A Reasoning System Based on a Logic to Handle Communication between Agents

Mistuo Watanabe (110123)

School of Information Science,
Japan Advanced Institute of Science and Technology

February 13, 2004

Keywords: Multi-Agent Model, Communication between Agents, Temporal Epistemic Logic, Reasoning System.

An agent is a computer system tha performs as an autonomous inference. The agent operates in a series of flows, reasons based on its information and perception, and performs actions based on their result. Logical formalization is studied as one of the architecture for a design of such an agent. A temporal epistemic logic is a system used in order to describe and reason its epistemic states such as agent's beliefs change in time. A number of systems including BDI logic are proposed as a temporal epistemic logic system. They are not logic systems to handle interaction of epistemic states between agents, but that to handle epistemic states of one agent or some isolated agents. However, generally, when we consider multi-agent models, interaction between agents, that is, communication between agents is one of the most important elements. Moreover, communication directly concerns to agent's epistemic states. Nevertheless, the logic system or reasoning system which took such communication into consideration directly are not found.

The purpose of this paper is to introduce logic for reasoning about agents' epistemic states with commutations between them and to present a reasoning system for this logic. Furthermore, we implement the reasoning system on a computer as proof machine. Then, by introducing reasoning accompanied with communication, we aim at making it possible to reason

how agents' epistemic states change by communication, or what epistemic states agents may have by communication.

In this paper, at first, we formalize communication between agents. This is based on "inform" in ACL (Agent Communication Language) that is an existing formalization defined by FIPA (Foundations of Intelligent Physical Agents) that is international standardization organization about agent technology. In the definition of the "inform" by FIPA, the pre-condition and the post-condition of "inform" are defined only according to an agents' epistemic states. Then, we add a communication channel between agents to the pre-condition of "inform". Furthermore, we add a progress of the time from the time when the precondition was held to the post-condition. By this, we change the definition of "inform" to the definition in consideration of the discrete time (if pre-condition was held and "inform" was performed at certain time, the post-condition is held at the next time).

Second, we introduce a temporal epistemic logic system for reasoning agents' epistemic states in consideration of the above communication. The logic system CB_{CTL} that we introduce is a propositional temporal epistemic logic system about plural agents' beliefs based on CTL (Computational Tree Logic) that has the branching time of temporal logic. CB_{CTL} also refers to the definition of BDI logic that is one of the temporal epistemic logic based on CTL. But, it differs from BDI logic in that we handle only beliefs of plural agents as epistemic states. Since CTL is used as the base, we can describe and reason about branching time, that is, a situation which agents may have various epistemic states in future in CB_{CTL}.

In this paper, we propose a reasoning system accompanied with the communication for the logic system CB_{CTL}.

This reasoning system evaluate truth value of logical formulas in logical model basically in accordance with Kripke semantics of CB_{CTL}. But, it also reason with communication between agents. For example, the reasoning system can reason following situation.

> An agent i have a belief p at the time t, an agent j does not have a belief about p, and these two agents can communicate each other. When we assume such a situation, a sentence (Since an agent i can inform an agent j of p) "an agent j can hold belief p at the next time of t" is true in time t.

Since the communication is included in reasoning, the result of reasoning with the communication differs from the result of the usual truth value evaluation in the model. Then we rebuild Kripke model to make coincide truth value defined by semantics of CB_{CTL} with result of reasoning with communication. Thus, we design the reasoning system that has the reasoning with communication and the usual reasoning in accordance with the semantics in a decidable procedure. Furthermore, we implement above reasoning system with communication on a computer in Prolog, and show its operations using some examples.

As the result of these, we introduce the logic system and reasoning system that is closely related to agents' epistemic states. In addition, for formalization of the communication in the process, we introduced the idea of a communication channel.

The following problems remained as future subjects.

- Although I restricted that "inform" can carry only an atomic formula in our system, it is necessary for us to enable it to inform more general logical formulas.
- It is necessary for us to introduce syntax of the logic system, and deduction system for it.
- Furthermore, we will be able to apply idea of communication to a logic system which handle epistemic states as not only belief but also other epistemic states (e.g. BDI logic).