ACL Semantics between Social Commitments and Mental Attitudes

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Abstract. There are two main traditions in defining a semantics for agent communication languages, based either on mental attitudes or on social commitments. In this paper, we translate both traditions in a different approach in which the dialogue state is represented by the beliefs and goals publicly attributed to the roles played by the dialogue participants. On the one hand, this approach avoids the problems of mentalistic semantics, such as the unverifiability of private mental states. On the other hand, it allows use to reuse the logics and implementations developed for FIPA compliant approaches.

1 Introduction

Communication in multi-agent systems is often associated with the roles agents play in the social structure of the systems [1, 2]. In contrast, most approaches to the semantics of agent communication languages (ACL) do not take roles into account. The semantics of speech acts in mentalistic approaches like FIPA [3] is specified in terms of plan operators whose preconditions refer to the beliefs, goals and intentions of agents, without considering the notion of role. Social semantics approaches are based on the idea that a speech act publicly commits the agents, regardless of the role of roles in communication.

A role-based semantics advances the idea that communication can be described in terms of beliefs and goals, but that those beliefs and goals must be maintained in public. The solution is to attribute beliefs and goals to roles played by the participants in the dialogue, rather than referring to the participants' private mental states, which are kept separate from the dialogue model. The roles' beliefs and goals are public and are constructed by the introduction or removal of beliefs and goals by the speech acts. The public beliefs and goals of a dialogue participant in a particular role may differ in interesting ways from his private beliefs and goals.

Thus, in this paper, we answer the following research questions:

- How to set up a role-based semantics for agent communication languages?
- How to translate the two traditional approaches into a role-based approach?

In [4] we started proposing a role-based semantics for ACL. However, that paper addresses the problem in a partial way and is focussed on persuasion dialogues and assertive speech acts only. The approach in [4] is based on our normative multi-agent

systems framework [5, 6]; it describes roles via the agent metaphor and is formalized in Input/Output logic. In this paper, we refer to a commonly known framework, the FIPA formal language, to translate the traditional ACL semantics to a role-based semantics. Moreover, we model additional categories of speech acts, like commissives and directives, that we apply in negotiation dialogues between cooperative agents.

The paper is structured as follows. In Section 2 we present our role model followed by the translation of FIPA-ACL and social semantics [7] into role-based semantics (Sections 3 and 4). In Section 5 we translate the Propose interaction protocol from FIPA and from social semantics to our role model, in order to be able to compare the two different approaches. Conclusions end the paper.

2 The role model

Communication among agents in a MAS is often associated with the roles agents play in the social structure of the systems. The GAIA methodology [1] proposes interaction rules to specify communication among roles, the ROADMAP methodology [8] specifies in the Social model the relations among roles, and in AALAADIN [2] interaction is defined only between the roles of a group: "The communication model within a group can be more easily described by an abstracted interaction scheme between roles like the 'bidder' and the 'manager' roles rather than between individual, actual agents".

Role names, like'speaker' and 'addressee' or 'buyer' and 'seller' are often mentioned in the definition of agent communications languages. However, these terms only serve the function to bind individual agents to the speech acts in the protocol, but they are not associated with a state which changes during the conversation as a result of the performed speech acts. In our approach the notion of roles is interpreted as role instances, sometimes also called *qua individuals* or Role Enacting Agents [9]. The function played by roles in dialogue is similar to the function they play in an organization, where they define the power of agents to create commitments. As in organizations, it is possible that different roles are filled in by the same agent, thus determining ambiguities and conflicts (e.g. a command issued by a friend may not be effective, unless the friend is also the addressee's boss).

In [4] we propose to use the notion of role as a basis for a semantics of agent communication languages. The basic idea is that speech acts can be modelled as plan operators with preconditions and effects which can refer to beliefs, goals and intentions, but the mental attitudes they refer to are not the private inaccessible ones of the agents. Rather, the beliefs, goals and intentions to which speech acts refer are attributed to a public image of the participants in the dialogue representing the role they play.

The advantage of this approach is that it overcomes the unverifiability problem of mental attitudes approaches, since the role's mental attitudes are publicly attributed by the rules of the dialogue according to the moves performed. Roles represent expectations, but the model remains neutral with respect to the motivations that agents have when they play a role: the agents can adopt the mental attitudes attributed to roles as a form of cooperation, or they can be publicly committed to their roles in more formal contexts. To play a role, an agent is expected to act *as if* the beliefs and goals of the

role were its own, and to keep them coherent, as it does for its own mental attitudes. It should adopt his role's goals and carry them out according to his role's beliefs.

