Making robots cheaper, more capable, and safer

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I. Introduction

The Bosch Research and Technology Center[1] is an active participant in the PR2 Beta Program run by Willow Garage, Inc[2]. This paper summarizes Bosch's goals for the two-year research program and the progress achieved during the first of year.

Bosch's research objective as part of the PR2 Beta Program is to accelerate the development of the robotics market by making robots cheaper, more capable, and safer[3]. As part of this initiative, we examine a combination of hardware and software solutions including: affordable sensing, shared autonomy, and remote experimentation. We integrate advanced sensor technology, such as MEMS accelerometers and gyros in the PR2 to enable new applications and to accelerate the wide-scale deployment of robot technology in new environments. We also explore how human users can effectively interact with a PR2 remotely and locally [1]. Our results demonstrate that including a human in the loop improves the PR2's performance and reliability. These improvements may allow robots to be deployed earlier, at lower cost, and in more complex environments. In order to give more people access to to quality robotics research platform such as the PR2, we built the *PR2 Remote Laboratory*[4]. This laboratory is designed to allow a larger group of researchers to perform research on a PR2 robot remotely.

II. Affordable Sensing

Affordable sensing capabilities can enable new applications. For example, low-cost MEMS gyros enabled the broad adoption of the electronic stability program (ESP) in automobiles[5].

We identified and integrated suitable sensor technologies to enable new applications and to lower the cost of robots. Sensors include accelerometers, gyros, force sensors, and air pressure sensors. We have developed the required drivers to integrate Bosch sensors into ROS and provided calibration algorithms with a focus on automatic calibration. Manipulators make up a large portion of a robot's production cost, which is a limiting factor for mass market adoption. Currently we are exploring inexpensive MEMS sensors for manipulator state estimation to replace the expensive encoders. The PR2 is an ideal platform for this project because the high precision arms enable precise error characterization of the state estimation techniques.

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[1] http://www.boschresearch.com

[2] http://www.willowgarage.com

[3] http://www.willowgarage.com/blog/2011/07/18/making-robots-cheaper-more-capable-and-safer-bosch

[4] http://www.pr2-remotelab.com

[5] http://www.bosch-esperience.com

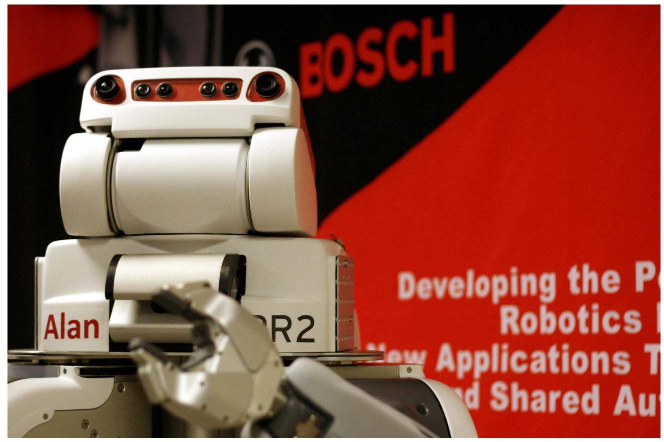

Fig. 1. Alan, the PR2 robot at Bosch Research and Technology Center.

In addition to our own research, we are providing Bosch MEMS sensors such as 3-axis accelerometers, gyros, and pressure sensors to the PR2 community to enable the development of additional applications.

III. Shared Autonomy

Reliability and availability are major concerns for autonomous systems. A generalized household robot must solve complex tasks, such as loading a dishwasher or folding laundry, with extremely high reliability in order to achieve customer acceptance. On the other hand, very complex tasks are difficult to automate robustly. Consequently, we strive to improve the reliability of task performance by enabling robots to accept help from a human operator.

Our work in shared autonomy aims to bridge the gap between full human control and full autonomy for tasks in the domain of personal robotics. Shared autonomy systems require balancing between two competing criteria: maximizing the robot's performance while minimizing human input. A teleoperated robot will perform poorly at complex tasks when there are long communication delays or when the human needs to control more degrees of freedom than are available as inputs. In such scenarios, a high level of autonomy would be beneficial. We investigated intuitive interfaces that would allow a remote teleoperator to control the PR2 to accomplish complex manipulation tasks such as loading and unloading a dishwasher. Our shared autonomy technologies enable an efficient and safe control of the PR2 over a web connection.

