Commitment Monitoring in a Multiagent System

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Abstract. Agent Communication Languages (ACLs) play a fundamental role in open multiagent systems where message exchange is the main if not the only way for agents to coordinate themselves. New proposals about ACL semantics based on social commitments aim at countering the shortcomings of the mainstream mental-state-based ones. The commitment solution does not come for free and calls for an adequate monitoring system that checks whether commitments are fulfilled or not.

1 Introduction

Agent Communication Languages (ACLs) play a very significant role in the context of multiagent systems, especially open ones, in which every agent’s internal architecture has been independently developed and so the only common ground it can share with other agents in the system is a standard communication framework. The most important ACL proposal so far, FIPA ACL \cite{kawa00}, has gone through some changes, but since its first version it has provided language specifications in terms of agents’ mental states. It has already been discussed elsewhere \cite{kesst04, vesena05} how several issues rise from this approach. Let us just remind here that standards relying on a theory involving mental states compel agent programmers to create software with a specific architecture, implementing such theory and thus enabling agents to communicate. In open multiagent systems, populated by heterogeneous, independently developed agents, communication standards should be specified so that agents’ internal architecture need not be taken into account. The issues that probably hindered the universal success of mental state-based proposals, also triggered an alternative approach. Some researchers have proposed a semantic framework for an ACL based upon the concept of social commitment \cite{sibani05, sibani06}, in which a communicative act is viewed as an action performed by an agent to create or modify the commitments by which it is bound to the others. Commitments, as opposed to mental states, are objective and public and thus have the great advantage of not needing to be reconstructed and attributed to other agents by means of inference processes, and they can be stored in public records for further reference.

2 The Formal Model

Commitments describe certain states of affairs at different instants, thus we need some formal definitions dealing with time, events, and actions. We provide here
a restricted version of a temporal logic that has already been illustrated in [15]. In this previous work the temporal model was relying on a frame branching in the future, because the aim was to deal with the truth conditions of future directed sentences without the need for departing from a classic two-valued logic. Instead, we take a more operational approach, and only evaluate the truth value of past and present directed portions of sentences, while keeping the future directed parts suspended for further consideration. Moreover, since in this work we propose a technique for monitoring, that is, checking temporal and atemporal properties of a multiagent system at runtime, we only need to focus on a single run of the system. With such working hypotheses, a branching model of time is superfluous, and we can simply make do with a linear one. Thus, our starting point is $\text{LTL}^\pm$, a temporal language close to LTL, a linear temporal logic including only future-directed temporal operators [8], to which we add past-directed operators, which allow us to express some properties of computational systems in a far more succinct way [12]. In $\text{LTL}^\pm$, time is assumed to be discrete, with a starting point but no ending point.

We rely on the classical $\text{LTL}^\pm$ semantic definitions, and take a model $M$ as comprised of a set of states $S$, an infinite sequence $x$ of states ($x(0), x(1), \ldots \in S$), and a function $v$ that labels each state with the atomic formulae true at that state [8]. Given a model $M$, an atomic formula $\phi$ holds at a state $x(t)$ if and only if $\phi \in v(x(t))$. The semantics of the following compound formulae is defined in the usual way: $\neg \phi$ (not $\phi$), $\phi \land \psi$ ( $\phi$ and $\psi$), $X^+ \phi$ (at the next state $\phi$), $X^- \phi$ (at the previous state $\phi$), $\phi U^+ \psi$ ( $\phi$ until $\psi$), and $\phi U^- \psi$ ( $\phi$ since $\psi$). We use the usual derived logical connectives and temporal operators: $\phi \lor \psi$ ( $\phi$ or $\psi$), $\phi \rightarrow \psi$ (if $\phi$ then $\psi$), $\phi \leftrightarrow \psi$ ( $\phi$ iff $\psi$), $F^+ \phi$ (sometimes in the future $\phi$), $F^- \phi$ (sometimes in the past $\phi$), $G^+ \phi$ (always in the future $\phi$), $G^- \phi$ (always in the past $\phi$), $\phi W^+ \psi$ ($\phi$ weak until $\psi$, that is, $\phi$ is always true in the future or until $\psi$), $\phi W^- \psi$ ($\phi$ weak since $\psi$), $\phi Z^+ \psi$ ($\phi$ until $\psi$ and then no longer $\phi$). This last operator may need further elaboration, as to our knowledge it is not used elsewhere. It is defined as follows,

$$\phi Z^+ \psi =_{\text{def}} \phi W^+ \psi \land G^+ (\psi \rightarrow G^- \neg \phi),$$

which holds iff $\psi$ never becomes true and $\phi$ is always true, or eventually $\psi$ becomes true and from that moment on $\phi$ is no longer true.

In our view, events are reified, and each event token belongs to at least an event type, and takes place at exactly one instant. An action is an event brought about by an agent, called the actor of the action. We write $\text{Done}(e, x, \tau)$ to mean that event $e$ of type $\tau$ is brought about by agent $x$. We use the “m-dash” character as a shorthand for existential quantification. For instance:

$$\text{Done}(e, -, \tau) =_{\text{def}} \exists x \text{Done}(e, x, \tau).$$

In our view, a commitment is a social state between agents comprised of four components: an event $e$ that has created the commitment, a debtor $x$ which is the agent who is committed, a creditor $y$ which is the agent the debtor is committed to, and a content $u$ which represents the state of affairs the debtor is committed to bring about, as in the following predicate: