A formal framework for inter-agents dialogue to reach an ontological agreement

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Abstract. We propose in this paper DIALOCR, *i.e.* a framework for inter-agents dialogue to reach an ontological agreement, which formalize a debate in which the divergent representations are discussed. For this purpose, we propose an argumentation-based representation framework which manages the conflicts between representations with different relevances for different audiences to compute their acceptance. Moreover, we propose a model for the reasoning of agents where they justify the definition to which they commit and take into account the definitions of their interlocutors. This framework bounds a dialectics system in which two agents play a dialogue to reach an agreement about a conflict of representation.

1 Introduction

A fundamental communication problem in open multiagent systems is caused by the heterogeneity of the knowledge of agents, in particular the underlying ontologies. The approaches, such as standardization [6] and ontology alignment [4], are not suited due to the openness of the system. Since the standardization require that all parties involved reach consensus on which ontology to use, this way is very unlikely. The ontology alignment is a technique that enables agents to keep their individual ontologies by making use of mappings. It assumes that the mappings can be predefined before the interactions. However, it is not known *a priori* which ontologies should be mapped in an open multiagent system. The conflicts of representation should not be avoid but resolved [1]. Contrary to [3], our work is not restricted to a protocol but also provide a model of reasoning and a model of agents.

In this paper, we aim at using argumentative technics in order to provide a dialogical mechanism for the agents reach an agreement on their representations. We extend here DIAL [7] to DIALROA (*DIALOCR Is an Argumentative Labour to Reach an Ontological Agreement*), *i.e.* a formal framework in which agents argue to reach a consensus about a representation. We propose an argumentation-based representation framework, offering a way to compare definitions with a contradiction relation to compute their acceptance. We propose a model of reasonning for the agents put forward some definitions and take into account other definitions coming from their interlocutors. We bound here a dialectics system in which a protocol makes possible for two agents to reach an agreement about a representation.

Paper overview. In the section 2, we provide the syntax and the semantics of the description logic which is adopted in the rest of the paper. Section 3 presents the argumentation framework which manages the interaction between conflicting representations. 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 debate. The section 6 presents the protocol used to reach an agreement. Section 7 concludes.

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2 Ontology

In this section, we provide the syntax and the semantics for the well-known $\mathcal{ALC}$ [8] which is adopted in the rest of the paper.

In $\mathcal{ALC}$, primitive concepts, denoted $C, D, \ldots$ are interpreted as unary predicates and primitive roles, denoted $R, S, \ldots$, as binary predicates. We call description a complex concepts which can be built using constructors. The syntax of $\mathcal{ALC}$ is defined by the following BNF definition : $C \rightarrow \top|\bot|C|\neg C|C \sqcup D|C \sqcap D|\exists R.C|\forall R.C$

The semantics is defined by an interpretation $\mathcal{I} = (\Delta^{\mathcal{I}}, \cdot^{\mathcal{I}})$, where $\Delta^{\mathcal{I}}$ is the non-empty domain of the interpretation and $\cdot^{\mathcal{I}}$ stands for the interpretation function. The semantics of the constructors are summarized in the table 1.

Name	Syntax	Semantics
top concept	$\top$	$\Delta^{\mathcal{I}}$
bottom concept	$\bot$	$\emptyset$
concept	C	$C^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}}$
concept negation	$\neg C$	$\Delta^{\mathcal{I}} - C^{\mathcal{I}}$
concept conjunction	$C_1 \sqcap C_2$	$C_1^{\mathcal{I}} \cap C_2^{\mathcal{I}}$
concept disjunction	$C_1 \sqcup C_2$	$C_1^{\mathcal{I}} \cup C_2^{\mathcal{I}}$
existencial restriction	$\exists R.C$	$\{x \in \Delta^{\mathcal{I}}; \exists y \in \Delta^{\mathcal{I}}((x,y) \in R^{\mathcal{I}} \wedge y \in C^{\mathcal{I}})\}$
universal restriction	$\forall R.C$	$\{x \in \Delta^{\mathcal{I}}; \forall y \in \Delta^{\mathcal{I}}((x,y) \in R^{\mathcal{I}} \rightarrow y \in C^{\mathcal{I}})\}$

Table 1. Semantics of the $\mathcal{ALC}$ constructors

A knowledge base (KBase for short) $\mathcal{K} = \langle \mathcal{T}, \mathcal{A} \rangle$ contains a T-box $\mathcal{T}$ and a A-box $\mathcal{A}$. The T-box includes a set of concept definition ($C \equiv D$) where C is the concept name and D is a description given in terms of the language constructors. The A-box contains extensional assertions on concepts and roles. For example, a (resp. (a,b)) is an instance of the concept C (resp. the role R) iff $a^{\mathcal{I}} \in C^{\mathcal{I}}$ (resp. $(a^{\mathcal{I}}, b^{\mathcal{I}}) \in R^{\mathcal{I}}$). We call **claims**, the set of concept definitions and assertions contained in the knowledge base. A notion of subsumption between concepts is given in terms of the interpretations.

Definition 1 (Subsumption) *Let C and D be two concepts. C **subsumes** D (denoted $C \sqsupseteq D$) iff for every interpretation $\mathcal{I}$ its holds that $C^{\mathcal{I}} \supseteq D^{\mathcal{I}}$.*

Indeed, $C \equiv D$ amounts to $C \sqsupseteq D$ and $D \sqsupseteq C$. We can remark that axioms based on subsumption ($C \sqsupseteq D$) are allowed in the KBases as partial definition. Below we will use $\mathcal{ALC}$.

3 Argumentation KBase

At first, we consider that the agents share a common KBase. In order to manage the interactions between conflicting claims, we considers an argumentation KBase.

We present in this section a value-based argumentation KBase, *i.e.* an argumentation framework built around the underlying logic language $\mathcal{ALC}$, where the revelance of definitions and assertions depends on the audience. The KBase is a set of sentences in a common language, denoted $\mathcal{ALC}_{\mho}$, associated with a classical inference, denoted $\vdash_{\mho}$. In a debate, we are concerned by a set of audiences (denoted $\mho_A = \{\mathrm{a}_1, \ldots, \mathrm{a}_n\}$). The audiences share an argumentation KBase, *i.e.* a set of claims promoting values:

Definition 2 *Let $\mho_A = \{a_1, \ldots, a_n\}$ be a set of audiences. The* ***value-based argumentation KBase*** *$AK_{\mho_A} = \langle \mathcal{K}, V, promote \rangle$ is defined by a triple where:*

- *$\mathcal{K} = \langle \mathcal{T}, \mathcal{A} \rangle$ is a KBase, i.e. a finite set of claims in $\mathcal{ALC}_{\mho}$;*
- *V is a non-empty finite set of values $\{v_1, \ldots, v_t\}$;*
- *promote : $\mathcal{K} \rightarrow V$ maps from the claims to the values.*

We say that the claim ϕ relates to the value v if ϕ promotes v. For every $\phi \in \mathcal{K}$, promote$(\phi) \in V$.

Since audiences differ by their hierarchies of values, the values have different priorities for different audiences:

Definition 3 *Let $a_i \in \mho_A$ be an audience. The* ***value-based argumentation KBase of the audience a_i*** *is a 4-tuple $AK_i = \langle \mathcal{K}, V, promote, \ll_i \rangle$ where :*

- *$AK_{\mho_A} = \langle \mathcal{K}, V, promote \rangle$ is a value-based argumentation KBase as previously defined;*
- *$\ll_i$ 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 KBase into finite non-overlapping sets. The priority level of a non-empty KBase $K \subseteq \mathcal{K}$ (written $\mathrm{level}_i(K)$) is the least important value promoted by one element in K. On the one hand, a priority relation captures the value hierarchy of a particular audience. On the other hand, the KBase gathers the claims shared by the audiences. The definitions are built on this KBase. A definition is a relation of consequence between a premise and a conclusion:

Definition 4 *Let K be a KBase in $\mathcal{ALC}_{\mho}$. A* ***definition*** *is couple $A = \langle \Phi, \phi \rangle$ where ϕ is a claim and $\Phi \subseteq K$ is a non-empty set of claims such as : Φ is consistent and minimal (for set inclusion); $\Phi \vdash_{\mho} \phi$. Φ is the premise of A, written $\Phi = premise(A)$. ϕ is the conclusion of A, denoted $\phi = conc(A)$.*

In other words, the premise is a set of claims from which the conclusion can be inferred. A' is a **sub-definition** of A if the premise of A' is included in the premise of A. A' is a **trivial definition** if the premise of A' is a singleton. Since the KBase K can be inconsistent, the set of definitions (denoted $\mathcal{A}(K)$) will conflict.

