DIAGAL: a Generic ACL for Open Systems

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Abstract. In this paper, we present the latest version of our dialogue games based agent communication language (DIAGAL) which allows the agents to manipulate the public layer of social commitments through dialogue. We show that DIAGAL is complete according to the sequential creation, cancellation, update and discharge of social commitments. We also extend and refine notions of success and satisfaction previously associated with speech-acts to this new dialogical setting. Finally, we explain why DIAGAL is a good candidate for open and heterogeneous MAS development.

1 Introduction

Regarding communication, the multi-agent systems (MAS) community has been concentrating for some years on building a standard interactional framework. Main current agent communication languages (ACL), KQML and FIPA-ACL [1], are both based on speech acts theory. In those ACLs, semantics of messages is formulated in terms of mental states, i.e., private aspects of agents [2]. Dialogue is supposed to emerge from the chaining of produced speech acts stemming from agents' intentions by way of recognition and reasoning on others' mental states.

More recently, the use of these approaches for artificial agents communication has been criticized [3, 4]. Among these critics, we can note the semantic verification problem: agents should be able to verify that the others act according to held dialogues[1]. For messages semantics to be verifiable, it would be necessary to have access to agents' private mental states which is generally not possible. A second major problem raised by this formulation is the sincerity assumption. This hypothesis, necessary for the definition of ACL mentalistic semantic, is considered too restrictive by the MAS community since it forbids certain dialogue types in domains where such a hypothesis would not hold, as is the case for negotiation dialogues in electronic business for instance [5].

[1] This semantics verification should not be mistaken with the formal semantics checking: agents are implemented in accordance with the ACL mathematical or logical semantics.

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This is why some authors have proposed social approaches for agent communication introducing a public conventional layer expressed in terms of social commitments [6]. These approaches (1) resolve the semantic verification problem, (2) do away with the sincerity hypothesis and, (3) facilitate the treatment of the social aspects of communication. These new approaches inaugurate a shift of paradigm since *agents do not necessarily have to reason on others intentions anymore but rather they must reason on taken and to be taken social commitments*. These social commitments are those stemming from past dialogues, issued from systems conventions and norms or associated to agents' roles. In that context, dialogue units (which could be speech acts as well as dialogue games) are seen as a means to manipulate the social commitments layer. For example, asking an agent to close the door would be seen as an attempt to commit him to do so (i.e. an attempt to create a new social commitment) instead of an attempt to make him adopt the corresponding (unverifiable) intention. Among these social commitments based approaches, which can be considered as conventional, dialogue games [7, 8, 9, 10] offer a compromise between strictly speech acts based approaches (with either "mentalistic" or "social" semantics) which do not specify anything about dialogue structure (which is supposed to emerge) and protocols which reduce the searching space for possible continuations to its strict minimum, causing the loss of the flexibility and adaptability of conversations.

The next sections will describe (section 2), discuss and exemplify (section 2.6) the main components of our dialogue games agent communication language (DIAGAL). We will then extend and refine the notions of success and satisfaction traditionally associated with speech acts (section 3). Finally, we will discuss DIAGAL for heterogenous agents communication in open systems (section 4) before concluding.

2 A Dialogue Game Agent Language

2.1 Social Commitments

The notion of social commitment should not be confused with the notion of individual commitment used to emphasize individual intention persistance in practical reasoning nor with collective commitments which stand for the internal commitment of a group of agents. Conceptually, commitments are oriented responsibilities contracted towards a partner or a group. Following Walton and Krabbe [11], we distinguish action commitments from propositional commitments. Since [12] discusses our modelling of flexible social commitments and their enforcement through sanctions, we simply re-introduce the basic notations here.

Commitments are expressed as predicates with an arity of 6. Thus, an *accepted* action commitment takes the form:

$$C(x, y, \alpha, t, s_x, s_y)$$

meaning that agent x is committed towards agent y to α at time t, under the sanctions s_x and s_y. An accepted propositional commitment would have propositional content p instead α. *Rejected* commitments, meaning that x is not committed toward y to α, take the form $\neg C(x, y, \alpha, t, s_x, s_y)$. This notation for commitments is inspired from [13], and allows us to compose the actions or propositions involved in the commitments: $\alpha_1|\alpha_2$ classically stands for the choice, and $\alpha_1 \Rightarrow \alpha_2$ for the conditional statement that α_2 will occur in case of the occurrence of the event α_1. Finally, agents keep track of each commitment in which they are debtor or creditor in their *agendas*, which constitutes a kind of distributed "Commitment Store".