Note that our model keeps apart the motivations for playing a role from the rules of the game which affect the state of the roles. In this way, we keep separate the public character of dialogue from the private motivations of the agents involved in a dialogue. The roles' attitudes represent what the agent is publicly held responsible for: if the agent does not adhere to his role, he can be sanctioned or blamed. So, an agent may be sincere (i.e., he really acts as expected from his role) for pure cooperativity, or for the fear of a sanction. Here, we focus on the relation between the role-based semantics and the existing approaches to ACL semantics, and we are not concerned with the way the obligation to play a role consistently can be enforced. The introduction of obligations requires the reference to an explicit multi-agent normative system, as described in [10].

The only thing agents have to do when communicating is to respect the rules of the dialogue or they are out of the game. The agents thus have to respect the cognitive coherence of the roles they play or they get into a contradictory position. We adopt Pasquier and Chaib-draa [11]'s view that dialogue arises from the need of maintaining coherence of mental states: "two agents communicate if an incoherence forces them to do so. [...] Conversation might be seen [...] as a generic procedure for attempting to reduce incoherence". An agent engaged in the dialogue tries to avoid contradictions, not with its private mental states, but with the public image which its role constitutes. As long as an agent plays a game following its constitutive rules, it cannot refuse that what it has said will be considered as a public display of its position in the game, according to its role. Consider the example of a liar, who once he starts lying, has to continue the dialogue consistently with what he said before, independently of his real beliefs.

In order to make the translation possible we need the following formal system:

Definition 1. *A dialogue game is composed of* $\langle A, R, PL, B, G, RL, CR\rangle$ *where*

- A *is a set of agents involved in the interaction, e.g.,* x, y.
- RN *is a set of role names, like* r_1, r_2, ...
- R *is a set of role enacting agents, e.g.,* $a = x : r_1$, $b = y : r_2$. *We denote with* i, j *variables over role enacting agents.*
- SA *is a set of speech act types, e.g.,* $inform$, $request$, *etc.*
- $PL : A \times RN \mapsto R$ *is a role playing function* $a = PL(x, r_1)$ *is a role* r_1 *enacting agent played by agent* $x \in A$. *We will write* $a = x : r_1$ *for* $a = PL(x, r_1)$.
- RL *is a set of axioms on the role model.*
- CR *are the constitutive rules of the dialogue game: they are common beliefs specifying how speech acts affect the roles' mental attitudes.*
- B *and* G *are the agents' beliefs and goals, respectively.*

We can now define the formal language, inspired by FIPA's specification language.

Definition 2 (Language).

Given a set of propositions L *and basic actions* ACT*:*

$q := p \mid \neg q \mid q \vee q \mid B(m, q) \mid G(n, q) \mid done(act) \mid done(i, act) \mid$
$message(x, y, SA(i, j, q)) \mid SA(i, j, q) \mid a = x : r_1$

$act := action \mid act; act$

where $p, q \in L$, $x, y \in A$, $i, j \in R$, $m, n \in A \cup R$, $r_1 \in RN$ and $action \in ACT$. B and G represent the beliefs and goals.

Note that according to this definition also roles can have beliefs and goals.

For simplicity here we do not distinguish goals from intentions.

The $done(act)$ and $done(i, act)$ expressions denote the execution of an action, specifying or not the agent of the action. We will use $done(act)$ later when act is a joint action, for example, $sell(i, j) = give(i); pay(j)$. Here we use a minimal definition of actions which allows us to cover the examples.

Is it possible that roles have mental attitudes? What we are modelling are public mental states of the same kind as the ones associated to role enacting agents in the model of [9]. A similar solution is proposed also by [12] where beliefs (but not goals) can be publicly attributed to agents by means of a grounding operator. The right perspective should be always $B(x, B(i, p)) \wedge B(y, B(i, p))$, where x and y play a role in the dialogue, rather than $B(i, p)$ when $i \in R$. However, for convenience we will use the latter formula $B(i, p)$. Preconditions and postconditions of speech acts will refer to beliefs and goals of the roles. The difference is that roles' mental attitudes have different properties with respect to those of their players. In particular, they are public: a role knows what the other role believes and wants, because speech acts are public.

We add the following axioms RL in a dialog game, representing rationality constraints; they are mostly inspired by FIPA, apart from those concerning public mental states and distribution of goals in joint plans. For all roles i, j:

- Each role has correct knowledge about its own mental states, in particular, its beliefs about its goals are correct. This axiom corresponds to FIPA's [3] schema $\phi \leftrightarrow B_i\phi$, where ϕ is governed by an operator formalising a mental attitude of agent i:
  $(B(i, G(i, p)) \supset G(i, p)) \wedge (B(i, \neg G(i, p)) \supset \neg G(i, p))$ (RL1)
  $(B(i, B(i, p)) \supset B(i, p)) \wedge (B(i, \neg B(i, p)) \supset \neg B(i, p))$ (RL2)
- Since the beliefs of the roles are public, each role has the complete knowledge about the other roles' beliefs and goals:
  $(B(j, p) \leftrightarrow B(i, B(j, p))) \wedge (\neg B(j, p) \leftrightarrow B(i, \neg B(j, p)))$ (RL3)
  $(G(j, p) \leftrightarrow B(i, G(j, p))) \wedge (\neg G(j, p) \leftrightarrow B(i, \neg G(j, p)))$ (RL4)
- Forwarding a message is a way to perform a speech act:
  $B(m, message(x, y, SA(i, j, p)) \supset SA(i, j, p))$ (RL5)
  where $SA \in \{inform, request, propose, \dots\}$, for all $x, y \in A$ and $m \in \{i, j\}$. Note that the sender of the message x is an agent playing the role i in the speech act and the receiver agent y plays the role j.
- Each agent is aware of which speech acts have been performed, where $i = x : r_1$, $j = y : r_2$ and $m \in \{i, j\}$:
  $message(x, y, SA(i, j, p)) \supset B(m, message(x, y, SA(i, j, p)))$ (RL6)
- A rationality constraint concerning the goal that other agents perform an action: if agent i wants that action act is done by agent j, then agent i has the goal that agent j has the goal to do act:
  $G(i, done(j, act)) \supset G(i, G(j, done(j, act)))$ (RL7)
- Some FIPA axioms like Property 1 ($G(i, p) \supset G(i, a_1|...|a_n)$, where $a_1|...|a_n$ are feasible alternatives to achieve p) [3] concern the execution of complex actions. In a

similar vein, we add two axioms concerning the distribution of tasks. Taking inspiration from [13], we add an axiom to express that if an agent intends a joint action, then it intends that each part is done at the right moment. If $act = act_1; ...; act_n$, where ";" is the sequence operator, act is a joint action :
$G(i, done(act)) \supset (done(act_1(i_1); \ldots; act_k(i_k)) \supset G(i, done(act_{k+1}(i))))$ (RL8)
If $act_{k+1}(j)$ and $i \neq j$, then by Axiom 7:
$G(i, done(act)) \supset$
$(done(act_1(i_1); \ldots; act_k(i_k)) \supset G(i, G(j, done(act_{k+1}(j)))))$ (RL9)
Each agent in the group wants that the others do their part.

Note that in the role model it is not assumed that the role's mental attitudes corresponds to the mental attitudes of their players. This assumption can be made only when an agent is sincere, and can be expressed as:
$(B(i, p) \wedge i = x : r \wedge sincere(x, r)) \supset B(x, p)$
$(G(i, p) \wedge i = x : r \wedge sincere(x, r)) \supset G(x, p)$
In the next two sections, we show how the semantics of speech acts defined by FIPA and by social semantics can be expressed in terms of roles.

3 From FIPA to roles

The semantics of agent communication languages provided by FIPA [3] are paradigmatic of the models based on mental attitudes. In FIPA, communicative acts are defined in terms of the mental state of the BDI agent who issues them. The bridge between the communicative acts and the behavior of agents is provided by the notions of rational effect and feasibility preconditions. The rational effect is the mental state that the speaker intends to bring about in the hearer by issuing a communicative act, and the feasibility preconditions encode the appropriate mental states for issuing a communicative act. To guarantee communication, the framework relies on intention recognition on the part of the hearer.

The main drawback of FIPA resides in the fact that mentalistic constructs cannot be verified [14, 15]. So, they are not appropriate in situations in which agents may be insincere or non cooperative, like in argumentation or negotiation. In contrast, meaning should be public as Singh [16], Walton and Krabbe [17], Fornara and Colombetti [7] claim.

In the following, we provide a role-based semantics for FIPA communicative acts by proposing a translation using constitutive rules CR of our dialogue game. Note, however, that the beliefs and goals of roles resulting from the translation have different properties than the beliefs and goals of the agents referred to by FIPA semantics.

The structure of the constitutive rules of dialogue reflects the structure of FIPA operators: the speech act is mapped to the antecedent, while feasibility preconditions and rational effects are mapped to the consequent. This methodology relies on some FIPA axioms according to which, when a speech act is executed, its feasibility preconditions and its rational effects must be true. So, after a speech act, its preconditions and its rational effect are added to the roles' beliefs and goals:
$B(i, done(act) \wedge agent(j, act)) \supset G(j, RE(act)))$ (Property 4 of FIPA) (RL10)

$B(i, done(act) \supset FP(act))$ (Property 5 of FIPA) (RL11)

where FP stands for feasibility preconditions, RE for rational effects, and i and j are the role enacting agents in the conversation. Since in the role-based semantics these axioms apply to roles, the belief that the preconditions of the speech act hold is publicly attributed to the role of the speaker, abstracting from the actual beliefs of the agent who plays the role.

For space reasons, we do not report here preconditions concerning uncertain beliefs (the modal operator Uif in FIPA), but the extension to them is straightforward.