Definition 5 *Let K be a KBase in $\mathcal{ALC}_{\mho}$ and $A = \langle \Phi, \phi \rangle, B = \langle \Psi, \psi \rangle \in \mathcal{A}(K)$ two definitions. A* ***attacks*** *B iff : $\exists \Phi_1 \subseteq \Phi, \Psi_2 \subseteq \Psi$ such as $\Phi_1 \vdash_{\mho} \chi$ and $\Psi_2 \vdash_{\mho} \neg\chi$.*

Because each audience is associated with a particular priority relation, the audiences individually evaluate the revelance of definitions.

Definition 6 *Let $AK_i = \langle \mathcal{K}, V, promote, \ll_i \rangle$ be the value-based argumentation KBase of the audience a_i and $A = \langle \Phi, \phi \rangle \in \mathcal{A}(\mathcal{K})$ a definition. According to AK_i, the* ***revelance of*** *A (written revelance$_i(A)$) is the least important value promoted by one claim in the premise.*

In other words, the revelance of definitions depends on the priority relation. Since the audiences individually evaluate the revelance of definitions, an audience can ignore the attack of a definition over another definition. According to an audience, a definition defeats another definition if they attack each other and the second definition is not more revelant than the first one:

Definition 7 *Let $AK_i = \langle \mathcal{K}, V, promote, \ll_i \rangle$ be the value-based argumentation KBase of the audience a_i and $A = \langle \Phi, \phi \rangle$, $B = \langle \Psi, \psi \rangle \in \mathcal{A}(\mathcal{K})$ two definitions. A* ***defeats*** *B* ***for AK_i*** *(written defeats$_i(A, B)$) iff $\exists \Phi_1 \subseteq \Phi, \Psi_2 \subseteq \Psi$ such as : i) $\Phi_1 \vdash_{\mho} \chi$ and $\Psi_2 \vdash_{\mho} \neg\chi$; ii) $\neg(level_i(\Phi_1) \ll_i level_i(\Psi_2))$. Similarly, we say that a set S of definitions defeats B if B is defeated by a definition in S.*

Considering the differenciate viewpoint of each audience, we focus on the following notion of acceptance:

Definition 8 *Let $AK_i = \langle \mathcal{K}, V, promote, \ll_i \rangle$ be the value-based argumentation KBase of the audience a_i. Let $A \in \mathcal{A}(\mathcal{K})$ be a definition and $S \subseteq \mathcal{A}(\mathcal{K})$ a set of definitions. A* ***is subjectively acceptable by AK_i with respect to S*** *iff $\forall B \in \mathcal{A}(\mathcal{K})$ defeats$_i(B, A) \Rightarrow$ defeats$_i(S, B)$.*

The following example illustrates this argumentation-based representation framework.

Example 1 *Let us consider two participants of the Foire de Paris arguing about the selection of a suitable transport service. Without loose of generality, we restrict the KBase to the T-box in this example. The value-based argumentation KBase of the audience a_1 (resp. a_2) is represented in the table 2 (resp. table 3). The audience is associated with a KBase, i.e. a set of claims ($\phi_{11}, \ldots, \phi_7$) and a set of values ($v_1, \ldots, v_7$). The claims corresponding to the goal relates to the value v_1. The common sense claims relate to the value v_2. The other claims relate to the values $v_3, \ldots, v_7$. According to an audience, a value above another one has priority over it. The five following definitions conflict:*
$A_1 = (\{\phi_{11}, \phi_3, \phi_{22}\}, Taxi(x))$;

$\ll_1$	V	$\mathcal{K}$	
↑	$\mathbf{v_1}$	$\phi_{\mathbf{11}}$: Trans$(\mathbf{x})$ $\phi_{\mathbf{21}}$: Trans$(\mathbf{x}) \sqsupseteq$ Subway$(\mathbf{x}) \sqcup$ Taxi$(\mathbf{x})$	
	$\mathbf{v_2}$	$\phi_{\mathbf{12}}$: Taxi$(\mathbf{x}) \sqcap$ Subway$(\mathbf{x}) \equiv \bot$ $\phi_{\mathbf{22}}$: Trans$(\mathbf{x}) \sqsupseteq$ Dest$(\mathbf{x}$, inParis$)$	
	v_7	ϕ_7 : Trans$(x) \sqsupseteq$ Dest$(x$, level2hallc$)$	
	v_6	ϕ_6 : Trans$(x) \sqsupseteq$ Dest$(x$, versailles$)$	
	v_5	ϕ_5 : Dest$(x$, versailles$) \sqsupseteq$ Taxi(x)	
	v_4	ϕ_4 : Dest$(x$, level2hallc$) \sqsupseteq$ Subway(x)	
	v_3	ϕ_3 : Dest$(x$, inParis$) \sqsupseteq$ Taxi(x)	