Now, we need to describe the mechanism by which the commitments are discussed and created, updated, cancelled or even discharged through dialogue. This mechanism is precisely modelled within our game structure.

2.2 Game Structure

The main particularity of social commitments is that they must be socially established in order to hold. This means that every change on the social commitment layer (reified in agendas) should be grounded by the conversing agents. We share with others [7, 8, 9] the view of dialogue games as structures regulating the mechanism under which some commitments are discussed through the dialogue. However, unlike previous models [7, 8, 9], we adopt a strict commitment-based approach within game structure and express the dialogue rules in terms of dialogical commitments [6]. To account for the fact that some commitments are established within the contexts of some games and only make sense within this context, we make explicit the fact that those *dialogical commitments* are particular to game g (by indicating g as a subscript). This will typically be the case of the dialogue rules involved in the games, as we will see below. In our approach, games are considered as bilateral structures defined by:

- *entry conditions*, (E): expressed in terms of extra-dialogical commitments, entry conditions are conditions which must be fulfilled to enter the game;
- *dialogue rules*, (R): expressed in terms of dialogical commitments, dialogue rules specify what the conversing agents are "dialogically" committed to do. The fulfilment of those rules will lead to reaching either the success or the failure conditions of the game;
- *success conditions*, (S): success conditions indicate the result, the effect in terms of extra dialogical commitments, of the dialogue game if the modification of the public layer which was the purpose of the game has been socially accepted;
- *failure conditions*, (F): failure conditions indicate the effect in terms of extra dialogical commitments of the dialogue game if the modification of the public layer has been socially rejected;

Move	Operations
$prop.in(x, y, g)$	$create(y, C_g(y, x, acc.in(y, x, g)$ $\|ref.in(y, x, g)\|prop.in(y, x, g'))))$
$prop.out(x, y, g)$	$create(y, C_g(y, x, acc.out(y, x, g)$ $\|ref.out(y, x, g))))$
$acc.in(x, y, g)$	create dialogical commitments for game g
$acc.out(x, y, g)$	suppress dialogical commitments for game g
$ref.in(x, y, g)$	no effect on the public layer
$ref.out(x, y, g)$	no effect on the public layer

Fig. 1. DIAGAL contextualization game

2.3 Grounding and Composing the Games

The specific question of how games are grounded through the dialogue is certainly one of the most delicate. *Grounding* refers to the process of reaching mutual belief (or common ground) [14]. We model it using presentation and acceptance. Following [15], we assume that agents can use some meta-acts of dialogue to handle the games structuration and thus propose to enter a game, propose to leave a game, and so on. Games can have different status: they can be *open*, *closed*, or simply *proposed*. How this status is discussed in practice is described in a *contextualization* game which regulates this meta-level communication as proposed in [6]. Figure 1 indicates the current contextualization moves and their effects in terms of commitments. For example, when a proposition to enter a game g ($prop.in(x, y, g)$) is played by agent x, agent y is committed to accept ($acc.in$), to refuse ($ref.in$) or to propose entering another game g' ($prop.in(y, x, g')$), which would lead to a presequencing type of dialogue games structuration.

Concerning the possibility of combining the games, the seminal work of [11] and the follow-up formalization of [15] have focused on the classical notions of *embedding* and *sequencing*. Recent works, including ours, extend this to other combinations [16, 9]:

- *Sequencing* noted $g_1; g_2$, which means that g_2 starts immediately after termination of g_1.
- *Choice* noted $g_1|g_2$, which means that participants play either g_1 or g_2 non-deterministically.
- *Pre-sequencing* noted $g_2 \hookrightarrow g_1$, which means that g_2 is opened while g_1 is proposed.
- *Embedding* noted $g_1 < g_2$, which means that g_1 is now opened while g_2 was already opened.

If one wants to make explicit the initiator and partner of each game, compositions can be rewritten as follows: $[x, y]g_1; [y, x]g_2$ or $[x, y]g_1|[y, x]g_2$ or $[x, y]g_2 \hookrightarrow [y, x]g_1$ or $[x, y]g_1 < [y, x]g_2$. In that case, $[x, y]g_1$ means that the initiator of g_1

is x and the partner is y. Notice that the previous contextualization game only considers sequencing, pre-sequencing and embedding.