Here is FIPA definition of the $inform$ communicative act (CA):

$< i, inform(j, p) >$

FP: $B(i, p) \wedge \neg B(i, B(j, p) \vee B(j, \neg p))$

RE: $B(j, p)$

- The first precondition $B(i, p)$ is modelled by the rule:
  $B(i, inform(i, j, p) \supset B(i, p))$ (CR12)
  The second precondition $\neg B(i, B(j, p) \vee B(j, \neg p))$ is modelled by
  $B(i, inform(i, j, p) \supset \neg B(i, B(j, p) \vee B(i, \neg p)))$ (CR13)
  Remember that $B(j, p) \supset B(i, B(j, p))$, so now this precondition can be verified on the public state of the dialogue.
- The effect is accounted for by
  $B(i, inform(i, j, p) \supset G(i, B(j, p)))$ (CR14)

To model FIPA's remark that "Whether or not the receiver does, indeed, adopt belief in the proposition will be a function of the receiver's trust in the sincerity and reliability of the sender" we need the following rule:

$B(j, (G(i, B(j, p)) \wedge reliable(i, p)) \supset B(j, p))$ (CR15)

We do not want to comment further on this issue here: see e.g., [18–20] for the subjects of reliability and trust. As illustrated in the previous section, we keep separate reliability and sincerity: sincerity is not part of the game, but it refers to the relation between the role's beliefs and the player's private beliefs.

Concerning the $request$ CA :

$< i, request(j, act) >$

FP: $\neg B(i, G(j, done(act))) \wedge agent(j, act)$

RE: $done(act)$

- The precondition is modelled as follows:
  $B(i, request(i, j, done(j, act)) \supset \neg B(i, G(j, done(j, act))))$ (CR16)
- The effect is modelled by
  $B(i, request(i, j, done(j, act)) \supset G(i, done(j, act)))$ (CR17)

Analogously to *inform*, a rule expresses that only a cooperative receiver adopts a speaker's goal:

$B(j, (G(i, done(j, act)) \wedge cooperative(j, i)) \supset G(j, done(j, act)))$ (CR18)

Note that $B(j, G(i, done(j, act))$ is not the result of an intention reconstruction by j about i's goals, but part of the state of the conversation. So only goals which are publicly stated are adopted in a cooperative dialogue.

Since it is of particular importance for our running example, we illustrate how the propose speech act is defined in FIPA and explain how we model it. Since propose is an *inform* act in FIPA, its definition in role-based semantics derives from the definition of the *inform* provided above, yielding the following definition:
$< i, propose(j, act) >$
FP: $B(i, G(j, done(act)) \supset G(i, done(act)))$
$\neg B(i, B(j, G(j, done(act)) \supset G(i, done(act))) \vee$
$B(j, \neg G(j, done(act)) \supset G(i, done(act))))$
RE: $B(j, G(j, done(act)) \supset G(i, done(act)))$

Where act is an action of i or a joint action, otherwise we call it a request and not a propose.

Since an agent is $reliable$ concerning its own mental states (it has a correct view of what he believes and intends) from rule 15 it follows that:
$B(j, propose(i, j, done(act)) \supset (G(j, done(act)) \supset G(i, done(act))))$ (CR19)

We illustrate how the accept and reject speech acts are modelled even if they are defined as *inform* acts in FIPA:
$< i, accept\ proposal(j, act) >$
FP: $B(i, G(i, done(act))) \wedge$
$\neg B(i, B(j, G(i, done(act))) \vee \neg B(j, G(i, done(act))))$
RE: $B(j, G(i, done(act)))$
Since an agent is accounted *reliable* about its own mental state:
$B(j, accept\ proposal(i, j, done(act)) \supset G(i, done(act))))$ (CR20)
$< i, reject\ proposal(j, done(act)) >$
FP: $B(i, G(i, done(act)))\neg B(i, B(j, G(i, done(act))) \vee \neg B(j, G(i, done(act))))$
RE: $B(j, \neg G(i, done(act)))$

4 From commitments to roles

Agent communication languages based on social commitment constitute an attempt to overcome the mentalistic assumption of FIPA by restricting the analysis to the public level of communication (Singh [16], Verdicchio and Colombetti [21]). Communicative acts are defined in terms of the social commitments they publicly determine for the speaker and the hearer. According to Singh [22], describing communication using social commitment has the practical consequence that "[...] one can design agents independently of each other and just ensure that their S-commitment would mesh in properly when combined".

The use of social commitments to model communication does not explain how the social dimension of commitment affects the behavior of the individual agents. While this approach is mostly appropriate in competitive environments, like negotiation, its advantages are less clearcut in cooperative ones, like information seeking dialogues. The reference to obligations to bridge this gap brings into social semantics the controversial issue of obligation enforcement [23].

