Communication as Agent Interaction: 
Toward a Public Semantics

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Abstract

The ability to communicate is one of the salient properties of agents, human or artificial. Although a number of agent communication languages (ACLs) have been developed, obtaining a suitable formal semantics for ACLs remains one of the greatest challenges of multiagent systems theory. Previous semantics have largely been mentalist in their orientation and are based solely on the beliefs and intentions of the participating agents. Such semantics are not suitable for most multiagent applications, which involve autonomous and heterogeneous agents, whose beliefs and intentions cannot be uniformly determined. Accordingly, we motivate a social semantics for ACLs that gives primacy to the interactions among the agents. A public orientation is essential to providing a rigorous basis for understanding communication protocols. Our semantics is based on social commitments and can be formalized in temporal logic.

1 Introduction

Interaction among agents is the distinguishing property of multiagent systems. Communication is a kind of interaction that respects the heterogeneity and preserve the autonomy of agents. In this respect, it differs from physical interaction. An agent may have no choice but to physically affect another agent—e.g., to bump into it or to lock a file it needs—or similarly be affected by another agent. By contrast, unless otherwise constrained, an agent need not communicate; if it is willing to handle the consequences, it can maintain silence and deny the requests or even the commands it receives. Our particular interest is in open multiagent systems, which find natural usage in modern applications such as electronic commerce. In open multiagent systems, the member agents are contributed by several sources and serve different interests. Thus, these agents must be treated as (a) autonomous—with few constraints on behavior, reflecting the independence of their users, and (b) heterogeneous—with few constraints on construction, reflecting the independence of their designers.

Openness means that all interfaces in the system, and specifically ACLs, be given a clear semantics. Current approaches to ACL semantics are either (a) purely behavioral and specify how tokens are ordered in a protocol without regard to what the tokens mean or (b) purely mentalist and specify the mental states of the participating agents and lack an account of how those might be confirmed or denied without full knowledge of the agents’ construction. Consequently, current approaches are either verifiable and support determining whether an agent is acting according to the given semantics or meaningful and can assign content to the tokens communicated, but not both. This is because current approaches are based on traditional approaches for the

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semantics of human communication. We propose an alternative, social approach to a semantics that places the semantic content of communications in the public domain, thereby meeting the above criteria of being verifiable and meaningful. Further, what often passes as semantics in these theories is better understood as pragmatics, e.g., how and when to cooperate. The pragmatics is of course essential, but should not be conflated with the semantics.

2 Concepts and Key Questions

Following [Austin, 1962], we treat communications as speech acts. An illocution is the core component of a communication and corresponds to what the communication is meant to accomplish independent both of how the communication is physically carried out (the locution) and the effect it has on a listener (the perlocution). For example, I could request you to open the window (the request is the illocution) by saying so directly or hinting at it (these are possible locutions). Whether or not you accede to my request is the perlocution. A proposition can be combined with illocutions of different types to yield different message. For example, my request to open the window is different from my assertion that the window is open. This paper mainly discusses the illocution types, not the propositions themselves.

It is customary to classify ACL primitives or message types into a small number of categories based on the different types of illocution. Usually these include the following categories—a sample primitive of each category is given in parentheses: assertives (inform), directives (request), commissives (promise), permissives (permit), prohibitives (forbid), declaratives (declare), and expressives (wish).

Mentalist versus Social Semantics. Work on speech act theory within AI was motivated from natural language understanding and concerned itself with identifying or inferring the “intent” of the speaker or, more generally, the mental states of the participants. Inferring the mental states of participants can sometimes be useful. However, there are a number of objections to using only the mental concepts for specifying ACL semantics [Singh, 1998], which we summarize next.

- **Philosophical.** Communication is a public phenomenon, but the mental concepts are private. Any semantics that neglects the public nature of communication is not telling the whole story. Something obviously takes place when agents interact through language even if they don’t have or share the “right” beliefs and intentions.

- **Practical.** Ensuring that only the desirable interactions occur is one of the most challenging aspects of multiagent system engineering. However, the mental concepts cannot be verified without access to the internal construction of the agents. In fact, we cannot uniquely determine an agent’s beliefs and intentions even if we know the details of its construction.

Pragmatics versus Semantics. What we refer to informally as meaning is is usually a combination of the semantics and pragmatics. The semantics is the component of meaning that is relatively fixed and minimal. The pragmatics is the component of meaning that is sensitive to the context of usage, including the social structure within which the communication takes place. Pragmatic claims would be based on considerations such as the Gricean maxims of manner, quality, and quantity [Grice, 1975].

The traditional “semantics” of communications is often loaded with pragmatics. For example, the pragmatic basis for inform might be that the sender believes the receiver does not already know what is being informed. Similarly, the pragmatic basis for permit might be that the receiver desires or intends the content that is being permitted. These might be useful basis to decide when to communicate, but they are are hardly describe the content of the communications.

To appreciate our distinction between pragmatics and semantics consider the requirement that only those propositions can be true that someone believes to be false! Or, alternatively, an agent can believe something
true only if another agent believes it false! As semantic requirements on truth or belief, these are silly. Yet, as pragmatic requirements on facts and beliefs that are worth talking about by the agents or by their designers, these are eminently reasonable.

3 Approach

Communication occurs during the execution of a multiagent system. For this reason, our semantics is based on commitments expressed in a logic of time. We develop the concept of social commitments as is studied in multiagent systems [Conte and Castelfranchi, 1995] and reasoning and dialogue in general [Walton and Krabbe, 1995]. Social commitments are the commitments of one agent to another. We define a commitment as involving three agents: the debtor (who makes it), the creditor (to whom it is made), and the context (the containing multiagent system in the scope of which it is made). Our technical definition differs from previous works in two main respects. Our approach [Singh, 1999]

- includes the notion of a social context; the social context refers to the team in which the given agents participate and within which they communicate; it too can be treated as an agent in its own right—e.g., it may enter into commitments with other agents.
- allows metacommitments to capture a variety of social and legal relations.

