

Abstract

As research progresses and capabilities of robots increase, robotic systems become viable solutions in more and more scenarios. This especially applies to multi-robotic systems, which combine the skills and functions of individual robots. Robustness, efficiency, and adaptivity are key characteristics for such future teams of autonomous mobile robots being employed in increasingly complex and dynamic scenarios. Hence, the question arises how different modelling and reasoning paradigms can be combined to describe the intended behaviour and achieve these characteristics. We present a comprehensive solution to modelling and execution of behaviour for teams of autonomous mobile robots. The proposed framework, ALICA (A Language for Interactive Cooperative Agents), combines modelling techniques drawn from different paradigms in an integrative fashion. Hierarchies of finite state machines are used to structure the behaviour of the team, such that temporal and causal relationships can be expressed. Utility functions are used to weigh different options against each other and to assign agents to different tasks. Finally, constraint satisfaction and optimisation problems are integrated, allowing for complex cooperative behaviour to be specified in a concise, theoretically well-founded manner. The system is geared towards highly dynamic environments, in which robots must act quickly, communication is unreliable, and individual robots can break down at any time. In such environments, it is imperative that agents act immediately whenever they are confronted with changing situations instead of establishing agreement beforehand. ALICA agents therefore make decisions locally and act accordingly before any communication takes place. Conflicts arising from incoherent decisions and beliefs can be reliably detected and resolved. Since ALICA works completely decentralised, no single point of failure exists.

From a modelling perspective, ALICA presents itself as a modern language in which the behaviour of a team can be modelled from a global perspective. Abstractions through hierarchical structures and program components make the inherent complexity of the topic transparent and foster reusability. The combination of state machines, utility functions, and non-linear continuous constraint satisfaction and optimisation problems is a completely new approach to describing the behaviour of a team of robots, extending the state-of-the-art.

The resulting execution layer is equipped with a novel anytime algorithm to solve the integrated constraint problems, which allows tracking of solutions over

time in a dynamic environment, coordinates solutions within the team, and exploits the distributed computational power available within the team for solving.

We evaluate our approach in the robotic soccer domain, which focuses on reactivity and robustness with respect to unreliable communication. In the domain of extraterrestrial exploration, we sketch some advanced techniques for describing dynamic formations of robots. Finally, we examine the scalability of ALICA and compare the employed techniques with other state-of-the-art methods using a popular rescue scenario.

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Mobile Robots

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