Here, we show how to define a particular social semantics presented by Fornara and Colombetti [7] in the role-based semantics (from now on, SC). In the SC model, speech acts introduce commitments in the dialogue state or manipulate them. A commitment

$C(i, j, p \mid q)$ has a *debtor* i, a *creditor* j, i.e., respectively, the agent which has the commitment, and the agent to which the commitment is made, a content p and a condition q. A commitment can have different states: unset (i.e., to be confirmed), pending (i.e., confirmed, but its condition is not true), active (i.e., confirmed and its condition is true), fulfilled (i.e., its content is true), violated (i.e., the content is false even if the commitment was active), cancelled (e.g., the debtor does not want to be committed to the action). A commitment instance is set by a speech act, with a certain state. This state can be modified by actions of the participants to the dialogue or by events, like the execution of an action fulfilling the new commitment state.

In order to perform the translation, we adopt the following methodology: we map each commitment state to a specific configuration of roles' beliefs and goals, then we define how speech acts change those beliefs and goals in such a way to reflect the changes in the commitment state.

In Fornara and Colombetti's model [7], the difference between propositional and action commitment lies only in their content. As a result, the difference between an inform and a promise is reduced to the fact that the content of the commitment they introduce is a proposition or an action respectively. By contrast, according to Walton and Krabbe [17], propositional commitment is an action commitment to defend one's position. In the mapping between SC and the role model a new distinction emerges: rather than having commitment stores, we model propositional commitments as beliefs of the role and action commitments as goals. How roles' beliefs capture the idea of a commitment to defend one's position is the topic of [4]. In this paper we focus on action commitment only.

Here, we represent conditionals commitment $C(i, j, p \mid q)$ in a simplified way, as a conditional goal p of role i in case q is true: $B(i, q \supset G(i, p))$. Conditional attitudes can be better accounted for in a conditional logic, like the Input/Output logic we used in [4]. Here, we stick to FIPA's solution for the sake of clarity, while aware of its limitations.

An unset commitment corresponds to a goal of the creditor. We translate this in the CR of a dialogue game in this way:

$$C(unset, i, j, done(i, act) \mid q) \equiv q \supset G(j, G(i, done(i, act))) \quad \text{(CR21)}$$

In the antecedent of this rule, the commitment condition q becomes a condition on the goal assumed by the creditor of the commitment. At this stage of the commitment life-cycle, no mental attitude is attributed to the debtor: it has not publicly assumed any actual goal, but has only been publicly requested to.

A commitment is pending when it is a goal of the creditor and the debtor of the commitment conditionally wants to perform the action if the associated condition q is true, and the creditor has this as a belief:

$$C(pending, i, j, done(i, act) \mid q) \equiv q \supset G(j, G(i, done(i, act))) \wedge B(i, q \supset G(i, done(i, act))) \wedge B(j, q \supset G(i, done(i, act))) \quad \text{(CR22)}$$

A commitment is active when it is both a goal of the debtor and of the creditor, and the pending condition is true:

$$C(active, i, j, done(j, act) \mid \top) \equiv G(i, done(i, act)) \wedge G(j, done(i, act)) \quad \text{(CR23)}$$

Note that to make active a pending commitment, it is sufficient that the condition q is believed true, since from

$$B(i, q \wedge q \supset G(i, done(i, act))) \quad \text{(CR24)}$$

we can derive $G(i, done(i, act))$ with Axiom 1.

Commitments are violated or fulfilled when they are goals of the creditor and the content of the commitment is respectively true or false according to the beliefs of the creditor (abstracting here from temporal issues):

$C(fulfilled, i, j, done(i, act) \mid \top) \equiv B(j, done(i, act)) \wedge G(j, done(i, act))$ (CR25)

$C(violated, i, j, done(i, act) \mid \top) \equiv B(j, \neg done(i, act)) \wedge G(j, done(i, act))$ (CR26)

Since roles are public, fulfilment and violation are not dependent on what the agents subjectively believe about the truth value of the content of the commitment, but on roles' public beliefs.

A commitment is cancelled if the creditor does not want the goal to be achieved anymore, no matter if the debtor still wants it:

$C(cancelled, i, j, done(i, act) \mid q) \equiv \neg G(j, done(i, act))$ (CR27)

Given the definition of the commitment state in terms of the mental states of the roles, we can provide the following translation of the speech acts semantics define by Fornara and Colombetti [7].

A *promise* introduces a pending commitment of the speaker (Axiom 22):

$$promise(i, j, done(i, act), q) \supset (q \supset G(j, G(i, done(i, act))) \wedge B(i, q \supset G(i, done(i, act))) \wedge B(j, q \supset G(i, done(i, act)))) \quad \text{(CR28)}$$

A *request* introduces an unset commitment with the receiver as debtor, i.e., the agent of the requested action (Axiom 21):

$$request(i, j, done(j, act), q) \supset (q \supset G(i, G(j, done(j, act)))) \quad \text{(CR29)}$$

Accept and *reject* change the state of an existing unset commitment to pending and cancelled respectively. In order to account for this fact, we insert in the antecedent of the rules for accept and reject the reference to the configuration of beliefs and goals that represent an existing commitment.

$$(B(i, (q \supset G(j, G(i, done(i, act))))) \wedge accept(i, j, done(i, act), q)) \supset (B(i, q \supset G(i, done(i, act))) \wedge B(j, q \supset G(i, done(i, act)))) \quad \text{(CR30)}$$

$$(B(i, q \supset G(j, G(i, done(i, act)))) \wedge reject(i, j, done(j, act), q)) \supset (B(i, \neg G(i, done(i, act))) \wedge B(j, \neg G(i, done(i, act)))) \quad \text{(CR31)}$$

A *propose* is a complex speech act composed by a *request* and a conditional *promise*; it introduces an unset commitment with the receiver as debtor and a pending commitment with the speaker as debtor. Since a *propose* is used in a negotiation, q and p refer respectively to an action of the speaker and of the receiver.

$$\textit{propose}(i, j, done(j, p), done(i, q)) \equiv \textit{request}(i, j, done(j, p), done(i, q)) \wedge \wedge \textit{promise}(i, j, done(i, q), s) \quad \text{(CR32)}$$

where $s \equiv B(i, done(i, q) \supset G(j, done(j, p))) \wedge B(j, done(i, q) \supset G(j, done(j, p)))$, i.e., p is a pending commitment of the receiver.

propose is expressed by the following constitutive rules:

$$\textit{propose}(i, j, done(j, p), done(i, q)) \supset B(i, (done(i, q) \supset G(i, G(j, done(j, p))))) \wedge B(i, s \supset G(i, done(i, q))) \wedge B(j, s \supset G(i, done(i, q))) \quad \text{(CR33)}$$

5 Example: the Propose protocol

In this section we propose an example of comparison between FIPA and SC using our role semantics, as a means to assess the feasibility of the role semantics as an intermediate language. We choose as example the Propose interaction protocol of FIPA [3]. This simple protocol consists of a *propose* followed by an acceptance or a refusal, and does not refer to group coordination or group action (differently from [24]).

In the following, we illustrate how the speech acts in the two approaches introduce and modify the beliefs and goals of the roles a and b. Eventually, we compare the set of beliefs and goals produced by the translation of FIPA and SC into the role-based semantics to assess whether the goals concerning executable actions are the same in the two approaches (i.e., the agents would act at the same moment), and whether it is possible to find in FIPA the same commitments as in SC.

The main difficulty in mapping FIPA onto SC concerns the FIPA *propose* communicative act. In SC it is viewed as a way to negotiate a joint plan: "If I do q, then you do p". This models for example auctions [7]. Instead, FIPA definition of *propose* refers to one action only. Here, we are inspired by the example reported in FIPA documentation [3], which reports the action of selling an item for a given amount of money: we explicit the fact that the action of selling is a joint plan composed of the proponent's action of giving the item and the receiver's subsequent action of giving the money:

$sell(i, j) = give(i); pay(j)$

In this way, the FIPA *propose* act becomes an act of proposing a plan to be performed by both agents. Once the goals of both agents to perform the plan have been formed, the plan is distributed between the agents according to Axioms 8 and 9, and the goals concerning the steps of the plan are formed.

Apart form the mapping of *propose* the translation of FIPA and SC semantics to the role-based semantic is straightforward: at each turn, the constitutive rules for translating the semantics of FIPA and SC into the role-based semantics are applied (see the definition of the rules in Sections 3 and 4). Then, modus ponens and the axioms are applied. Beliefs and goals which are not affected by subsequent speech acts persist through the example.

In FIPA (see Figure 1, where a simplified notation is used), the *propose* to sell (*propose*$(a, b, done(sell(a, b)))$ is an *inform* that introduces in the role a the belief that the precondition $G(b, done(sell(a, b)))) \supset G(a, done(sell(a, b)))$ is true. We skip for space reasons the other feasibility precondition, but the reader can easily check that it is true and consistent with the state of the dialogue. The rational effect is a goal of the speaker, but since the speaker is reliable (it has correct beliefs about its own mental states), after the proposal, the receiver believes $G(b, done(sell(a, b))) \supset G(a, done(sell(a, b)))$ too, by rule 15.

