Computational logic in multi-agent systems:  
Recent advances and future directions  

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Starting from the early days of multi-agent systems research, considerable effort has been devoted to giving formal foundations to agent technologies. Work done in this direction, based on computational logic, is an attempt to bridge an existing gap, between theoretical frameworks and their practical implementations. In the last two editions of the workshop on Computational Logic in Multi-Agent Systems, CLIMA’01 and CLIMA’02, two discussion panels have been organized, aimed at bringing researchers together and exchanging ideas on a number of topics. In this article, we elaborate on the outcome of such panels, to draw some considerations about the recent advances and future directions of Computational Logic in Multi-Agent Systems.

Keywords: computational logic, logic programming, multi-agent systems

1. Introduction

CLIMA has now been running for five years, as a satellite event of the main Logic Programming related events: in 1999, under the heading of MAS-LP (Workshop on Multi-Agent Systems in Logic Programming), organized by Stephen Rochefort, Fariba Sadri and Francesca Toni at New Mexico State University in Las Cruces, then subsequently in its current incarnation, CLIMA (Computational Logic in Multi-Agent Systems), organised by Ken Satoh and Fariba Sadri in London in 2000, by Ken Satoh and Jürgen Dix in 2001 in Paphos, and by Jürgen Dix, João Leite and Ken Satoh in 2002 in Copenhagen. CLIMA-IV is going to be held in Fort Lauderdale, Florida, in January 2004, in conjunction with LPNMR and AI & Math, and sponsored by CologNET.

CLIMA’01 ended with a panel session on the role of Computational Logic (CL) in Multi-Agent Systems (MAS). Two dimensions in MAS development were identified and discussed: on the one hand reactivity vs. rationality, and on the other hand individuals vs. societies. Most of the points discussed aimed at justifying and motivating the application of CL techniques to MAS development: how can be logics used to implement individual agents, societies, institutions? how can be logics used to model reactivity and rationality in agents? what is possible to achieve in terms of properties, openness to integration, etc.?

A most intuitive reply to these questions is that logic should be used for what logic is good at. For instance, logic programming-based techniques such as abductive logic
programming seem suitable for modelling agent hypothetical reasoning in the presence of incomplete knowledge [15]. Modal logic operators such as those adopted by a BDI agent model [51] could be a powerful and synthetic way to describe the agent mental state and behaviour, and extensions have been proposed to it to make agents aware of each other and to reason with social categories, such as obligations [13] and cooperativity [5]. Model checking-based techniques can be applied to the verification of agent systems [8]. A combination of multiple approaches, like modal and temporal logics, or abduction and induction in a logic programming framework, could be the key to achieve a more comprehensive agent and agent system architecture. But in this case, to determine which properties of the chosen combinations hold is not an easy task.

At the time of CLIMA’02, while the debate about the role of CL in MAS is still open, we are witnessing an increasing interest in MAS from the CL community. This is due to many reasons, among which is the need to put “abstract” reasoning in the context of a “concrete” environment: the multi-agent metaphor of intelligent individuals that are situated in dynamic and unpredictable environments and that can interact with each other by updating their beliefs, can be regarded then as the basis for a new symbolic model of cognition.

The two CLIMA panels of 2001 and 2002 addressed some central issues in the area of logic-based multi-agent systems: the relationship between the internal reasoning of agents and the outer world, the semantics of a system composed of agents that reason on a private knowledge, and the practicability of BDI-inspired architectures.

Logic-based agents and the outer world. Some recent work in Logic Programming outlines this new concept of intelligent system. In [40], Kowalski says:

“it is the objective perspective of multi-agent systems that forces me to acknowledge the existence of a real environment, which exists independently of individual agents: As I see it now, if there is only one agent, then that agent’s environment might only be virtual. But if there are several agents interacting with one another, and if all of them are equally real, then the environment of each agent must include the other agents, and therefore that environment itself must also be real. This real environment, shared by several agents, can be understood as a classical model-theoretic, semantic structure. It gives meaning to the agents’ thoughts, making some thoughts true and other thoughts false. It grounds their thoughts in reality.”

Much of the work presented at CLIMA’01 [21] and CLIMA’02 [20] well reflected this concept. Speculative computation and planning together with action execution [33, 36] reconcile the agent reasoning with the effect of actions made on an external world. Techniques proposed to deal with message loss or modification [56] clearly picture the idea of an environment where logic based agents are situated that could indeed be very different from the model that they have of it. The introduction of hierarchies, roles, protocols and norms [39] puts the agent in a context that sometimes we can call society, or institution, which is at a higher level than that of the single individuals, and which gives a meaning to the agents’ thoughts and behaviour.