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(Editors)

Plan-Based Control of Robotic Agents

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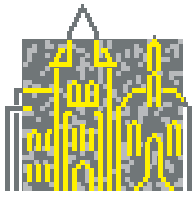

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Background

In recent years, autonomous robots, including Xavier, Martha, Rhino, Minerva, and Remote Agent, have shown impressive performance in long term demonstrations. In NASA's Deep Space program, for example, an autonomous spacecraft controller, called the Remote Agent, autonomously controlled a set of scientific experiments in space. At Carnegie Mellon University, Xavier, another autonomous mobile robot, has navigated through an once environment for more than a year, allowing people to issue navigation commands and monitor their execution via the Internet. In 1998, Minerva acted for thirteen days as a museum tour guide in the Smithsonian Museum, and led several thousand people through an exhibition.
These autonomous robots have in common that they perform plan-based control in order to achieve better problem-solving competence. In the plan-based approach robots produce control actions by generating, maintaining, and executing a plan that is effective and has a high expected utility with respect to the robots' current goals and beliefs. Plans are robot control programs that a robot can not only execute but also reason about and manipulate. Thus a plan-based controller is able to manage and adapt the robot's intended course of action – the plan – while executing it and can thereby better achieve complex and changing goals. The use of plans enables these robots to flexibly interleave complex and interacting tasks, exploit opportunities, quickly plan their courses of action, and, if necessary, revise their intended activities.

Content

The first Dagstuhl seminar on "plan-based control of robotic agents" took a technological view and provided us with an overview of recent developments in the plan-based control of autonomous robots. We identified a number of computational principles that enable autonomous robots to accomplish complex, diverse, and dynamically changing tasks in challenging environments and seen a variety of ways to incrementally advance the existing techniques.
Unlike the first seminar, the primary focus of the second seminar has been target problems in the hopes that by investigating these problem thoroughly and identifying the challenges and issues implied by them we will get a better understanding of how the field of plan-based robot control should advance in the next decade. Thus, key questions that we have seeked to answer included, what are the big gaps?, what can we do to close them?, and what are the promising techniques? Our main target problem has been the plan-based control of autonomous household robots.
Thus In the seminar we have considered recent developments in the plan-based control of autonomous robots and identified computational principles that enable autonomous robots to accomplish complex, diverse, and dynamically changing tasks in challenging, uncertain environments. These principles include plan-based high-level control, probabilistic reasoning, plan transformation, formalizations of robot control programs, and context and resource adaptive reasoning.

In the seminar we have worked towards comprehensive and integrated computational models of plan-based control that consider different aspects of plan-based control – plan representation, reasoning, execution, and learning – together and not in isolation. Our hope is that such integrated approaches will enable us to exploit synergies between the different aspects and thereby come up with more powerful computational models.
To achieve these goals we have invited leading experts from areas such as AI planning, plan execution, probabilistic robotics, intelligent control theory, cognitive robotics, robot perception and state estimation, robot learning, and verification of embedded control systems. To focus discussion, we plan to investigate selected applications, such as an autonomous household robot, for which we will provide informal descriptions well in advance.

Main Results

Besides the talks, discussions, and joint research plans started and intensified as part of the seminar two main results have been accomplished:

A roadmap for research in plan-based control of robotic agents.
(`http://www.dagstuhl.de/files/Proceedings/03/03261/03261.chapter.pdf`)
Michael Beetz was the editor of the roadmap of research in plan-based control of robotic agents. Substantial parts of the roadmap were discussed and produced in the seminar. The roadmap gives an introduction to the field, a framework for integrated plan-based control, and an outline of the projected and suggested lines of research for the next decade. Indeed one of the reviewers of the roadmap (who was not at the seminar) stated that he could not imagine that such a comprehensive and coherent roadmap could have produced without the impact of the sessions at the Dagstuhl seminar.

Challenge scenario.
(`http://www.dagstuhl.de/files/Proceedings/03/03261/03261.challenge.pdf`)
A second important result is a challenge scenario for plan-based robot control. We consider a humanoid robot, such as the Sony SDR-3 or the Honda Asimov, with additional manipulation skills that is to do household chores as an interesting challenge for the field of plan-based control of autonomous robots. The challenge is to develop a plan-based controller for such a robot that enables the robot to be put in another household, to operate in this household for some months, and do a substantial part of the household chores satisfactorily.

The topic "Plan-based Control of Robotic Agents" has become a field of steadily and impressively growing research interest. In particular, the NASA has initiated several well funded research programs that cover our field. Their interest are mainly autonomous space explorers that should be controlled by plan-based control mechanisms. A much bigger program is planned for the next five years. Three of the seminar organizers give academic advice for this program that is to be launched next year. It is vital for our

research community in Germany and Europe to continue doing research at an internationally competitive level. The Dagstuhl seminars on "Plan-based Control of Robotic Agents" are important meetings that help us to achieve these objectives.

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