

Role-Based Semantics for Agent Communication

Embedding of the ‘Mental Attitudes’ and ‘Social Commitments’ Semantics

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ABSTRACT

In this paper we illustrate how a role-based semantics for agent communication languages can embed the two main existing models of agent communication languages, respectively based on ‘mental attitudes’ and ‘social commitments’ semantics. These two models have been presented as incompatible approaches, but recently we illustrated for persuasion dialogues and using our normative multi-agent systems framework, that they can be seen also as complementary ones. Independently from our own multi-agent model, in this paper we illustrate for the speech act ‘inform’ how the role based semantics embeds the other two semantics.

1. SYNTHESIS

In [1] we argue that a *role metaphor* can be used to bridge the gap between the mental attitudes approach [4] and the social commitments approach [8] to the semantics of agent communication languages. We show how dialogues can be modelled as games in normative systems and how mental attitudes can be attributed not only to agents, but also, in a public manner, to the roles of the game. The dialogue moves allow an agent playing a role to modify the roles’ mental states, as specified by so-called counts-as conditionals or constitutive norms defining the game. The player of a role is expected to act as if he has the mental attitudes attributed to his role and to prevent his role’s mental attitudes from becoming incoherent, just as he does for his own private mental attitudes.

Thus, we embed the mentalistic approach by showing how mental attitudes can be attributed to public roles instead of agents. The motivation of maintaining a mentalistic semantics, albeit referred to roles, is to be able to reuse the extensive FIPA work on the agent communication semantics. It is sufficient to refocus the model from the agents’ beliefs and goals to the roles’ beliefs and goals. However, though the mentalistic approach is embedded, the following drawbacks of the FIPA approach are not inherited.

- Communication is intersubjective and public, while beliefs and goals are private and, thus, not accessible by the receiver.
- An independent observer cannot verify whether agents conform to the agent communication semantics [11].

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- The sincerity assumption that is necessary to reason with mentalistic semantics does not apply to non-fully cooperative dialogue contexts, like argumentation and negotiation.

Moreover, we embed the social approach by showing how roles as descriptions of expected behavior maintain the normative character of social semantics. Roles are useful because mental attitudes attributed to roles of a dialogue game capture the public character of meaning which is offered by commitment approaches. The following limitations of the social commitments approach are not inherited by our role-based semantics:

- Commitment interpreted as an obligation is too strong in cooperative dialogues, where the notion of expectation is sufficient. Moreover obligations are associated with sanctions, which are specific only in some kinds of dialogues.
- Commitment is related to the notion of obligation, while the notion of permission is not considered even if it is necessary to explain the notion of concession. Walton and Krabbe [10] argue that after an ‘inform’ the receiver can make a concession explicitly, or implicitly by not challenging or failing to challenge the ‘inform’. In case of concessions the receiver becomes weakly committed to the proposition: he can no longer make the speaker committed to defending the proposition by challenging him, albeit the receiver does not have to defend the proposition himself if challenged. This situation cannot be expressed in social semantics.
- Propositional commitment is not clearly distinguished from action commitment. Thus it has the same conditions of fulfillment as action commitment, while propositional commitment for Walton and Krabbe is fulfilled when the receiver concedes, instead of when the commitment is true in the world.
- The action of informing is not related with any effect on the hearer, only the attitude of the speaker is considered. A precondition that the speaker does not believe that the receiver knows what is communicated is not expressible.

Our approach in [1] discusses persuasion dialogues and assertive speech acts, and uses our normative multi-agent systems framework describing roles via the agent metaphor and formalizing mental attitudes of the agents in Input/Output logic [7]. In this paper we consider the general problem of embedding mentalistic and social semantics in a role based semantics, independently from the dialogue type or agent model. In the following section we use visualizations of the communicative act ‘inform’ to illustrate how the role-based semantics can be seen as a natural combination of the ‘mental attitudes’ and ‘social commitments’ semantics. In the final section we sketch some formal aspects.

2. EMBEDDING IN ROLE SEMANTICS

Figure 1 visualizes the communicative act ‘inform’ in a mental attitudes approach like the one provided by FIPA [4]. This figure should be read as follows. The two ovals represent the two agents x and y . Within the ovals the mental state of the agent is represented. The top half of the oval contains the beliefs (B) of the agent, and the lower half his goals (G). Agent x thus has the belief p and the goal that agent y believes p ; in a modal language, these may be represented by $B_x p$ and $G_x B_y p$. Note that the outer modalities are not represented in the figure. Agent y believes p too if he trusts x . The arrow between the agents visualizes a communication channel.