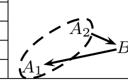


Table 2. The value-based argumentation KBase of the first participant

$\ll_2$	V	$\mathcal{K}$	
↑	$\mathbf{v_1}$	$\phi_{\mathbf{11}}$: Trans$(\mathbf{x})$ $\phi_{\mathbf{21}}$: Trans $\sqsupseteq$ Taxi$(\mathbf{x}) \sqcup$ Subway$(\mathbf{x})$	
	$\mathbf{v_2}$	$\phi_{\mathbf{12}}$: Taxi$(\mathbf{x}) \sqcap$ Subway$(\mathbf{x}) \equiv \bot$ $\phi_{\mathbf{22}}$: Trans$(\mathbf{x}) \sqsupseteq$ Dest$(\mathbf{x}$, inParis$)$	
	v_3	ϕ_3 : Dest$(x$, inParis$) \sqsupseteq$ Taxi(x)	
	v_4	ϕ_4 : Dest$(x$, level2hallc$) \sqsupseteq$ Subway(x)	
	v_5	ϕ_5 : Dest$(x$, versailles$) \sqsupseteq$ Taxi(x)	
	v_6	ϕ_6 : Trans$(x) \sqsupseteq$ Dest$(x$, versailles$)$	
	v_7	ϕ_7 : Trans$(x) \sqsupseteq$ Dest$(x$, level2hallc$)$	

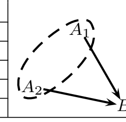


Table 3. The value-based argumentation KBase of the second participant

$A_2 = (\{\phi_{11}, \phi_5, \phi_6\}, Taxi(x))$;
$B = (\{\phi_{11}, \phi_4, \phi_7, \phi_{12}\}, \neg Taxi(x))$;
$B' = (\{\phi_{11}, \phi_4, \phi_7, \}, Subway(x))$.
B' is a sub-definition of B.
If we consider the value-based argumentation KBase of the audience a_1, the revelance of A_1 is v_3 and the revelance of B' is v_4. Therefore, B defeats A_1 but A_1 does not defeat B. If we consider the value-based argumentation KBase of the audience a_2, the revelance of A_1 is v_3 and the revelance of B' is v_7. Therefore, A_1 defeats B but B does not defeat A_1. Whatever the audience is, the set $\{A_1 A_2\}$ is subjectively acceptable wrt $\mathcal{A}(\mathcal{K})$.

We have defined here the mechanism to manage interactions between conflicting claims. In the next section, we present a model of agents which put forward claims and take into account other claims coming from their interlocutors.

4 Model of agents

In multi-agent setting it is natural to assume that all the agents do not use exactly the same ontology. Since the representations of agents can be common, complementary or contradictory, the agents exchange hypothesis and argue. Our agents individually valuate the perceived commitments wrt the estimated reputation of the agents from whom the information is obtained.

The agents, which have their own representations, record the commitments of their interlocutors [5]. Moreover, the agents individually valuate the reputation of their interlocutors. Therefore, an agent is in conformance with the following definition:

Definition 9 *The **agent** $a_i \in \mho_A$ is defined by a 6-tuple $a_i = \langle \mathcal{K}_i, V_i, \ll_i, promote_i, \cup_{j \neq i} CS^i_j, \prec_i \rangle$ where:*

- *$\mathcal{K}_i$ is a personal KBase, i.e. a set of personal claims in $\mathcal{ALC}_\mho$;*
- *V_i is a set of personal values;*
- *$promote_i : \mathcal{K}_i \to V_i$ maps from the personal claims to the personal values;*
- *$\ll_i$ is the priority relation, i.e. a strict complete ordering relation on V_i;*
- *CS^i_j is a commitment store, i.e. a set of claims in $\mathcal{ALC}_\mho$. $CS^i_j(t)$ contains commitments taken before or at time t, where agent a_j is the debtor and agent a_i the creditor;*
- *$\prec_i$ is the reputation relation, i.e. a strict complete ordering relation on $\mho_A$.*

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

We can distinguish two ways for an agent to valuate the commitments of her interlocutors: either in accordance with a global social order, or in accordance with a local perception of the interlocutor, called reputation. Obviously, this way is more flexible. Reputation is a social concept that links an agent to her interlocutors. It is also a leveled relation [2]. The individuated reputation relations, which are transitive, irreflexive, asymmetric, and complete relations on $\mho_A$, preserve these properties. $a_j \prec_i a_k$ denotes that an agent a_i trusts an agent a_k more than another agent a_j.In order to take into account the claims notified in the commitment stores, each agent is associated with the following extended KBase:

Definition 10 *The **extended KBase of the agent a_i** is the value-based argumentation KBase $AK^*_i = \langle \mathcal{K}^*_i, V^*_i, promote^*_i, \ll^*_i \rangle$ where:*

- *$\mathcal{K}^*_i = \mathcal{K}_i \cup [\bigcup_{j \neq i} CS^i_j]$ is the extended personal KBase of the agent composed of the personal KBase and the set of perceived commitments;*
- *$V^*_i = V_i \cup [\bigcup_{j \neq i} \{v^i_j\}]$ 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;*
- *$promote^*_i : \mathcal{K}^*_i \to V^*_i$ is the extension of the function $promote_i$ which maps from the claims in the extended personal KBase to the extended set of personal values. On the one hand, the personal claims relate to the personal values. On the other hand, the claims in the commitment store CS^i_j relate to the reputation value v^i_j;*
- *$\ll^*_i$ is the extended priority relation of the agent, i.e. an ordering relation on V^*_i.*

Since the debate is a collaborative social process, the agents share common claims (goal, common sense, ...) of prime importance. Therefore, the common values have priority over the other values.

Let us consider a debate between two agents, a visitor and a guide in the Foire de Paris. The guide considers that the claims of the visitor make authority and adjust her own representation to adopt these claims. By opposite, we will assume the visitor gives priority to the guide's claims. Therefore, there is an authority relation between the visitors and the guides. On the one hand, a guide should consider that the claims of a visitor are more revelant than her own claims. Therefore, the reputation values of her interlocutor have priority over her personal values. If a_j is a visitor, the extended priority relation of a guide a_i is constrained as follows : $\forall v_\omega \in V_{\Omega_A} \forall v \in V_i - V_{\Omega_A}$ $(v \ll^*_i v^i_j \ll^*_i v_\omega)$. On the other hand, a visitor should consider that her own claims are more revelant than the claims of a guide. If a_j is a guide, the extended priority relation of a visitor a_i is constrained as follows: $\forall v_\omega \in V_{\Omega_A} \forall v \in V_i - V_{\Omega_A}$ $(v^i_j \ll^*_i v \ll^*_i v_\omega)$.

We can easily demonstrate that the extended priority relation is a strict complete ordering relation. The one-agent notion of conviction is defined as follows:

Definition 11 *Let $a_i \in \mho_A$ be an agent associated with the extended KBase $AK^*_i = \langle \mathcal{K}^*_i, V^*_i, promote^*_i, \ll^*_i \rangle$ and $\phi \in \mathcal{ALC}_\mho$ a claim. The **agent a_i is convinced by the claim** ϕ iff ϕ is the conclusion of an acceptable definition of AK^*_i with respect to $\mathcal{A}(\mathcal{K}^*_i)$.*

The agents utter messages to exchange their representations. 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 ($S_k = \text{speaker}(M_k)$) and addressed to a hearer ($H_k = \text{hearer}(M_k)$). $A_k = \text{act}(M_k)$ is the speech act of the message. It is composed of a locution and a content. The locution is one of the following: `question`, `propose`, `unknow`, `concede`, `counter-propose`, `challenge`, `withdraw`. The content, also called **hypothesis**, is a claim or a set of claims in $\mathcal{ALC}_\mho$.

The speech acts have an argumentative and public semantics. Because a commitment enriches the extended KBase of the creditor, the speech acts have a public semantics. Because a commitment is justified by the extended KBase of the debtor, the speech acts have an argumentative semantics.

For example, an agent can propose a hypothesis if she has a definition for it. The corresponding commitments stores are updated. More formaly, an agent a_i can propose to the agent a_j an hypothesis h at time t if a_i has a definition for it. The corresponding commitments stores are updated: for any agent a_k ($\neq$ a_i) $CS_i^k(t) = CS_i^k(t-1) \cup \{h\}$.

The argumentative and social semantics of the speech act `counter-propose` is equivalent with the proposition one. The rational condition for the proposition and the rational condition for the concession of the same hypothesis by the same agent distinguish themselves. Agents can propose hypothesis whether they are supported by a trivial definition or not. By contrast, an agent does not concede all the hypothesis she hears in spite of they are all supported by a trivial definition which is in the commitment stores.

The other speech acts (question(h), challenge(h), unknow(h), and withdraw(h)) are used to manage the sequence of moves (cf section 6). They have no particular effects on the commitments stores, neither particular rational conditions of utterance. Since the speech act withdraw(h) has no effect on the commitments stores, we consider that the commitments stores are cumulative [9].

The hypothesis which are received must be valuated. For this purpose, the commitments will be individually considered in accordance with the estimated reputation of the agents from whom the information is obtained. The following example illustrates this principle.

Example 2 *If the agent a_1 utters the following message: $M_1 = \langle a_1, a_2, propose(Subway(x))\rangle$, then the extended KBase of the agent a_2 is as represented in the table 4.*

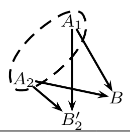
$\ll_2^*$	V_2^*	$\mathcal{K}_2^*$	
	$\mathbf{v_1}$	$\phi_{\mathbf{11}}$: Trans$(\mathbf{x})$ $\phi_{\mathbf{21}}$: Trans $\sqsupseteq$ Taxi$(\mathbf{x}) \sqcup$ Subway$(\mathbf{x})$	
	$\mathbf{v_2}$	$\phi_{\mathbf{12}}$: Taxi $\sqcap$ Subway $\equiv \bot$ $\phi_{\mathbf{22}}$: Trans$(\mathbf{x}) \sqsupseteq$ Dest$(\mathbf{x}$, inParis$)$	
	v_3	ϕ_3 : Dest$(x$, inParis$) \sqsupseteq$ Taxi(x)	
	v_4	ϕ_4 : Dest$(x$, level2hallc$) \sqsupseteq$ Subway(x)	
	v_5	ϕ_5 : Dest$(x$, versailles$) \sqsupseteq$ Taxi(x)	
	v_6	ϕ_6 : Trans$(x) \sqsupseteq$ Dest$(x$, versailles$)$	
	v_7	ϕ_7 : Trans$(x) \sqsupseteq$ Dest$(x$, level2hallc$)$	
	v_1^2	$\{$Subway(x)$\} = CS_1^2$	

Table 4. The extended KBase of the agent a_2

We have presented here a model of agents who exchange hypothesis and argue. In the next section, we bound a formal area where debates take place.

5 Dialectics system

When a set of social and autonomous agents argues, they reply to each other in order to reach the goal of the interaction, i.e. reach an agreement about a claim. We bound a formal area, called dialectics system, which is inspired by [7] and adapted to ontological dialogues.

During exchanges, the speech acts are not isolated but they respond each other. The moves are messages with some attributes to control the sequence. The syntax of moves is in conformance with the common **moves language** : $\mathcal{ML}_{\mho}$. A move $\text{move}_k = \langle M_k, R_k, P_k\rangle \in \mathcal{ML}_{\mho}$ has an identifier move_k. It contains a message M_k as defined before. $R_k = \text{reply}(\text{move}_k)$ is the identifier of the move to which move_k responds. A move (move_k) is either an initial move ($\text{reply}(\text{move}_k) = \text{nil}$) or a replying move ($\text{reply}(\text{move}_k) \neq \text{nil}$). $P_k = \text{protocol}(\text{move}_k)$ is the name of the protocol which is used.

A dialectics system is composed of three agents. In this formal area, two agents play moves to check an initial hypothesis, *i.e.* the topic.

Definition 12 *Let $AK_{\Omega_A} = \langle \mathcal{K}_{\Omega_A}, V_{\Omega_A}, promote_{\Omega_A}\rangle$ be a common value-based argumentation KBase and ϕ_0 a claim in $\mathcal{ALC}_{\mho}$. The* ***dialectics system*** *on the topic ϕ_0 is a quintuple $DS_{\Omega_M}(\phi_0, AK_{\Omega_A}) = \langle N, H, T, protocol, Z, \rangle$ where :*

- *$N = \{init, part\} \subset \mho_A$ is a set of two agents called players: the initiator and the partner;*
- *$\Omega_M \subseteq \mathcal{ML}_{\mho}$ is a set of well-formed moves;*
- *H is the set of histories, i.e. the sequences of well-formed moves s.t. the speaker of a move is determined at each stage by a turn-taking function and the moves agree with a protocol;*
- *$T : H \to N$ is the turn-taking function determining the speaker of a move. If $|h| = 2n$ then $T(h) = init$ else $T(h) = part$;*
- *$protocol : H \to \Omega_M$ is the function determining the moves which are allowed or not to expand an history;*
- *Z is the set of debates, 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 initiator to the partner and a replying move from a player references an earlier move uttered by the other player. In this way, backtracks are allowed. We call debate line the sub-sequence of moves where all the backtracks are ignored. In order to avoid loops, the redundancy of hypothesis is forbidden in the propositions of the same debate line. Obviously, all the moves should contain the same value for the protocol parameter.

