Mobile Manipulation

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We are excited to present the first *IEEE Robotics & Automation Magazine* (*RAM*) special issue on mobile manipulation. This issue is the culmination of a long chain of events: the renewed academic interest in mobile manipulation over the past decade, the increased availability of mobile manipulation research platforms, resulting in a large increase in relevant publications, and an increased awareness from funding agencies, including the National Science Foundation National Robotics Initiative, the Defense Advanced Research Projects Agency's (DARPA's) Autonomous Robust Manipulation program, and the Cognitive Systems and Robotics Program in the Seventh Framework Programme of the European Commission. This motivated us to start the RAM Technical Committee on Mobile Manipulation in 2010 and to put together a snapshot of the state of the art in mobile manipulation in this issue of *RAM*.

The late 1980s and early 1990s saw the birth of a new type of robot that combined mobility with manipulation capabilities. These mobile manipulation platforms turned out to be a new type of robot, and they turned out to be a game changer for robotics. All of a sudden, manipulation was able to leave the confined space of the research laboratory and had to face the adversities of the real world. Also, in the real world, many assumptions routinely made by roboticists did not hold. As a result, a number of new and fundamental challenges became apparent. For example, in the real world, perception becomes essential as the robot must acquire information about the world to execute tasks successfully. To operate robustly, it was not sufficient any more to demonstrate a specific skill; also, robots have to detect, recover, and learn from failure. To achieve any reasonable level of autonomy, robots cannot be single-purpose devices. Instead, they have to exhibit a broad range of capabilities autonomously in response to the changing state of the environment.

Researchers in the field of mobile manipulation are dedicated to bringing manipulation capabilities into the real world. Their research aims at addressing the fundamental challenges that arise from this goal. In the broadest sense, these objectives are to increase the task generality of manipulation systems while at the same time relaxing inherent assumptions and reducing the amount of a priori knowledge required to perform manipulation tasks.

Each article in this special issue on mobile manipulation addresses in its own way a specific aspect of this grand challenge we call mobile manipulation.

Dietrich et al. describe reactive, dynamic, mobile manipulation with Justin, a humanoid robot composed of a pan–tilt head and pair of torque-controlled arms mounted atop a reconfigurable four-wheeled mobile base. They advocate the use of high bandwidth torque-based controllers that constantly monitor safety, physical constraints, task execution, and posture, motivating their need by observing that human environments are often unmodeled and dynamic, requiring a robot that reacts quickly. They achieve this by means of operational space control, prioritizing and resolving tasks by exploiting the redundancy naturally provided by Justin's many degrees of freedom. The key contribution is the demonstration of fast, reactive control for real-world grasping tasks.

Stückler et al. detail the strategies used by NimbRo, the winner of the RoboCup@Home mobile manipulation competition. The competition challenges robots to demonstrate a robust integration of object recognition, grasping, navigation, and human–robot interaction. They advocate the use of simple, efficient, and robust strategies orchestrated by a high-level behavior engine. Their key contribution is in designing a balanced system capable of robustly operating a wide range of conditions and quickly adapting to changing scenarios.

Vahrenkamp et al. address the challenge of grasping in the real world, one of the fundamental prerequisites of mobile manipulation and long-standing challenges in robotics. The key contribution in this article is the synergistic algorithmic integration of grasp and motion planning. Rather than relying on a precomputed set of grasps for a hand/object pair, the most suitable grasp is determined during planning of the overall motion. As a result, both grasp and motion planning can limit search to those regions of their respective search spaces that contain a solution to a combined problem. Thus, a combination of these two search problems can lead to a reduction of the search space associated

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with the combined problem. This broadens the applicability of grasp planning by relaxing the requirement of a priori object knowledge and by making the planning process more efficient.

Chitta et al. present a variety of research activities in Willow Garage geared toward solving pick-and-place tasks in unstructured and dynamic environments. The key contribution of this work is the integration of several software components providing navigation, perception, and manipulation capabilities. Additional contributions include the development of a new grasp-planning framework capable of dealing with uncertainty due to object recognition and localization, and a real-time update of the environment's representation. This work represents the recent transition from developing isolated perceptual, grasping, manipulation, and planning capabilities to the realization of integrated systems capable of addressing a variety of tasks. By integrating several aspects of mobile manipulation, the robustness and reliability of subcomponents is validated and the interaction between them can be studied further.

Mason enriches this special issue with a real treat: a perspective on the origins of mobile manipulation and some insights on what is ahead of us. This article reviews the early goals and accomplishments of robotics research, focusing on the themes of uncertainty and structure. All articles in this special issue consider uncertainty and target unstructured environments. But in this article, Mason analyzes what uncertainty and structure mean in mobile manipulation. Instead of the usual binary classification, Mason proposes to consider uncertainty and structure as points on a continuum. Thus, the contribution of this article is in encouraging researchers to take advantage of lessons learned in domains that are typically considered to be outside the scope of mobile manipulation, such as factory floor automation.

We acknowledge the important contribution made by the reviewers of the articles submitted to this special issue. They are responsible for the high quality of the papers presented here. And our most heartfelt thanks go to Peter Corke, our editor-in-chief, who gave us much support while putting this issue together.

For more information on mobile manipulation and related activities, please visit the Web site of the IEEE Robotics and Automation Society technical committee: http://www.mobilemanipulation.org. We hope you will enjoy reading the articles.

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