2.4 Dialog Games

Within our framework, extra-dialogical commitments capture the shared semantics of dialogues seen as the grounded manipulation of the social layer. Being able to cancel or modify commitments is then a key feature that allows the agents to rediscuss the consequences, the common interpretation, of past dialogue as time goes on according to environment changes. This feature is essential in modern MAS deployed in dynamic and complex environments. This *semantical flexibility* should not be confused with the structural flexibility of dialogues.

Our social commitment model (which gives the operational semantics of the dialogue games presented below) is presented in [12] and considers five operations: creation, cancellation, update, discharge of fulfilled commitments and discharge of violated commitments. We have defined basic dialogue games for those operations according to the different types of commitments which can hold between two agents x and y. However, in order to save space and because the games for manipulating propositional commitments are highly similar to those that concern action commitments, we will present only the games that manipulate action commitments. DIAGAL contains 7 dialogue games that allow agents to attempt the aforementioned operations on action commitments:

1. for an attempt to have an action commitment from y toward x accepted, agent x can use a *Request* game (rg);
2. for an attempt to have an action commitment from x toward y accepted, agent x can use an *Offer* game (og);
3. for an attempt to retract an action commitment from x toward y, agent x can use a *Cancel.ActionC* game (cag);
4. for an attempt to retract an action commitment from y toward x, agent x can use a *Release.ActionC* game (rag);
5. for an attempt to update an action commitment , agent x or y can use an *Update.ActionC* game (uag);
6. for an attempt to discharge a violated action commitment, agent x can use a *Discharge.Violated.ActionC* game ($dvag$);
7. for an attempt to discharge a fulfilled commitment, agent x can use a *Discharge.Fulfilled.ActionC* game ($dfag$);

Notice that in the assumption that dialogue moves are made sequentially, the set of DIAGAL dialogue games is sound and complete according to our social commitment model (presented in [12]). *Completeness* means that all transitions (creation, cancellation, updating and discharge) of the underlying social-commitment model can be consumed by those games whereas *soundness* indicates that nothing other than those permitted transitions is possible. The latter is ensured through entry conditions that prevent, for example, cancelling a commitment that has not been created,...

Within commitments, time is expressed using a simple instant theory with $<$ as the precedence relation. The next subsections detail these games. Sanctions were omitted in our games specifications for better readability. Notice that the game rules structure provides an elegant turn-taking mechanism by entailing that $t_j < t_k < t_l < t_f$.

Request Game (rg) – This game captures the idea that the initiator x "requests" an action α from the partner y and the latter can "accept" or "refuse". The conditions and rules of the *request* game are as follows:

$$
\begin{array}{l|l}
E_{rg} & \neg C(y,x,\alpha,t_i) \text{ and } \neg C(y,x,\neg\alpha,t_i) \;\; \forall\, t_i,\; t_i < t_j \\
S_{rg} & C(y,x,\alpha,t_f) \\
F_{rg} & \neg C(y,x,\alpha,t_f) \\
R_{rg} & 1)\; C_g(x,y,\mathit{request}_{d_1}(x,y,\alpha),t_j) \\
 & 2)\; C_g(y,x,\mathit{request}_{d_1}(x,y,\alpha) \Rightarrow \\
 & \quad C_g(y,x,\mathit{accept}_{d_2}(y,x,\alpha)|\mathit{refuse}_{d_3}(y,x,\alpha),t_k),t_j) \\
 & 3)\; C_g(y,x,\mathit{accept}_{d_2}(y,x,\alpha) \Rightarrow C(y,x,\alpha,t_f),t_j) \\
 & 4)\; C_g(y,x,\mathit{refuse}_{d_3}(y,x,\alpha) \Rightarrow \neg C(y,x,\alpha,t_f),t_j)
\end{array}
$$

Offer Game (og) – An offer is a promise that is conditional upon the partner's acceptance. To make an offer is to put something forward for another's choice (of acceptance or refusal). To offer then, is to perform a conditional commissive. Precisely, to offer α is to perform a commissive under the condition that the partner accepts α. Conditions and rules of the DIAGAL *offer* game are as follows:

$$
\begin{array}{l|l}
E_{og} & \neg C(x,y,\alpha,t_i) \text{ and } \neg C(x,y,\neg\alpha,t_i) \;\; \forall\, t_i,\; t_i < t_j \\
S_{og} & C(x,y,\alpha,t_f) \\
F_{og} & \neg C(x,y,\alpha,t_f) \\
R_{og} & 1)\; C_g(x,y,\mathit{offer}_{d_1}(x,y,\alpha),t_j) \\
 & 2)\; C_g(y,x,\mathit{offer}_{d_1}(x,y,\alpha) \Rightarrow \\
 & \quad C_g(y,x,\mathit{accept}_{d_2}(y,x,\alpha)|\mathit{refuse}_{d_3}(y,x,\alpha),t_k),t_j) \\
 & 3)\; C_g(x,y,\mathit{accept}_{d_2}(y,x,\alpha) \Rightarrow C(x,y,\alpha,t_f),t_j) \\
 & 4)\; C_g(x,y,\mathit{refuse}_{d_3}(y,x,\alpha) \Rightarrow \neg C(x,y,\alpha,t_f),t_j)
\end{array}
$$

Cancel.ActionC Game (cag) – This game can be used in order to have an already accepted commitment rejected, i.e. to cancel a commitment. In this game, the debtor (x) of a commitment C_i proposes its cancellation. Then, the creditor can agree or not with the cancellation. If the creditor agrees with the retraction, the debtor will not have to face the sanction attached with the commitment C_i while he will have to do so if he disagrees. According to the creditor's opinion (agree or disagree), the debtor can decide to really cancel the commitment and face the associated sanction or change his mind and keep it (probably to avoid facing the sanctions). The conditions and rules of the *Cancel.Action* game are as follows:

$$
\begin{array}{l|l}
E_{cag} & \exists\ t_i,\ t_i < t_j : C(x, y, \alpha, t_i) \\
S_{cag} & \neg C(x, y, \alpha, t_i) \\
F_{cag} & C(x, y, \alpha, t_i) \\
R_{cag} & 1)\ C_g(x, y, cancel_{d_1}(x, y, (\alpha, t_i)), t_j) \\
 & 2)\ C_g(y, x, cancel_{d_1}(x, y, (\alpha, t_i)) \Rightarrow \\
 & \quad C_g(y, x, agree_{d_2}(y, x, cancel_{d_1}(\alpha, t_i))| \\
 & \qquad disagree_{d_3}(y, x, cancel_{d_1}(\alpha, t_i)), t_k), t_j) \\
 & 3)\ C_g(x, y, disagree_{d_3}(y, x, cancel_{d_1}(\alpha, t_i)) \Rightarrow \\
 & \quad C_g(x, y, confirm_{d_4}(x, y, cancel_{d_1}(\alpha, t_i))| \\
 & \qquad decline_{d_5}(x, y, cancel_{d_1}(\alpha, t_i)), t_l), t_j) \\
 & 4)\ C_g(x, y, agree_{d_2}(y, x, cancel_{d_1}(\alpha, t_i)) \Rightarrow \neg C(x, y, \alpha, t_i), t_j) \\
 & 5)\ C_g(x, y, confirm_{d_4}(x, y, cancel_{d_1}(\alpha, t_i)) \Rightarrow \neg C(x, y, \alpha, t_i), t_j) \\
 & 6)\ C_g(x, y, decline_{d_5}(x, y, cancel_{d_1}(\alpha, t_i)) \Rightarrow C(x, y, \alpha, t_i), t_j)
\end{array}
$$

Release.ActionC Game (*rag*) – Similar to the *Cancel.ActionC* game, the *Release.ActionC* game allows retracting an action commitment and negotiating the sanction applications, but contrary to the former it allows the creditor instead of the debtor to attempt the cancellation. The rules of the *Release.ActionC* game are thus similar to the *Cancel.ActionC* game rules and they are as follows:

$$
\begin{array}{l|l}
E_{rag} & \exists\ t_i,\ t_i < t_j : C(y, x, \alpha, t_i) \\
S_{rag} & \neg C(y, x, \alpha, t_i) \\
F_{rag} & C(y, x, \alpha, t_i) \\
R_{rag} & 1)\ C_g(x, y, release_{d_1}(x, y, (\alpha, t_i)), t_j) \\
 & 2)\ C_g(y, x, release_{d_1}(x, y, (\alpha, t_i)) \Rightarrow \\
 & \quad C_g(y, x, agree_{d_2}(y, x, release_{d_1}(\alpha, t_i))| \\
 & \qquad disagree_{d_3}(y, x, release_{d_1}(\alpha, t_i)), t_k), t_j) \\
 & 3)\ C_g(x, y, disagree_{d_3}(y, x, release_{d_1}(\alpha, t_i)) \Rightarrow \\
 & \quad C_g(x, y, confirm_{d_4}(x, y, release_{d_1}(\alpha, t_i))| \\
 & \qquad decline_{d_5}(x, y, release_{d_1}(\alpha, t_i)), t_l), t_j) \\
 & 4)\ C_g(x, y, agree_{d_2}(y, x, release_{d_1}(\alpha, t_i)) \Rightarrow \neg C(y, x, \alpha, t_i), t_j) \\
 & 5)\ C_g(x, y, confirm_{d_4}(x, y, release_{d_1}(\alpha, t_i)) \Rightarrow \neg C(y, x, \alpha, t_i), t_j) \\
 & 6)\ C_g(x, y, decline_{d_5}(x, y, release_{d_1}(\alpha, t_i)) \Rightarrow C(y, x, \alpha, t_i), t_j)
\end{array}
$$

Update.ActionC Game (*uag*) – If an agent wants to modify a commitment (change any attribute(s) of the commitment except the debtor or the creditor), he can try to retract the commitment and create a new one with the new attribute. However, the cancellation may cause some undesirable sanctions to be applied. This is why, we have defined the *Update.ActionC* and *Update.PropC* games that allow attempts to update commitments without having to face sanctions.

In the *Update.ActionC* game, agent x who initiates the game asks agent y if he agrees to cancel the commitment C_i and replace it with the commitment C_j. Then, agent y can agree or not to the modification of the commitment. If

the agent y agrees with the modification, the commitment C_i is cancelled and a new commitment C_j is created.

The conditions and rules of the *Update.ActionC* game are indicated here, assuming that: (1) if the initiator x is the creditor then $cre = x$ and $deb = y$ while (2) if the initiator x is the debtor then $cre = y$ and $deb = x$:

$$
\begin{array}{l|l}
E_{uag} & \exists\ t_i,\ t_i < t_j : C(deb, cre, \alpha, t_i) \\
S_{uag} & \neg C(deb, cre, \alpha, t_i) \text{ and } C(deb, cre, \alpha', t_f) \\
F_{uag} & C(deb, cre, \alpha, t_i) \\
R_{uag} & 1)\ C_g(x, y, update_{d_1}(x, y, (\alpha, t_i), \alpha'), t_j) \\
 & 2)\ C_g(y, x, update_{d_1}(x, y, (\alpha, t_i), \alpha') \Rightarrow \\
 & \quad C_g(y, x, agree_{d_2}(y, x, update_{d_1}((\alpha, t_i), \alpha'))| \\
 & \qquad disagree_{d_3}(y, x, update_{d_1}((\alpha, t_i), \alpha')), t_k), t_j) \\
 & 3)\ C_g(x, y, agree_{d_2}(y, x, update_{d_1}((\alpha, t_i), \alpha')) \Rightarrow \\
 & \quad C(deb, cre, \alpha', t_f), t_j) \\
 & 4)\ C_g(x, y, agree_{d_2}(y, x, update_{d_1}((\alpha, t_i), \alpha')) \Rightarrow \\
 & \quad \neg C(deb, cre, \alpha, t_i), t_j) \\
 & 5)\ C_g(x, y, disagree_{d_3}(y, x, update_{d_1}((\alpha, t_i), \alpha')) \Rightarrow \\
 & \quad C(deb, cre, \alpha, t_i), t_j)
\end{array}
$$

Discharge.Violated.ActionC and Discharge.Fullfilled.ActionC Games. A socially accepted extra-dialogical commitment can be active (its conditions of satisfaction[2] can be met), violated (its conditions of satisfaction could not be met anymore) or fulfilled (its conditions of satisfaction has been met).

In our model, the violation as well as the fulfilment of an extra-dialogical action commitment must be grounded, and the agents may want the eventual associated sanctions or rewards to apply. The *Discharge.Violated.ActionC* (dvg) is the tool for attempting such a grounding while the *Discharge.Fullfilled.ActionC* (dfg) is used to discharge fulfilled action commitment. The use of those games eventually entail positive (for fulfilment) or negative (for violation) sanctions to apply as discussed in [12]. The conditions and rules of those games are as follows:

$$
\begin{array}{l|l}
E_{dfg} & \exists\ t_i,\ t_i < t_j : C(deb, cre, \alpha, t_i) \\
S_{dfg} & \neg C(deb, cre, \alpha, t_i) \\
F_{dfg} & C(deb, cre, \alpha, t_i) \\
R_{dfg} & 1)\ C_g(x, y, discharge_{d_1}(x, y, C(deb, cre, \alpha, t_i), t_j) \\
 & 2)\ C_g(y, x, discharge_{d_1}(x, y, C(deb, cre, \alpha, t_i) \Rightarrow \\
 & \quad C_g(y, x, accept_{d_2}|refuse_{d_3}, t_k), t_j) \\
 & 3)\ C_g(x, y, accept_{d_2}(y, x, \alpha) \Rightarrow apply(s_x) \text{ and } \neg C(x, y, \alpha, t_i), t_j) \\
 & 4)\ C_g(x, y, refuse_{d_3}(y, x, \alpha) \Rightarrow C(x, y, \alpha, t_i), t_j)
\end{array}
$$

[2] Which will not be defined here since they depend on the choice of a particular content language, which we leave open for genericness.

E_{dvg} | $\exists\ t_i,\ t_i < t_j : C(deb, cre, \alpha, t_i)$
S_{dvg} | $\neg C(deb, cre, \alpha, t_i)$
F_{dvg} | $C(deb, cre, \alpha, t_i)$
R_{dvg} | 1) $C_g(x, y, discharge_{d_1}(x, y, C(deb, cre, \alpha, t_i), t_j)$
| 2) $C_g(y, x, discharge_{d_1}(x, y, C(deb, cre, \alpha, t_i) \Rightarrow$
| $C_g(y, x, accept_{d_2} | refuse_{d_3}, t_{j+1}), t_j)$
| 3) $C_g(x, y, accept_{d_2}(y, x, \alpha) \Rightarrow apply(s_x)$ and $\neg C(x, y, \alpha, t_i), t_j)$
| 4) $C_g(x, y, refuse_{d_3}(y, x, \alpha) \Rightarrow C(x, y, \alpha, t_i), t_j)$

2.5 DIAGAL Extra-Features

Intensity Degrees – Notice that in previous games, the embedded speech acts are labelled with an integer d_x indicating the *illocutionary force intensity degree* relative to the default basic illocutionary force degree in Vandervecken [17] classification. For example, in the *request* game the embedded request speech act stands for the directive category for action which is mapped to: $suggest = -2$, $direct = -1$, $request = 0$, $demand = 1$, $order = 2$, according to the intensity degree factor dynamically chosen by the agent. Allowing agents to use the appropriate illocutionary forces intensity degree for each dialogue/speech act leads to many variations of those basic games. While being crucial in mixed communities, this feature is also important in modern agent communication language since some agent architectures allow the agent to use different meaningful intensity degrees [18].

Deontic Version – In order to use DIAGAL, agents should embed our *dialogue manager* (described in [18]) which (1) loads the contextualization game and the various dialog games and (2) manages the agenda according to dialogues. While doing so reduces the aforementioned semantic flexibility, in certain systems, it is simpler to model commitment as directed obligation that cannot be updated nor cancelled. To do so within DIAGAL, the dialogue managers just have to load the games for creations and discharges only.

Social Context – A great number of agents applications rely on an organizational level that structures the agents acquaintances and facilitates social control. In such systems, it can be the case, for example, that an agent is not allowed to reject requests from a hierarchical superior. In order to take this social context into account, we have supplied our dialogue manager with special features to update the rules of the different dialogue games to take into account three possibilities: (1) the conversing agent is on the same social level as the concerned agent, (2) the conversing agent is superior to the agent, (3) the conversing agent is inferior to the agent. For space reasons, we will just mention those features here.