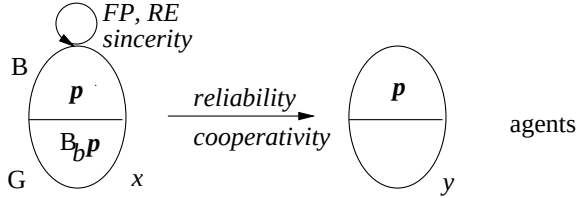


Figure 1: Mental attitudes semantics

In the mental attitudes semantics, 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 (RE in Figure 1) is the mental state that the speaker has the goal to bring about in the receiver by issuing a communicative act; the feasibility preconditions (FP) encode the appropriate mental states for issuing a communicative act. From the execution of a communicative acts it can be inferred that the speaker believes the feasibility preconditions and has the goal to achieve the rational effects. This kind of inference can be compared to presupposition accommodation [9]. However, this inference does not guarantee that the speaker actually has these attitudes nor that he would agree that these are the effects of a communicative act. Moreover, RE and FP are concerned only with the speaker, since they do not say anything about the receiver. Thus, assumptions about the reliability and sincerity of the speaker and about the cooperativity of the receiver are necessary to infer that the receiver believes what has been communicated, or wants to comply with a request.

Figure 2 visualizes the same communicative act ‘inform’ in the social commitment approach. This figure should be read as follows. Again there are a speaker x and a hearer y with their beliefs and goals. Moreover, there are also two commitment stores, represented by the two squares, but not distinguished between propo-

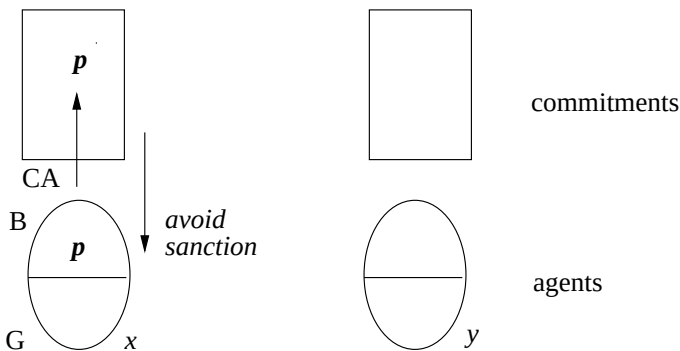


Figure 2: Social commitment semantics

sitional and action commitment. The arrows represent that due to agent x informing p , and to avoid a sanction, he may believe it. In this way, 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.

In the social commitments approach, communicative acts are defined in terms of the social commitments they publicly determine for the speaker and the hearer (see Figure 2). However, there are many ways in which this has been made more precise, and the term of commitment has been used in different ways. For example, Walton and Krabbe focus on propositional commitments: “to assert a proposition may amount to becoming committed to subsequently defending the proposition, if one is challenged to do so by another speaker” [10]. However, this kind of propositional commitment is biased towards argumentation dialogue, thus failing to be general enough for other kinds of dialogue. By contrast, Singh is interested in negotiation, and he investigates action commitments, that typically result from commissives and directives. According to Fornara and Colombetti [5], commitment is “a social relationship between the speaker and the hearer”.

In Figure 3 we visualize the role-based semantics of ‘inform’. The ovals x and y represent two agents playing respectively the roles a and b in the dialogue game. The constitutive rules of the game operate on the mental states of both roles. Only external assumptions like sincerity attribute beliefs to the agents, but they are not part of the game. The basic idea is that communicative 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.

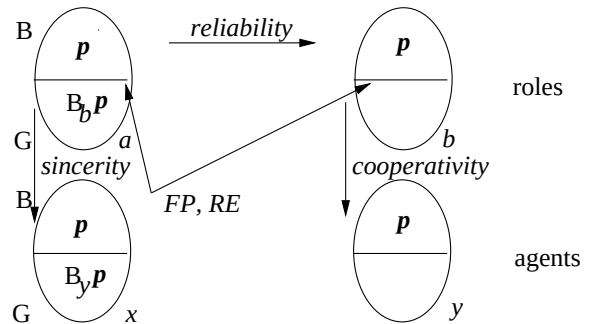


Figure 3: Role-based semantics

Of course, communication among agents is often associated with the roles played in the social structure of the systems, and role names like ‘speaker’ and ‘addressee’ or ‘buyer’ and ‘seller’ are often mentioned in the definition of agent communications languages. However, usually these terms only serve the function to bind individual agents to the speech acts in the protocol, whereas in our role semantics they are associated with a state which changes during the conversation as a result of the performed speech acts. Technically, attitudes are attributed to agents enacting a role; we just abstract over the agent. So what we are modelling, is similar to the public mental states associated with role enacting agents (REAs) in the model of Dastani *et al.* [3]. A similar solution is also proposed by Gaudou *et al.* [6], where beliefs (but not goals) can be publicly attributed to agents by means of a grounding operator.

