Summary for the Dagstuhl Seminar

Cognition, Control and Learning for Robot Manipulation in Human Environments

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1 Motivation

High performance robot arms are faster, more accurate, and stronger than humans. Yet many manipulation tasks that are easily performed by humans as part of their daily life are well beyond the capabilities of such robots. The main reason for this superiority is that humans can rely upon neural information processing and control mechanisms which are tailored for performing complex motor skills, adapting to uncertain environments and to not imposing a danger to surrounding humans. As we are working towards autonomous service robots operating and performing manipulation in the presence of humans and in human living and working environments, the robots must exhibit similar levels of flexibility, compliance, and adaptivity.

The goal of this Dagstuhl seminar is to make a big step towards pushing robot manipulation forward such that robot assisted living can become a concrete vision for the future.

In order to achieve this goal, the computational aspects of everyday manipulation tasks need to be well-understood, and requires the thorough study of the interaction of perceptual, learning, reasoning, planning, and control mechanisms. The challenges to be met include cooperation with humans, uncertainty in both task and environments, real-time action requirements, and the use of tools. The challenges cannot be met by merely improving the software engineering and programming techniques. Rather the systems need built-in capabilities to deal with these challenges. Looking at natural intelligent systems, the most promising approach for handling them is to equip the systems with more powerful cognitive mechanisms.

The potential impact of bringing cognition, control and learning methods together for robotic manipulation can be enormous. This urge for such concerted approaches is reflected by a large number of national and international research initiatives including the DARPA cognitive systems initiative of the Information Processing Technology Office, various integrated projects funded by the European Community, the British Foresight program for cognitive systems, huge Japanese research efforts, to name only a few.

As a result, many researchers all over the world engage in cognitive system research and there is need for and value in discussion. These discussions become particularly promising because of the growing readiness of researchers of different disciplines to talk to each other.

Early results of such interdisciplinary cross-fertilization can already be observed and we only intend to give a few examples: Cognitive psychologists have presented empirical evidence for the use of Bayesian estimation and discovered the cost functions possibly underlying human motor control. Neuroscientists have shown that reinforcement learning algorithms can be used to explain the role of dopamine in the human basal ganglia as well as the functioning of the bee brain. Computer scientists and engineers have shown that the understanding of brain mechanisms can result into reliable learning algorithms as well as control setups.

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Insights from artificial intelligence such as Bayesian networks and the associated reasoning and learning mechanisms have inspired research in cognitive psychology, in particular the formation of causal theory in young children.

These examples suggest that (1) successful computational mechanisms in artificial cognitive systems tend to have counterparts with similar functionality in natural cognitive systems; and (2) new consolidated findings about the structure and functional organization of perception and motion control in natural cognitive systems indicate in a number of cases much better ways of organizing and specifying computational tasks in artificial cognitive systems.

1.1 Workshop Summary

This Dagstuhl seminar gathered internationally renowned researchers across a range of disciplines including Computer Science and Artificial Intelligence, Cognitive Psychology and Neurobiology, Control Theory and Mechatronics, etc. together in order to discuss robot manipulation in the presence of humans as a cognitive control problem from different points of view. This will help the researchers to import results and insights from other research fields into their own research. We also believe that the seminar could successfully fuel interdisciplinary research cooperations.

During the first part of the workshop, every participating researcher presented their research work and related research issues in the context of Robot Manipulation in Human Environments.

During the second phase of the workshop, each organisers formed a presentation of four related four specific scientific questions:

- Limitiations and beyond current methodologies - necessity for a paradigm shift?
- Learning, learning, learning - the necessity for a new learning approach?
- "Turing test" - towards scalability - necessity for benchmarking actions?
- Robotic mechanisms needed to support sophisticated manipulations - what will it take to move beyond current state-of-the-art?

Upon the presentations of the specific questions posted, suitable sub-groups was identified for break-out sessions to challenge these questions and proposed further challenges.

During reformation of the seminar, each of the break-out groups presented a report of their discussions.

to this end, a Springer LNAI book representing the state-of-the-art in mobile manipulation in human-robot cohabited environments has been planned as the outcome of this Dagstuhl Seminar.

Thanks

We wish to thanks the Schloss Dagstuhl for their kindness in allowing us to host this event - especially, for the kind patiences of Drs. Annette Beyer, Christian Lindig, Jutka Gasiorowski, Thomas Schillo and many of the staffs at Dagstuhl.

Many thanks also all the participants of our seminar, for making the journey. The event was one of the highlight of a fruitful 2009 for many of us - we look forward to fostering of future research collaboration taken away from this event.

Take care,
Gordon, Jan, Michael, Olivier

2 Information on the Organizers

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Michael Beetz is a professor for Computer Science at the Department of Informatics of the Technische Universität München and heads the Intelligent Autonomous Systems group. He is also managing director of the German cluster of excellence COTESYS (Cognition for Technical Systems) where he is also co-cordinator of the research area "Knowledge and Learning". Michael Beetz received his diploma degree in Computer Science with distinction from the University of Kaiserslautern. He received his MSc, MPhil, and PhD dgrees from Yale University in 1993, 1994, and 1996 and his Venia Legendi from the University of Bonn in 2000. Michael Beetz was a member of the steering committee of the European network of excellence in AI planning (PLANET) and coordinating the research area "robot planning". He was also principal investigator of a number of research projects in the area of AI-based robot control. His research interests include plan-based control of robotic agents, knowledge processing and representation for robots, integrated robot learning, and cognitive perception.

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Jan Peters is a research scientist and head of the Robot Learning Laboratory (RoLL) at the Max-Planck Institute for Biological Cybernetics in the Departement of Bernhard Schoelkopf. Before joining MPI, Jan Peters graduated with a Ph.D. in Computer Science from University of Southern California (USC) with the thesis committee of Stefan Schaal, Firdaus Udwadia, Gaurav Sukhatme, and Chris Atkeson (CMU) and remains affiliated with the Computational Learning and Motor Control Lab at USC as an adjunct researcher. He holds four Masters Degrees in Informatics, Computer Science, Electrical Engineering and in Mechanical Engineering from both German and American universities. Jan Peters has extensive experience in machine learning for robotics collected also at the Department of Robotics at the German Aerospace Research Center (DLR) in Germany, the Robotics & Control Division at Siemens Advanced Engineering in Singapore, at the Department of Humanoid Robotics and Computational Neuroscience at the Advanced Telecommunication Research (ATR) Center in Japan, as well as the National University of Singapore (NUS).

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