2.6 Conversation Example

Suppose an agent x wishes that an agent y repair its car. Therefore, agent x proposes to agent y to enter a request game (the only game whose success condition is an action commitment of the wanted form). When the agent y receives the mes-

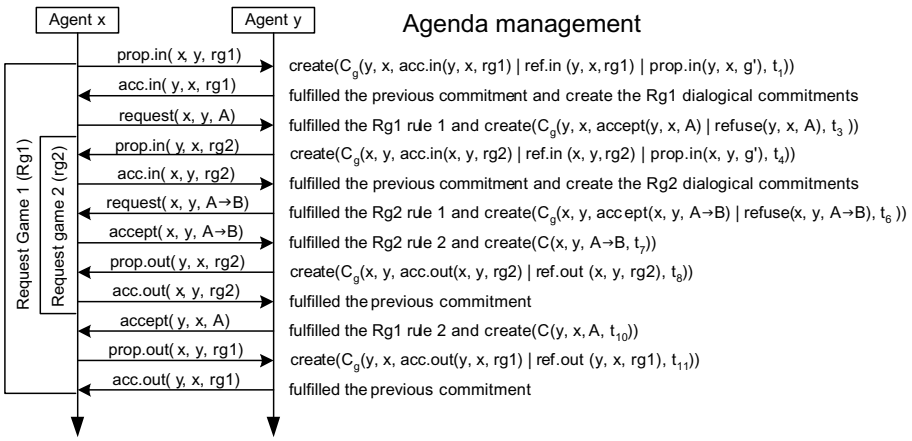

Fig. 2. Conversation example with agendas management

sage *prop.in(x,y,rg)* (issued from the contextualisation game, Figure 1) his dialogue manager adds the commitment $C(y, x, acc.in(y, x, rg)|ref.in(y, x, rg)|prop.in(y, x, g'))$ to his agenda. Agent y thus has three choices to fulfill this commitment: accept to play the game, refuse to play the game or propose another game.

For the sake of our example, we assume that y accepts to play a *Request* game, meaning that he has the resources and the will to enter a dialogue with x. The dialogue managers of x and y then add all the *Request* game rules (indicated in section 2.4) to their respective agendas. The first rule stipulates that x is committed to make a request $C(x, y, request(x, y, \alpha))$. Agent x thus makes his request in order to fulfill this dialogical commitment. The second rule indicates that if x makes a request, y is committed to accept or reject it. On its side, before responding to x's request, y decides to embed another *Request* game as an attempt to commit x to pay him if he accepts the request and repairs the car. The conversation continues according to the different rules sustaining dialogues games and agents' decisions. Finally, at the end of the conversation, two extra-dialogical commitments remain: $C(y, x, A)$ and $C(x, y, A \Rightarrow B)$ where A stands for the action "Repair the car" and B stands for the action "Pay for the car repairs". The complete conversation is presented in Figure 2. The left side of the figure presents the sequence diagram of the conversation between x and y while the right side presents the effects of each message on the contents of their agendas. Notice that the discharge of those commitments will occur once their fulfilment or violation have occurred, which are detected in the way described in [12].

3 Success and Satisfaction in DIAGAL

In standard speech act theory [17], success and satisfaction conditions play a central role. This section indicates how such fundamental notions are extended and refined in DIAGAL.

Success conditions of a speech act are the conditions that must hold in the utterance context in order for the speaker to succeed in its accomplishment. In the case of a promise, for example, the speaker should be ready to commit on the content of his promise and succeed in uttering his promise and he should be heard and understood by the appropriate agents [19].

By providing a dialogical rather than monological approach to language primitives, dialogue games allow extending and redefining success conditions in two different categories: dialogical success and extra-dialogical success. First, each DIAGAL game is played with *dialogical success* (which is close to the monological success conditions previously defined) if and only if all the dialogical commitments attached to it are fulfilled. That means the agents accept to enter the game and play it until the failure or success conditions are reached, with possible interruptions due to dialogue structure. Secondly, through success and failure conditions of the dialogue games, *extra-dialogical success* allows taking into account the hearer and thus introducing a more socially aware notion of success. Since from the hearer's point of view, an assertive succeeds if he agrees to it (independently of the truth of the content which is more related to the satisfaction conditions), a request succeeds if he accepts it.... In this context, there are several reasons why a dialogue game can fail: (1) the hearer can refuse to enter the game for several possible reasons (his attention is kept somewhere else, he doesn't have enough resources to process the communication at this particular time, he doesn't want to communicate with the initiator agent, ...) (2) the initiator embedded speech act success conditions are not fulfilled (meaning that the corresponding dialogical commitments is not fulfilled) (3) the failure conditions are reached, meaning that the hearer refuses the wanted change on the social layer. A dialogue game can thus be played with dialogical success and extra-dialogical failure.

