Social Network Semantics for Agent Communication (Extended Abstract)

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ABSTRACT

In this paper we introduce a semantics for agent communication languages based on social networks, providing us with a principled way to define and reason about their dynamics. As an instance we consider dependence networks, where the social relations represent that an agent depends on another agent to achieve its intentions. We suggest how FIPA semantics can be reconstructed in this social semantics. Our approach reveals that we need special semantics for relations like ownership, authority or fear: all kinds of interesting social relations, not previously studied by multiagent systems.

1. DYNAMICS OF SOCIAL NETWORKS

Social networks are a popular way to represent social relationships, because due to their graph structure, representation and reasoning methods from graph theory can directly be applied to an area where before mostly informal methods were used. One of the main current challenges at this moment is to define formal representation and reasoning methods for the dynamics of social networks, because, on the one hand, social networks, like virtual communities on the web, change continuously, and, on the other hand, most graph theoretic methods are based on static graphs. One of the informal frameworks to model the dynamics of social networks is Searle's notion of the construction of social reality [9]. There are many relationships between people: love, family ties, dependency on goals, dependency on resources, parenthood, and also properties of people, like knowledge, ownership, etc., whose dynamics (change) needs to be regulated in some way.

EXAMPLE 1. *In the well known game called diplomacy, the state of the game is a map with countries, which are occupied by armies of players. At each move, countries attack other countries, possibly in alliance with other countries; countries collect taxes from their domains; countries invest in their army, or in their economy. The main social relation is that countries need an alliance with another country for an attack to succeed, otherwise their army is not powerful enough.*

It is well known since Austin [1] that speech acts (performatives) both presuppose and create or change social facts. The classic example is a marriage created by a formula "I hereby declare you man and wife" being uttered by an appropriate official or clergyman in front of a congregation. Many of these social facts take the shape of a relationship, marriage being just one of them. Another interesting social relationship is power or authority. For example, a command presupposes that the speaker has some authority over the addressee. If there is no authority a command is not appropriate. Moreover, when the command is accepted by the addressee, this reinforces the authority of the speaker, but when the addressee refuses to 'take up' the command, this undermines the authority relation [8].

Some social relationships take the shape of a dependency. For example, social commitments are created by an accepted promise, or by an accepted request. The commitment means that one agent is now dependent on the other agent for the execution of some task or the achievement of some condition. Social commitments are only one example of such a dependency relation, which has been studied widely [6, 10, 11]. Other dependencies are based on access to resources, such as money, tools, or labour. A special kind of resource one may depend upon is information. Thus a question is a speech act which signals that the speaker depends on the addressee to provide some information.

This leads to a general view of the semantics of communication as relationship building, rather than mental attitude building. Such a view is more in the spirit of multiagent systems, than the traditional mental attitude semantics. Essentially, it views communication as the means to express the *dynamics* of social networks.

EXAMPLE 2. *In the diplomacy game, players can make requests, promises, form coalitions (some of it public, some of it only known in separate coalitions), make threats and induce fear, and so on.*

2. SOCIAL ACL SEMANTICS

We propose a semantics of speech acts as 'relationship building'. The meaning of a speech act (type of utterance) can be given by its pre and post conditions. In our social semantics, the pre and post conditions of speech acts are given as (constraints on) social networks.

DEFINITION 1. *A social network is a tuple $\langle A, R, L\rangle$ where A is a set of agents, L is a set of labels, and $R \subseteq A \times A \times L$ is a labelled binary relation on the set of agents. We write N for the set of all social networks. A speech act theory is a tuple $\langle A, S\rangle$ where A is a set of agents and S is a set of speech acts. The semantics of speech act $s(a, b)$ with $a, b \in A$, $s \in S$ is a function from N to N.*

Social networks allow us to take a 'data structure view' on semantics. Here, the data structure is a social network, which is assumed to be commonly known. Transitions `add` and `del` modify relations. In Figure 1 (where `dep_bel` means dependency on a belief, `dep_int` dependency on an intention, and `comm_bel` commitment to a belief), we illustrate the results of some of those transitions communicated through speech acts (performatives).

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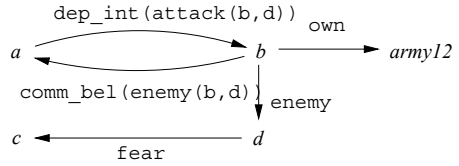

Figure 1: Resulting state after the performatives of Example 3.