3. TOWARDS FORMALIZATION

In the following, we sketch how a role-based semantics can be defined for FIPA and social semantics. With some adjustments of notation, the FIPA definition of the *inform* communicative act is as follows.

$$\begin{aligned} & \text{inform}(a, b, p) \\ & \text{FP: } B(a, p) \wedge \neg B(a, B(b, p) \vee B(b, \neg p)) \\ & \text{RE: } B(b, p) \end{aligned}$$

We assume that a, b are variables that range over roles, whose attitudes are maintained in public. The inference that can be based on the *feasibility preconditions* (FP) of a speech act, is modeled in the following way:

$$\begin{aligned} & \text{inform}(a, b, p) \rightarrow B(a, p) \\ & \text{inform}(a, b, p) \rightarrow \neg B(a, B(b, p) \vee B(b, \neg p)) \end{aligned}$$

Because roles' beliefs are maintained in public, these preconditions can indeed be verified.

The inference that is based on the *rational effect* (RE) is as follows. This inference is based on a kind of abduction. Uttering a speech act only makes sense when the rational effect is a goal of the speaker.

$$\text{inform}(a, b, p) \rightarrow G(a, B(b, p))$$

In the social commitments model, speech acts introduce commitments in the dialogue state or manipulate them. A commitment has a *debtor* and a *creditor*, i.e., respectively, the agent who has the commitment, and the agent to which the commitment is made. A commitment can have different states: unset (i.e., to be confirmed), active (i.e., confirmed), fulfilled, etc.

In our translation, a commitment state corresponds to a specific configuration of roles' beliefs and goals. So the commitment to defend a proposition (c.f. [10]), is treated as equivalent to a public belief: the agent must not contradict himself by means of conflicting speech acts or by failing to defend his beliefs.

We focus here on propositional commitment and concessions. Consider a dispute between debtor and creditor about a propositional variable p . A propositional commitment PC is *active* whenever the debtor publicly believes the proposition, while nothing is required for the creditor:

$$PC(\text{active}, a, b, p) \equiv B(a, p)$$

A propositional commitment PC is *fulfilled* when the creditor concedes the proposition:

$$PC(\text{fulfilled}, a, b, p) \equiv \neg B(b, \neg p)$$

Regarding the effect of speech acts in such a dispute, we can say that a *concession*, means that the debtor does not publicly believe (and defend) the opposite:

$$\text{concede}(a, b, p) \rightarrow \neg B(a, \neg p)$$

An 'inform' introduces an active propositional commitment of the speaker and, if it is not challenged, also a concession of the receiver:

$$\begin{aligned} & \text{inform}(a, b, p) \rightarrow B(a, p) \\ & \text{inform}(a, b, p) \wedge \neg \text{challenge}(b, a, q \rightarrow \neg p, q) \rightarrow \\ & \neg B(b, \neg p) \end{aligned}$$

The second part of the rule prevents the player of role b from asserting the opposite proposition $\neg p$ in the subsequent dialogue, since this would lead to a contradiction: $\neg B(b, \neg p) \wedge B(b, \neg p)$.

Please note the similarity between the inferences that can be made based on FIPA-style FP and RE, and the inferences that can be made on the basis of propositional commitments. For both the $\text{inform}(a, b, p)$, we get $B(a, p)$ and $\neg B(b, \neg p)$: the difference rests in the effect of challenging or failing to defend beliefs.

Thus, in our framework we are able to model both the mental attitudes and social commitment approaches, but avoiding their major limitations. First, with respect to FIPA, mental attitudes are public, because they are attributed to roles; second, the semantics of speech acts is public too since it consists in public constitutive rules; third, the model is not restricted to cooperative situations, since sanctions can be added to the expectations represented by roles [2].

With respect to social commitment, first, we can consider also cooperative situations were expectations are sufficient; second, as in Walton and Krabbe we can model the notion of concession, but, with respect to them, we can also distinguish between propositional and action commitment by means of the distinction between roles' beliefs and goals. Finally, we can refer to beliefs and goals of roles to express more complex preconditions on speech acts.

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