On their side, *Satisfaction* conditions of a speech act gathers the conditions that must be obtained for the perlocutionary effects of this speech act to be obtained. For example, an assertion is satisfied if it's true, a request is satisfied if it is granted, a promise is satisfied if it is kept,... Satisfaction conditions relate speech acts to the world through their coverage of the different directions of fit between world and words. In social commitment based approaches, we need to consider only two of the four basic directions of fit[3]:

1. *The words-to-world direction of fit:* the point of speech acts having this direction of fit is to represent how things were/are/will be in the world. Such speech acts are satisfied when their propositional contents fit the state of affairs existing in the world.
2. *The world-to-words direction of fit:* the point of speech acts having this direction of fit is to have the world transformed by the speaker (commissive) or by the hearer (directive) in order to match the propositional content of

[3] The two other directions of fit are not necessary since no operation corresponding to the double direction of fit nor the empty one were defined in those approaches yet. The rationale for that is beyond the scope of this paper.

the utterance. Such a speech act is satisfied when the world is transformed to fit its propositional content.

Within DIAGAL, conditions of satisfaction are captured by the notion fulfilment of social commitments which indicate that the direction of fit between words and world is resolved. In our approach, social commitments keep track of the dialogues from which they are issued between the moment of extra-dialogical success and a hypothetical actual satisfaction time.

Thus, while traditional success and satisfaction conditions have always been problematic to implement and verify in distributed settings (without accessing the agents' mental states), the DIAGAL approach takes a step ahead. Notice that as in speech act theory, success and satisfaction conditions are linked in the sense that one cannot expect satisfaction without previous extra-dialogical success which itself requires dialogical success. Finally, the crucial question of establishing and verifying the fulfilment of social commitments is addressed in [12].

4 DIAGAL for Open Systems

An *open MAS* is characterized by its variable number of agents and the heterogeneity of its agents that are usually independently developed. Since DIAGAL semantics does not relate to any supposition about the decision making mechanisms of the conversing agents, it's an appropriate tool for open and heterogeneous systems communications. In order to use an ACL automatically, agents should be able to process its semantic. With previous mentalistic semantics, a strong assumption was made about the nature of rational agents that should at least have mental states which form and semantics match those used for the ACL semantics. This constraint was known as the semantic alignment problem, described in [5]. DIAGAL does not rely on such a strong assumption about the architecture of agents nor on their decision making mechanism. Since DIAGAL does not involve any references to agents' (hypothetical) mental states, it solves the semantic alignment problem.

Actually, DIAGAL can be used by agents which hold mental states (like the various BDI-like architectures) as well as by agents involving other internal decision process mechanisms. To use DIAGAL, the only assumptions needed are that (1) agents embed our dialogue manager enabling them to use DIAGAL and (2) they shared the model of flexible social commitments and their enforcement described in [12] which gives the operational semantics of the games and (3) the sanction system chosen for the enforcement of commitments should be respected as indicated in [12].

5 Conclusion

We hope to have shown that as an ACL, DIAGAL offers a complete set of tools to manipulate the social commitments layer (reifying in agents agendas) in open or

heterogeneous MAS. At the syntactic level, dialogue games appear to be a good alternative between strictly "mentalistic" or "social" approaches and protocols. At the semantic level, the sincerity assumption is avoided and dialogue games are defined in terms of entry conditions, success conditions and failure conditions expressed in terms of verifiable extra-dialogical social commitments. Finally, the conventional part of pragmatics is expressed in terms of conditional dialogical social commitments specifying the rules of the games. Besides, the contextualization game ensures the grounding of dialogue games (taking into account the attentional level of agents) while dialogue games ensure the grounding of each modification in the social commitments layer.

There are at least two ways of using DIAGAL in MAS:

1. DIAGAL can be used to specify protocols as particular compositions of dialogue games. For example, one can express the request for action protocol using DIAGAL games, as in [20].
2. DIAGAL can also be used dynamically as an agent language. For any attempt to get a particular modification on the social commitments layer, an agent just has to choose the DIAGAL game whose success condition unifies with the wanted change. This approach was used to validate our theory of agent communication pragmatics [18].

Finally, a dialogue game simulator (DGS) including many dialogue metrics has been developed to support previous DIAGAL version prototyping. In this framework, contextualization and dialogue games are XML files with their DTD while the standard dialogue manager has been implemented in Java. As future work, we plan to adapt it to the new version presented here and to make this complete yet versatile agent communication framework and test-bed available to the community.

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