3.1 Validity Claims

The semantics of ACLs, which concerns us here, relates to the essence of communication. The currently popular approaches to ACL semantics are based on the speaker’s intent [Grice, 1969]. Under this doctrine, the illocution is what the speaker believed and intended it to be. This doctrine, championed by Searle and others, however, leads to the philosophical and practical problems discussed above.

In philosophy, another of the best known approaches to communicative action is due to Habermas [1984]; a tutorial is available in [Verharen, 1997, chap. 2]. The Habermas approach associates three “worlds” or aspects of meaning with communication. These correspond to the three validity claims implicitly made with each communication:

- **objective**, that the communication is true
- **subjective**, that the communication is sincere
- **practical**, that the speaker is justified in making the communication

In conversation, each of the above claims may be challenged and shown to be false. However, even if false, these claims are made with each communication. The claims involve different aspects of meaning including the subjective, but by fact of being claims in a conversation, they are public and social. If I tell you something, I am committed to being true, and you are entitled to check if I am. I am also committed to be sincere, even though you may not be able to detect my insincerity unless you can infer what I believe, e.g., through contradictory statements that I make at about the same time.

Perhaps more than his followers in AI, Searle too recognizes the institutional nature of language. He argues that the “counts as” relation is the basis for “constitutive reality” or institutional facts, including definitions of linguistic symbols [Searle, 1995, pp. 152–156]. But institutions are inherently objective. For example, in an auction, raising your hand counts as making a bid whether or not you have the intention to actually convey that you are bidding. In on-line commerce, pushing the “submit” button on your browser counts as authorizing a charge on your credit card.
3.2 Social Semantics

The different claims associated with a communicative action are mapped to different commitments among the participants and their social context. Consequently, although our semantics is social in orientation, it admits the mental viewpoint.

Objectively, the sender commits for inform that its content is true, for promise that its content will be accomplished, for permit that its content may be realized, for declare that its content is true. For request, the sender expects that the receiver will commit to making it true, and for forbid that the receiver will commit that its content will not be realized. Although these are not part of the objective meaning, they are related to the practical meaning given below.

Subjectively, the sender commits for inform that he believes its content, for promise that he intends to carry it out, for permit that he does not intend the negation of its content, for declare that he intends to bring it about. For request, the sender expects that the receiver will commit to intending to make it true, and for forbid that the receiver will commit that its content will not be realized. These expectations are not directly incorporated in the semantics.

The practical aspect of the semantics is the most complex. Practically, the sender commits for inform that he has reason to know the content, for promise that if he promises something he can make it happen, for permit that he has the authority to relieve the receiver of any commitment to do otherwise, and for declare that his saying so, brings it about. For request, the sender commits that the receiver has committed to accepting a request from him. For forbid, the sender commits he can cause the receiver to take on a commitment to not let the condition come about. The above meanings are naturally phrased as metacommitments to the group. Some of them refer to the communication itself.

Conceivably, even the commitments relating to the subjective expectations might be added here, but we suggest they would be too strong for the basic practical meaning. This is because our goal with this semantics is to specify the objective and the practical components of the semantics for use in the construction and validation of multiagent protocols. This is facilitated when the subjective criteria are not included in the practical meaning.

The above semantic validity claims, even the practical claims, are different from pragmatics. Some of the pragmatic constraints would be the public versions of the expectations listed above in the subjective component of the semantics.

3.3 Properties

Our semantics satisfies the criteria of Section 1. It offers different levels of verifiability. Every commitment to a putative fact can be verified or falsified by challenging that putative fact. Every commitment to a mental state can be similarly verified or falsified, but only through the more arduous route of eliciting the agent’s beliefs and intentions. These might elicited by observing the agent’s further communications or other actions. Every commitment to some institutional fact can be verified or falsified by appeal to some external authority. This authority is the context within which the communication takes place. The context could be defined as just the group of everyone involved, but would in practice refer to some sort of a leader, typically one that was elected.

By being based on the commitments of the participating agents, our semantics provides a basis for describing the conversational state of a multiagent system in high-level terms, i.e., using commitments. Thus, the state, defined in terms of commitments, is independent of the history, i.e., the steps of a protocol that may have been executed. History-freedom is essential to establishing protocols that can tolerate digressions and ad hoc extensions (necessary in practice) and compositionality of protocols.
4 Discussion

Communication involves the exchange of messages with a streamlined set of tokens. Our approach assigns public, i.e., observable, meanings in terms of social commitments. This leads to the ability to test compliance at a level of abstraction higher than just the ordering of events. It also promises a canonical form of communication protocols, which would give us a meaningful basis for determining the state of a specific conversation realizing a protocol. Low-level protocols, e.g., for turn-taking, will continue to be useful, however, even with our approach. For instance, a bidder shouldn’t make a bid prior to the advertisement, or the commitment content of the bid won’t be fully defined.

The social approach opens up interesting theoretical questions. One of these is the longstanding topic of presuppositions and consensus. Presuppositions are essential to understanding and properly interpreting any communication. Potentially, we can interpret the implicit claims behind every communication as presuppositions [Walton and Krabbe, 1995]. If they are not challenged, they become accepted as consensus, which corresponds to commitments by the entire group of communicating agents. Consensus might offer a tractable alternative to mutual beliefs, which are used by current theories of dialogue, but which cannot be obtained in realistic environments, e.g., those with unreliable asynchronous communication [Fagin et al., 1995].

References


