Taming Complex Beliefs*

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Abstract. A novel formalization of beliefs in multiagent systems has recently been proposed by Dunin-Keplicz and Szalaś. The aim has been to bridge the gap between idealized logical approaches to modeling beliefs and their actual implementations. Therefore the stages of belief acquisition, intermediate reasoning and final belief formation have been isolated and analyzed. In conclusion, a novel semantics reflecting those stages has been provided. This semantics is based on the new concept of epistemic profile, reflecting agent’s reasoning capabilities in a dynamic and unpredictable environment. The presented approach appears suitable for building complex belief structures in the context of incomplete and/or inconsistent information. One of original ideas is that of epistemic profiles serving as a tool for transforming preliminary beliefs into final ones. As epistemic profile can be devised both on an individual and a group level in analogical manner, a uniform treatment of single agent and group beliefs has been achieved.

In the current paper these concepts are further elaborated. Importantly, we indicate an implementation framework ensuring tractability of reasoning about beliefs, propose the underlying methodology and illustrate it on an example.

1 Beliefs in Multiagent Systems

During the past years awareness has been intensively investigated both from the theoretical as well as from the practical perspective. Its importance manifested itself especially in the context of cooperating teams of agents or other mixed groups in the context of intelligent, autonomous systems. In multiagent systems, agents’ awareness is typically expressed in terms of different (combinations of) beliefs about

- the environment;
- an agent itself;
- other agents/groups involved.

Such beliefs are built using various forms of observations, communication and reasoning. Existing modern, fine-grained logic-based approaches typically

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explore rather subtle (combinations of) multi-modal logics [16,18,19,20]. Unfortunately this usually leads to high complexity of reasoning that is unacceptable from the point of view of their implementation and use. In fact, the underlying semantical structures are rather abstract and hardly reflect the way beliefs are acquired and finally formed. To make it even worse, in many applications one needs to take into account relevant features of perception, including:

– limited accuracy of sensors and other devices;
– restrictions on time and other resources affecting measurements;
– unfortunate combinations and unpredictability of environmental conditions;
– noise, limited reliability and failure of physical devices.

In multiagent systems during belief formation initial and intermediate beliefs are confronted with other beliefs originating from a variety of sources. The resulting beliefs can then substantially deviate from the initial ones. Moreover, there might still exist areas of agents’ ignorance and inconsistencies. A low quality of information does not waive agents’ responsibility of decision making. Therefore, reducing the areas of ignorance and inconsistencies is vital. In modern systems this can be accomplished in many different ways, including

– a variety of reasoning methods;
– belief exchange by communication;
– belief fusion;
– supplementary observations.

Apparently there is no guarantee to acquire the whole necessary information and/or to resolve all inconsistencies. Information may still remain partly unknown and/or inconsistent. Such situations may be sorted out by the use of

– paraconsistent models allowing for inconsistencies and lack of information;
– nonmonotonic reasoning techniques for completing missing information and resolving inconsistencies.

However, both paraconsistent and nonmonotonic reasoning, in their full generality, are intractable [5,17,21,25]. This naturally restricts their use in multiagent systems and calls for a shift in perspective. In [10] we proposed a novel framework for flexibly modeling beliefs of heterogeneous agents, inspired by knowledge representation and deductive database techniques.

The key abstraction is that of epistemic profiles reflecting agent’s individual reasoning capabilities. In short, epistemic profile defines a schema in which an agent reasons, deals with conflicting information and deals with its ignorance. These skills are achievable by combining various forms of reasoning, including belief fusion, disambiguation of conflicting beliefs or completion of lacking information. This rich repertoire of available methods enables for heterogeneity of agents’ reasoning characteristics. More importantly, the same approach may be applied to groups of agents or even more complex mixed groups, allowing for uniform treatment of these, essentially different, cases.