EXAMPLE 3 (SAMPLE PERFORMATIVES).
Who is your enemy?
$\mathtt{ask}(a, b, ?y\ \mathtt{enemy}(b, y)) =$
$\quad \mathtt{add}(\mathtt{dep\_bel}(a, b, ?y\ \mathtt{enemy}(b, y)))$
My enemy is d.
$\mathtt{answer}(b, a, ?y\ \mathtt{enemy}(b, y), \mathtt{enemy}(b, d) =$
$\quad \mathtt{del}(\mathtt{dep\_bel}(a, b, ?y\ \mathtt{enemy}(b, y)));$
$\quad \mathtt{add}(\mathtt{comm\_bel}(b, a, \mathtt{enemy}(b, d)))$
Will you attack d?
$\mathtt{request}(a, b, \mathtt{attack}(b, d)) =$
$\quad \mathtt{add}(\mathtt{dep\_int}(a, b, \mathtt{attack}(b, d)))$
– giving –
$\mathtt{give}(a, b, army_{12}) =$
$\quad \mathtt{del}(\mathtt{ownership}(a, army_{12}));$
$\quad \mathtt{add}(\mathtt{ownership}(b, army_{12}))$
– threatening –
$\mathtt{menace}(c, d, \mathtt{attack}(c, d)) = \mathtt{add}(\mathtt{fear}(d, c))$

3. DEPENDENCE ACL SEMANTICS

We explore a particular kind of social network for ACL semantics, called dependence networks, to replace mental attitudes approaches like the FIPA standard. Roughly, dependence networks are a social network where the relations among agents are labelled with intentions, to represent that agents depend on other agents to achieve their intentions. Agent a depends on agent b when agent a has an intention i, and agent b can ensure that the intention i is achieved. FIPA speech act theory is mainly based on two primitives: inform and request. Other speech acts are defined in terms of these two primitives. For example, a question is a request to be informed. Roughly, the effect of an inform action of agent a is the intention that agent b adopts a belief, and the effect of a request of agent a is the intention that agent b adopts an intention. In other words, they both have result in the creation of a dependence of agent a on agent b, that agent b accepts the message.

The interesting dynamics of dependence networks due to agent communication is determined by the indirect effect of speech acts. If agent b accepts a request, then he adopts an intention, and if he cannot achieve the intention himself, then he becomes dependent on other agents. For example, if agent b accepts the request of agent a to attack agent c together, he becomes dependent on agent a. Likewise, if agent b accepts an inform and, thus, adopts a new belief, then this new belief may create new dependencies. For example, if agent a informs agent b that he is going to attack agent c and agent b believes it, then b becomes committed to defend his belief when requested by other agents.

DEFINITION 2. *A conditional dependence network is a tuple $\langle A, I, D, C\rangle$ where A is a set of agents, I is a set of intentions, $D \subseteq A \times 2^A \times I$ is a set of dependencies, and $C \subseteq I \times A \times 2^A \times I$ is a set of conditional dependencies that are created when the first intention is achieved. As before, we write N for the set of all social networks, speech act theory is a tuple $\langle A, S\rangle$ and the semantics of speech act $s(a, b)$ is a function from N to N.*

Dependence networks are often studied in coalition theory since they allow to study reciprocity structures [3]. In the case of dialogue, we see two issues. First, communication protocols like contract net aim at creating such reciprocity structures, for example to exchange goods. Second, a request from an agent reveals that he considers the addressee as a possible partner of a coalition, since the speaker cannot hope that the request is accepted just for benevolence, but he believes that the addressee is dependent on him.

This last point raises another issue: are the dependence networks public and objective or private and subjective? In [5] dependencies have a subjective nature. However, communication has a public character and it cannot be based on private representations [2, 7]. Thus, transitions should operate at the public level, since they represent the meaning of speech acts. However, we need also to represent private networks, even if they do not have a role in the proper semantics, since a speech act can reveal information about the view of the speaker, like in the example above.

4. SUMMARY

We re-invent speech acts at a different level, because they are needed to communicate changes to social networks. An advantage is that we can use a relatively simple graph-theory like language for the representation of the 'data structure'. This is exactly what is needed, e.g., in the Semantic Web community: a semantics of speech acts in terms of another well established formalism. But it also works the other way around: speech acts can account for the dynamics of dependency networks, or more generally, social networks. The dynamics of dependence networks has been not studied enough yet [4].

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