The acceptance of the proposal by b in FIPA is an *inform* that b has the goal $G(b, done(sell(a, b))$: $acceptproposal(a, b, done(sell(a, b)))$

Again, the receiver believes the content of the accept proposal speech act because an agent is reliable about its own mental states. Since the speaker believes $G(b, done(sell(a, b)))G(a, done(sell(a, b)))$ and $G(b, done(sell(a, b))$, it believes also to have $done(sell(a, b))$ as a goal (by modus ponens) and, by Axiom 1, it actually has

the goal to sell. Most importantly, if an agent has the goal to make the joint plan, by the Axiom 8, then it has the goal to do its part at the right moment (and the other knows this) and the goal that the other does its part as well. The result of the distribution is: $B(a, give(a) \supset G(a, done(pay(b)))) \wedge B(b, give(a) \supset G(b, done(pay(b))))$. Thus, when $done(give(a))$ is true, from $done(give(a)) \supset G(a, done(pay(b))))$, we derive that a wants that b does its part $G(b, done(pay(b)))$.

The translation from SC ACL semantics to the role-based semantics is accomplished in the same way as the translation from FIPA illustrated above, by applying the rules defined in the previous Section. Figure 2 represents the example protocol.

Given the FIPA *propose* CA, the corresponding speech act in SC ACL is *propose*$(a, b, done(give(a)), done(pay(b)))$.

By applying the rule that translates this speech act in the role-based ACL semantics, we get to the state in which both a and b have the belief that $done(give(a)) \supset G(a, G(b, done(pay(b))))$ representing an unset commitment of b. Moreover, $done(give(a)) \supset G(b, done(pay(b)))) \supset G(a, done(give(s)))$ corresponds to a pending commitment by a.

The *accept proposal* is modelled in SC ACL by $accept(b, a, C_i(unset, b, a, pay(b) \mid give(a))$. This speech act, whose precondition is true, results in b's act of creating the belief of a that b believes $done(give(a)) \supset G(b, done(pay(b)))$. The application of modus ponens to this new belief and the existing belief $done(give(a)) \supset G(b, done(pay(b)))) \supset G(a, done(give(s))))$ results in the introduction of an active commitment whose debtor is role a: $G(a, done(give(a))) \wedge G(b, done(give(a)))$

When $give(a)$ is executed, then the commitment of a to do $give(a)$ is fulfilled and the commitment of b to do $pay(b)$ becomes active since its condition $done(give(a))$ is satisfied.

The *reject proposal* communicative act in FIPA in SC corresponds to the speech act $reject(b, a, C_i(unset, b, a, pay(r) \mid give(a)))$. The reject speech act attributes to both a and b the belief that b does not have the goal $done(pay(a))$, thus retaining a's pending commitment from becoming active and cancelling the unset commitment from b role.

Which are the main differences between these approaches? By comparing the two tables in Figures 1 and 2, it is possible to observe that, once translated in the role-based semantics, the actual commitments and their state coincide in the two approaches, with a significant exception. The difference can be observed in the first row, where after the *propose* speech act there is no equivalent in FIPA of the belief - publicly attributed to the proponent - that it has the goal that the addressee forms a conditional goal to pay the requested amount of money for the sold item, where the condition consists of the proponent giving the item.

This difference is to be ascribed to the definition of the act of proposing in FIPA. In practice, FIPA does not express the advantage of the proponent in proposing the plan. For example, in the selling case, there is no clue of the fact that reason why the proponent proposes the joint plan is that it wants to receive the specified amount of money. However, this is implicit in the definition of the selling plan. In SC, reciprocity is expressed by the fact that a *propose* is composed by a conditional *promise* together with a *request* (see also the model in [25]), thus providing a way to express any kind of arrangements, even non conventional ones. In SC, the subsequent accept speech act

CA	Seller a (FIPA)	Buyer b (FIPA)
propose	BELIEFS $G(b, sell(a,b)) \supset G(a, sell(a,b))$	BELIEF $G(b, sell(a,b)) \supset G(a, sell(a,b))$
	GOALS $B(b, G(b, sell(a,b)) \supset G(a, sell(a,b)))$	GOALS
accept	BELIEFS $G(b, sell(a,b)) \supset G(a, sell(a,b))$ $G(b, sell(a,b))$ $G(a, sell(a,b))$ $G(a, give(a))$ $give(a) \supset G(a, pay(b))$ $give(a) \supset G(b, pay(b))$	BELIEF $G(b, sell(a,b)) \supset G(a, sell(a,b))$ $G(b, sell(a,b))$ $G(b, give(a))$ $give(a) \supset G(b, pay(b))$
	GOALS $give(a)$	GOALS $B(a, G(b, sell(a,b)))$
give(a)	BELIEFS $G(b, sell(a,b)) \supset G(a, sell(a,b))$ $give(a) \supset G(b, pay(b))$ $give(a) \supset G(a, pay(b))$ $G(a, give(a))$ $give(a)$ $G(b, pay(b))$ $G(a, pay(b))$	BELIEFS $G(b, sell(a,b)) \supset G(a, sell(a,b))$ $give(a) \supset G(b, pay(b))$ $G(b, give(a))$ $give(a)$ $G(b, pay(b))$
	GOALS	GOALS $pay(b)$
pay(b)	BELIEFS $G(b, sell(a,b)) \supset G(a, sell(a,b))$ $give(a) \supset G(b, pay(b))$ $give(a) \supset G(a, G(b, pay(b)))$ $G(b, pay(b))$ $pay(b)$	BELIEFS $G(b, sell(a,b)) \supset G(a, sell(a,b)))$ $give(a) \supset G(b, pay(b))$ $G(b, pay(b))$ $pay(b)$
	GOALS	GOALS
reject	BELIEFS $G(b, sell(a,b)) \supset G(a, sell(a,b))$ $\neg G(b, sell(a,b))$	BELIEF $G(b, sell(a,b)) \supset G(a, sell(a,b))$ $\neg G(b, sell(a,b))$
	GOALS	GOALS $B(a, \neg G(b, sell(a,b)))$

