The Logical Characterization of Goal-Directed Behavior in the Presence of Exogenous Events

1 Our Topic

Logics of action and change were originally conceived for the design of intellligent agents, as McCarthy proposed the situation calculus as the logic to be used by a logic-based "advice taker". In more recent research one can distinguish two motives for these logics, namely, for what is now called *cognitive robotics* and for *common-sense reasoning*. The difference is that in cognitive robotics, the logic must also account for an incoming flow of sensory data and for the actuation of actions by the robot, whereas common-sense reasoning is oriented towards natural-language communication of the premises and the conclusions of the reasoning process.

The present article addresses the case where logics of actions and change are used for cognitive robotics purposes. An intelligent robotic agent will necessarily have a quite complex design, since it has to account for all of the following:

- Goal-directed behavior, including the principle of *deliberated retry*, that is, if the robot takes an action in order to pursue a goal and the action fails, then it is to consider some other action or sequence of actions that is likely to achieve the same goal.

- World modellling and the description of the effects of actions on *several levels of detail*, ranging from simple approximations such as precondition/postcondition descriptions, to the detailed specification in control theory terms of how an action is performed.

- The problem of *imprecise and unreliable sensors*.

- The occurrence of *exogenous events*, including both the prediction and early reaction to those exogenous events that can reasonbly be predicted, and the proper dealing with those exogenous events that come as a surprise to the agent. In fact, it is not sufficient that the agent be able to deal exogenous events in prediction mode and synchronous mode (recognizing them at the moment they occur), but it must also sometimes be able to diagnose aberrant situations and understand them in terms of exogenous events that may have occurred earlier in time, that is, it must be capable of postdiction as well as prediction.

In order to master the design of such complex devices, it is necessary to make use of concise and high-level specifications. It is somewhat remarkable, therefore, that most research on logics of actions and change has avoided the issues mentioned above. It has focussed on the actions performed by the agent, the restrictions that may be imposed on them, and their indirect effects due to some kind of causation. These logics have not generally been used for characterizing the behavior of the agent, goal-directed or otherwise, and there has only been a small number of contributions on reasoning about unreliable sensor data.

Research in the area of *intelligent systems* have approached some of these topics from another angle, and in a few recent cases they have also used logic as a means of characterizing the system design. We believe that this area at the intersection of two current research traditions – reasoning about actions and change, and intelligent agent systems – will attract a lot more attention in the forthcoming years.

In the present invited lecture, we are going to describe our own recent work in the area that has now been described. In particular, [j-etai-1-105] and [c-kr-98-304] describes a method for characterizing the goal-directed behavior of deliberated retry in a first-order logic of time and action. Also, [j-aicom-9-214] and [c-hart-97-3] describe a method of relating high-level and low-level action descriptions in a similar logic. The results in those articles are complementary, and the present lecture will show how to combine them into an integrated framework.

2 Related Work

As a joint reference for these and other articles, we are maintaining a webpage structure with a summary of related work by others and links to those other articles. This structure is continuously extended with new references and commentary, so it is kept up-to-date in a way that a reference list in an article can not do. Please refer to the URL of the first mentioned article,

`http://www.ep.liu.se/ea/cis/1997/019/`

for links to all such further information in its up-to-date form.

References:

[c-hart-97-3] Erik Sandewall. *Relating high-level and low-level action descriptions in a logic of actions and change.* Proc. Hybrid and Real-Time Systems, 1997, pp. 3-17.

[c-kr-98-304] Erik Sandewall. *Logic Based Modelling of Goal-Directed Behaviou.* Proc. International Conf on Knowledge Representation and Reasoning, 1998, pp. 304-315.

[j-aicom-9-214] Erik Sandewall. *Towards the validation of high-level action descriptions from their low-level definitions.* AI Communications, vol. 9 (1996), pp. 214-224.

[j-etai-1-105] Erik Sandewall. *Logic-Based Modelling of Goal-Directed*

Behavior. Electronic Transactions on Artificial Intelligence, vol. 1, pp. 105-128.