We have bound here the area in which the ontoligical debates take place. We formalize in the next section a particular protocol to reach an agreement on a representation.

6 Protocol

When two agents have an ontological dialogue, they collaborate to confront their representations. For this purpose, we propose in this section a protocol.

To be efficient, the protocol is a unique-respond one where players can reply just once to the other player's moves. The protocols is a set of sequence rules (cf table 5). Each rule specifies the authorized replying moves.

For example, the rule of "Propose/Counter-Propose" (written $sr_{P/C}$) specifies the authorized moves replying to the previous propositions (propose(Φ)). The speech acts resist or surrender to the previous one. Contrary to resisting acts, surrendering acts close the debate. A concession (concede(Φ)) surrenders to the previous proposition. A challenge (challenge(ϕ)) and a counter-proposition (counter-propose(ϕ)) resist to the previous proposition.

Sequences rules	Speech acts	Resisting replies	Surrendering replies
$sr_{Q/A}$	question(ϕ)	propose$(\phi'), \phi \vdash \mho\phi'$	unknow(ϕ)
$sr_{P/C}$	propose(Φ)	challenge$(\phi), \phi \in \Phi$ counter-propose$(\phi), \phi \notin \Phi$	concede$(\phi), \Phi \vdash_{\mho} \phi$
$sr_{C/P}$	challenge(ϕ)	propose$(\Phi), \Phi \vdash_{\mho} \phi$	withdraw(ϕ)
$sr_{Rec/P}$	counter-propose(Φ)	propose$(\Phi'), \Phi \subseteq \Phi'$	withdraw(Φ)
sr_T	unknow(Φ)	$\emptyset$	$\emptyset$
	concede(Φ)	$\emptyset$	$\emptyset$
	withdraw(Φ)	$\emptyset$	$\emptyset$

Table 5. Set of speech acts and the potential answers.

As said in the section 4, the argumentative and social semantics of a counter-proposition is equivalent to the proposition one. Due to their place in the sequence of moves, these two speech acts are different.

The figure 1 shows a debate in the extensive form game representation where nodes are game situations and edges are associated with moves. For example, 2.3^{init} denotes a game situation where the exponent indicates that the initiator is the speaker of the next move. The exponent of game-over situations are boxes (*e.g.* $2.1^{\square}$, $3.2^{\square}$, and $4.2^{\square}$). For evident clarity reasons, the game which follows the situation 2.2^{init}, 4.4^{init}, and 6.3^{init} are not represented. In order to confront her representation with a partner, an initiator begins a debate. If the partner has no representation of the topic, she pleads ignorance and closes the dialogue (cf game situation $2.1^{\square}$). If the players have the same representation, the dialogue closes (cf game situation $3.2^{\square}$). Otherwise, the goal of the dialogue is an ontological agreement by verbal means. The following example illustrates such a debate.

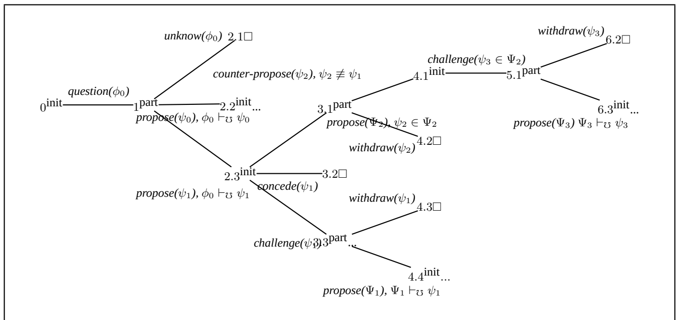


Figure 1: Debate in an extensive form game representation

Example 3 *Let us consider a dialogue between a visitor and a guide in the Foire de Paris. In the initial situation, the value-based argumentation KBase of the visitor (resp. the guide) are represented in the table 6 (resp. table 7). The commitments stores are the results of the sequence of moves (cf table 8).*

$\ll_1^*$	V_1^*	$\mathcal{K}_1^*$	
↑	$\mathbf{v_1}$	$\phi_{\mathbf{11}}$: Trans($\mathbf{x}$) $\phi_{\mathbf{21}}$: Trans $\sqsupseteq$ Taxi($\mathbf{x}$) $\sqcup$ Subway($\mathbf{x}$)	
	$\mathbf{v_2}$	$\phi_{\mathbf{12}}$: Taxi $\sqcap$ Subway $\equiv \bot$ $\phi_{\mathbf{22}}$: Trans($\mathbf{x}$) $\sqsupseteq$ Dest($\mathbf{x}$, inParis)	
	v_6	ϕ_6 : Trans(x) $\sqsupseteq$ Dest(x, versailles)	
	v_2^1	$\emptyset = \mathrm{CS}_2^1$	

Table 6. Extended argumentation KBase of the visitor

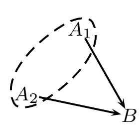
$\ll_2^*$	V_2^*	$\mathcal{K}_2^*$	
↑	$\mathbf{v_1}$	$\phi_{\mathbf{11}}$: Trans($\mathbf{x}$) $\phi_{\mathbf{21}}$: Trans $\sqsupseteq$ Taxi($\mathbf{x}$) $\sqcup$ Subway($\mathbf{x}$)	
	$\mathbf{v_2}$	$\phi_{\mathbf{12}}$: Taxi $\sqcap$ Subway $\equiv \bot$ $\phi_{\mathbf{22}}$: Trans($\mathbf{x}$) $\sqsupseteq$ Dest($\mathbf{x}$, inParis)	
	v_1^2	$\emptyset = \mathrm{CS}_1^2$	
	v_3	ϕ_3 : Dest(x, inParis) $\sqsupseteq$ Taxi(x)	
	v_4	ϕ_4 : Dest(x, level2hallc) $\sqsupseteq$ Subway(x)	
	v_5	ϕ_5 : Dest(x, versailles) $\sqsupseteq$ Taxi(x)	
	v_6	ϕ_6 : Trans(x) $\sqsupseteq$ Dest(x, versailles)	
	v_7	ϕ_7 : Trans(x) $\sqsupseteq$ Dest(x, level2hallc)	

Table 7. Extended argumentation KBase of the guide

We have proposed here a protocol to reach an ontological agreement.

7 Conclusions

We have proposed in this paper DIALROAR, *i.e.* a framework for inter-agents dialogue to reach an ontological agreement, which formalizes a debate in which divergent concept definitions and assertions are discussed. For this purpose, we have proposed an

$\mathcal{K}_1^* - \mathcal{K}_{\Omega_A}$		$\mathcal{K}_{\Omega_A}$ $\phi_{11}, \phi_{21}, \phi_{12}, \phi_{22}$	$\mathcal{K}_2^* - \mathcal{K}_{\Omega_A}$	
$\mathcal{K}_1$	CS_2^1	Game situation	CS_1^2	$\mathcal{K}_2$
ϕ_6	$\emptyset$	0	$\emptyset$	$\phi_3, \ldots, \phi_7$
		$\rightarrow$ question(Trans(x)) $\rightarrow$		
ϕ_6	$\emptyset$	1	$\emptyset$	$\phi_3, \ldots, \phi_7$
		$\leftarrow$ propose(Taxi(x)) $\leftarrow$		
ϕ_6	Taxi(x)	2	$\emptyset$	$\phi_3, \ldots, \phi_7$
		$\rightarrow$ challenge(Taxi(x)) $\rightarrow$		
ϕ_6	Taxi(x)	3	$\emptyset$	$\phi_3, \ldots, \phi_7$
		$\leftarrow$ propose(ϕ_3, ϕ_{22}) $\leftarrow$		
ϕ_6	Taxi(x), ϕ_3	4	$\emptyset$	$\phi_3, \ldots, \phi_7$
		$\rightarrow$ counter-propose(ϕ_6) $\rightarrow$		
ϕ_6	Taxi(x), ϕ_3	5	ϕ_6	$\phi_3, \ldots, \phi_7$
		$\leftarrow$ propose(Taxi(x), ϕ_6, ϕ_5) $\leftarrow$		
ϕ_6	Taxi(x), ϕ_3, ϕ_5	6	ϕ_6	$\phi_3, \ldots, \phi_7$
		$\rightarrow$ concede(Taxi(x)) $\rightarrow$		
ϕ_6	Taxi(x), Φ_3, ϕ_5	$\square$	ϕ_6, Taxi(x)	$\phi_3, \ldots, \phi_7$

Table 8. Dialogue to reach an ontological agreement

argumentation-based representation framework which manages the conflicts between definitions having different relevances for different audiences to compute their acceptance. Moreover, we propose a model for the reasoning of agents where they justify the claims to which they commit and take into account the claims of their interlocutors. This framework bounds a dialectics system in which two agents play a dialogue to reach an agreement about a claim.

Future works will investigate the possiblity to combine the dialogues with different participants to reach the global goal of the open multiagent system.

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