Epistemic Logic and Knowledge Management

Prof. Dr. Marcus Spies
Knowledge Management
Ludwig-Maximilians-Universität München
marcus.spies@computer.org

For several decades, knowledge representation was studied in AI under the assumption of a single knowing agent. From the general problem solving approach in the sixties over the expert systems of the late eighties up to ontology-based reasoning approaches in modern knowledge management, there used to be one intelligent system considered at a time. Multiagent systems became a major topic in AI research during the eighties and the nineties of the last century. However, these systems have found applications in rather limited domains of artificial life and some robotics applications. Sometimes, object orientation was taken as a sufficient condition for emulating multiagent systems.

I would like to argue, instead, that a true multiple intelligent systems approach to knowledge representation in AI requires a deeper extension of the underlying logic. More specifically, epistemic logic seems to offer a sufficiently rich framework for describing deducible and emerging properties of multiagent intelligent systems. As for applications, I will focus on requirements occuring in modern knowledge management support systems.

Basically, there are two variants of epistemic logic being discussed in recent publications. One variant is derived from modal logic, see the monograph by Meyer and van der Hoek [3]. It is concerned with possible worlds under different agents' perspectives. The basic concept here is that of a knowledge state (a single possible world for each agent) and an accessibility relation of possible worlds by single agents (Kripke structures). Accessible possible worlds are those compatible with an agents's knowledge state. Knowledge or epistemic truth for one agent is then defined as truth in the usual sense of propositional calculus for all accessible possible worlds of the agent. Formally, this variant of epistemic logic allows for sound and complete axiomatizations and it has useful applications in specification and validation of multiagent systems and corresponding algorithms. Moreover, intuitively appealing concepts like implicit knowledge or common knowledge can be rigorously defined in such theories. There are further applications to decision analysis, see [1]. However, this variant of epistemic logic is confined to propositional calculus.

The second variant of epistemic logic is concerned with knowing facts about objects and knowing these objects themselves, i.e., it is based on predicate logic. This variant has been outlined in several writings of Gabriel Sandu and Jaakko Hintikka, [2] in particular. Syntactically, we need at least a first-order theory and a knowledge operator with two uses: First, it can qualify a formula as "known" by some individual, which corresponds to expressing factual knowledge (or "knowing that" – this construction would comprise Kripke structures if the underlying language had zero-place predicates only). Second, it can qualify an existential quantifier, which means that values of its bound variable that satisfy the formula are known. This corresponds to "knowing which". An obvious example of knowing which would be knowledge of which information resource to consult for some data in a project. Additionally, it seems reasonable to allow nesting of these operators, which expresses so-called "transactive knowledge" [4], i.e. knowledge about other individuals' knowledge.

In the design of today's enterprise information portal systems (EIP), the epistemic concepts mentioned are not given much attention. The consequence is that these systems can only support flat knowledge processes consisting basically of sequences of single questions and single answers (which may involve some deduction process). However, the effective design and management of deeper knowledge processes like transfer of knowledge between departments in a large organisation require consideration of epistemic phenomena like common knowledge vs. shared knowledge. The reason for this is that questions will be asked from members of department A according to assumptions about knowledge of members of department B. Likewise, the answers from department B will be formulated differently according to B's members' assumptions about knowledge in department A. In real organisations, faulty assumptions about other people's knowledge lead to high e-mail traffic with low business effect. Moreover, if the common knowledge of both departments is not taken into account, superfluous trainings or integration meetings are administered. On the information technology side, such deficiencies can greatly reduce the efficiency of today's collaborative filtering products. Similarly, role-based access profiles in EIP systems are likely to miss important dimensions of real users' interest profiles.

References

[1] M.O.L. Bacharach, L. A. Gérard-Varet, P. Mongin, and H.S. Shin, editors. *Epistemic Logic and the Theory of Games and Decisions.* Kluwer, Dordrecht, 1997.

[2] Jaakko Hintikka. *The principles of Mathematics revisited.* Cambridge University Press, Cambridge, 1996.

[3] J.-J. Ch. Meyer and W. van der Hoek. *Epistemic Logic for AI and Computer Science.* Cambridge Tracts in Theoretical Computer Science. Cambridge University Press, Cambridge, 1995.

[4] Marcus Spies, Elisabeth Brauner, Rudolf Kerschreiter, and Andreas Mojzisch. Sozialpsychologische erfolgsfaktoren des wissensmanagement. In Elke van der Meer and et al., editors, *43. Kongreß der Dt. Ges. f. Psychologie*, page 347, Berlin, 2002. Pabst Science Publishers.