyset$	premise(C)
		$\rightarrow$ a_1 assert$(g(1000))$ $\rightarrow$		
premise(B)	$\emptyset$	2	$g(1050)$	premise(C)
		$\leftarrow$ a_2 assert$(g(800))$ $\leftarrow$		
premise(B)	total$(a_x, 800)$	3	$g(1000)$	premise(C)
		$\leftarrow$ buyer challenge$(g(800))$ $\leftarrow$		
premise(B)	total$(a_x, 800)$	4	$g(1000)$	premise(C)
		$\leftarrow$ $a_2$assert(premise(C)) $\leftarrow$		
premise(B)	premise(C)	5	total$(a_x, 1000)$	premise(C)
		$\leftarrow$ buyer challenge$(g(1050))$ $\leftarrow$		
premise(B)	premise(C)	6	$\emptyset$	premise(C)
		$\rightarrow$ a_1 assert(premise(B)) $\rightarrow$		
premise(B)	premise(C)	7	premise(B)	premise(C)
		$\leftarrow$ buyer concede(premise(A)) $\rightarrow$		
premise(B)	premise(C)	8	premise(B)	premise(C)

Table 3: Deliberation to reach an agreement

Example 2 *Let us consider a deliberation between two services providers (a_1 and a_2) in front a buyer who judges. The value-based competence of the agents a_1 (resp. a_2) is composed of the common competence and the rules in the premise(B)) (resp. the rules in the premise(C)). The value-based competence of the buyer is composed of the common competence and the rule $g(< 1050)$ The commitments stores result from the sequence of moves (cf table 3). The arbitrage of the buyer depends on the advanced plans, the estimated authority of the players and her personal rule total$(buyer, < 1050)$. At the end of the dialogue, the buyer composes the services and is convinced by a plan for transportation from Lille to Ottawa which costs less than 1050 euros (the argument A).*

We have formalized here a protocol to reach a practical agreement. Since this paper extends [8], we can warrant as in [8] that the dialogue are finite and leads to an agreement.

7 Related works

Classicaly, argumentation has been mainly concerned with theoretical reasoning to check beliefs veracity [6, 3, 4]. A coherent framework has been proposed in [8] to reconcile, combine and extend these technics. In this paper, our contribution, like other recent works [12, 13, 14], is concerned with practical reasoning with our own instantiation of the *abstract* argumentation framework of Dung [6] (cf section 3).

On one hand, Amgoud [12] has presented an argumentation framework for generating argumentative plans from a given set of beliefs, goals and planning rules. This work was later was extended in [13] with argumentation frameworks that generate the goals themselves from beliefs. In [11], the generation of goals are more general. On the other hand, Hulstijn and van der Torre [14] propose argumentative plans which contains only goals in the conclusions. By constrast with Amgoud's and Hulstijn's frameworks which focus a generic mechanism allowing an agent to compose her beliefs, goals and plans for generating consistent plans or consistent goals, we focus in this paper on a dialogical mechanism between software agents to jointly elaborate common plans, reason, exchange and compose them (cf sections 4, 5, and 6).

8 Conclusions

We have proposed in this paper a framework for inter-agents dialogue on actions, which formalize a deliberative process. This framework bounds a dialectical system in which argumentative agents arbitrate and play to reach a practical agreement. For this purpose, we have proposed an argumentation-based reasoning to manage the conflicts between plans having different strengths for different agents. Moreover, we have proposed a model of agents which justify the plans to which they commit and take into account the plans of their interlocutors. In the scope of our dialectical system, a third agent is responsible of the final decision outcome which is taken according to the autority of the players, the uttered plans and her own rules and priorities. We have illustrated this paper with a services composition.

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