Fig. 1. The example with FIPA. Note that for space reasons $done(i, act(i))$ is abbreviated in $act(i)$.

CA	Seller a (SC)	Buyer b (SC)
propose	BELIEFS $give(a) \supset G(a, G(b, pay(b)))$ $(give(a) \supset G(b, pay(b))) \supset G(a, give(a)))$	BELIEFS $(give(a) \supset G(b, pay(b))) \supset G(a, give(a)))$
	GOALS	GOALS
accept	BELIEFS $give(a) \supset G(a, G(b, pay(b)))$ $(give(a) \supset G(b, pay(b))) \supset G(a, give(a)))$ $give(a) \supset G(b, pay(b))$ $G(a, give(a))$	BELIEFS $(give(a) \supset G(b, pay(b))) \supset G(a, give(a)))$ $give(a) \supset G(b, pay(b))$ $G(a, give(a))$
	GOALS $give(a)$	GOALS
give(a)	BELIEFS $give(a) \supset G(a, G(b, pay(b)))$ $(give(a) \supset G(b, pay(b))) \supset G(a, give(a)))$ $give(a) \supset G(b, pay(b))$ $G(a, give(a))$ $give(a)$ $G(b, pay(b))$	BELIEFS $(give(a) \supset G(b, pay(b))) \supset G(a, give(a)))$ $give(a) \supset G(b, pay(b))$ $G(a, give(a))$ $give(a)$ $G(b, pay(b))$
	GOALS	GOALS $pay(b)$
pay(b)	BELIEFS $G(b, pay(b))$ $pay(b)$	BELIEFS $G(b, pay(b))$ $pay(b)$
	GOALS	GOALS
reject	BELIEFS $give(a) \supset G(a, G(b, pay(b)))$ $(give(a) \supset G(b, pay(b))) \supset G(a, give(a)))$ $\neg G(b, pay(b))$	BELIEF $(give(a) \supset G(b, pay(b))) \supset G(a, give(a)))$ $\neg G(b, pay(b))$
	GOALS	GOALS

Fig. 2. The example with commitments. Note that for space reasons $done(i, act)$ is abbreviated in $act(i)$.

presupposes the existence of an unset commitment having as debtor the role to which the proposal has been addressed. However, the *accept proposal* act in the second turn fills the gap in FIPA: when the addressee displays the goal to take part in the joint plan, the distribution of the tasks of giving and paying takes place, generating the appropriate goals in the two roles.

6 Conclusions

In this paper we propose a role-based semantics for agent communication languages. In this approach, the state of a dialogue is represented by beliefs and goals publicly attributed to the roles played by the participants in the dialogue. These beliefs and goals are added and removed by the speech acts performed by the roles and are distinct - and potentially different - from the agents' private ones. The role-based semantics opens the way to the possibility that they diverge, so that a wide range of cooperative and non-cooperative situations can be modelled.

By means of an example, we show that the mentalistic and the social commitment approach can be translated in terms of roles, showing the differences in the definition of speech acts as well as the similarities. The comparison shows that it is possible to interpret the role model produced by FIPA in term of commitments.

Here, we did not consider some issues. In particular, we did not consider communicative protocols. This does not mean that we adopt a first principle methodology which defines protocols starting from the definition of the speech acts. Dialogue protocols have been proposed in various traditions, ranging from mentalistic theories like Joint Intention theory [26] to axiomatic characterizations [27]. Another tradition in agent communication we do not consider here is dialogue games, which describe simple patterns and the order in which moves must be made.

However, dialogue rules modelled as hard constraints can not deal with conflicts between applicable rules, and prevents contrary-to-duty reasoning. Although expectations can be represented by roles, we need an explicit way to represent expectations towards moves [28], that can distinguish between violations and inconsistencies.

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This is not the only possible use of our model: e.g., in [4] we propose a role-based semantics for persuasion games.

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