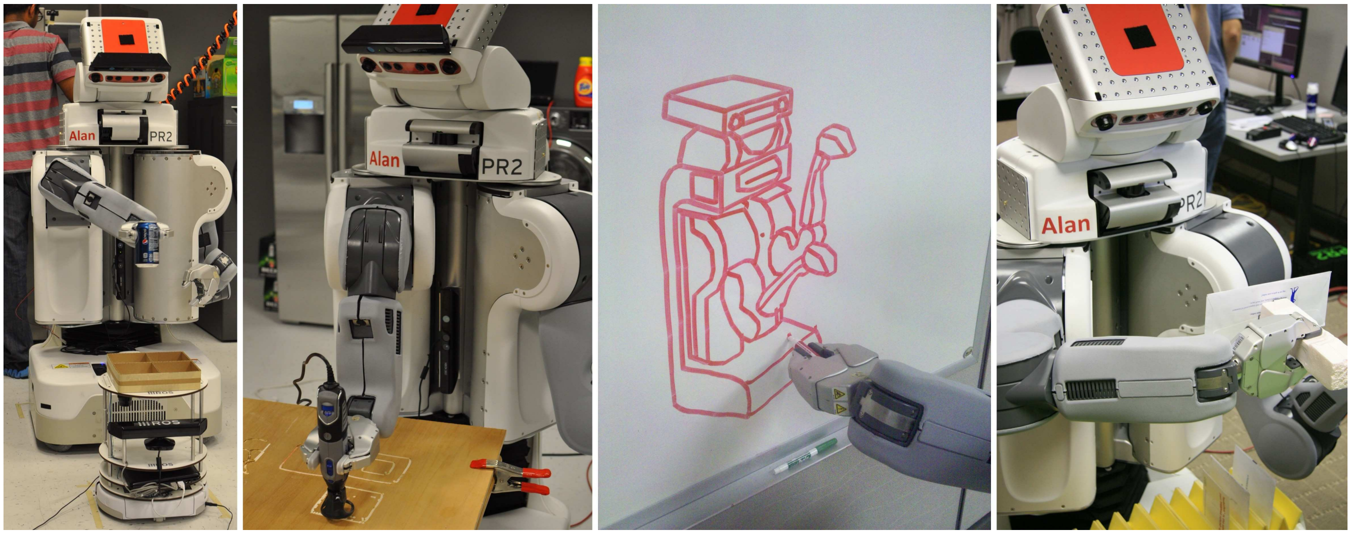

Fig. 2. New applications for the PR2 are explored through one week project sprints or so called *hackathons*. From left to right: a drink serving application using a PR2 and a TurtleBot™, carving wooden nameplates using a Dremel® power tool, drawing on a whiteboard, and autonomous mail delivery.

We also investigated scenarios where the human may function as a limited resource for the robot, providing information that may be used to close planning, control, or perception loops. In [1] we presented a system capable of solving the perceptual inference in combination with a human, such that a human operator functions as a resource for the robot and helps to compensate for limitations of its autonomy. Our system asks a human operator to identify objects, which the robot cannot recognize or find, by drawing boxes and strokes on a camera image. We experimentally demonstrated that this shared autonomy system performs more robustly than the robot system alone and is capable of tasks which are difficult to accomplish by an autonomous agent.

IV. PR2 Remote Lab

As illustrated by the large number of responses to the PR2 Beta program, the current demand for high quality research platforms far outweighs the supply. The scarcity of such platforms limits the productivity of the robotics research community. Additionally, these platforms often come expensive making them difficult to obtain for smaller universities and research groups. To address these problems, we proposed the *PR2 Remote Lab*, a research lab in which users can develop, test, and compare robot algorithms remotely.

In collaboration with Brown University, we built web-based user interfaces to allow users to visualize the results of their code and to interact with the robot remotely. New web technologies such as HTML5 and Javascript provide nice user interfaces without requiring users with a supported web browser to download additional software or plugins. We use `rosbridge` [2] to allow users to run experiments on the robot without ROS running locally on their machine.

The first application for the *PR2 Remote Lab* was robot learning from demonstration. The 2011 Robot Learning from Demonstration Challenge,[6] held in conjunction with the 2011 AAAI Conference, showcased advances in demonstration learning systems. We provided the option to use the Bosch PR2 robot to participating researchers through our Bosch *PR2 Remote Lab* facility. As a result, this was the first year the majority of participants were able to demonstrate their results performing a common tasks on the same platform.

[6]http://www.lfd-challenge.org

V. Hackathons

In addition to the research topics discussed in this abstract, we explored new potential applications for the PR2 through short project sprints called hackathons. Hackathons are one week, agile development projects involving a larger team focusing on a single project. During the course of the Beta program, we have investigated four applications: a drink serving application using a PR2 and a TurtleBot, carving wooden nameplates using a Dremel power tool, drawing on a whiteboard, and autonomous mail delivery (see Fig. 2). These projects both serve as a way to learn about new packages and advancements in the robotics community and a means to rapidly prototype and test new potential use cases for robotics.

VI. Conclusion

We found that the PR2 is a very suitable platform for our research since it allowed us to focus on new capabilities. The PR2 and ROS are great steps towards reproducible research. However, more efforts such as the 2011 LfD Challenge are required to make robotics research more comparable. Finally, we would like to thank Willow Garage for generously providing and maintaining the PR2 robot and ROS.

References

[1] B. Pitzer, M. Styer, C. Bersch, C. DuHadway, and J. Becker, “Towards perceptual shared autonomy for robotic mobile manipulation,” in *IEEE International Conference on Robotics & Automation (ICRA)*, 2011.

[2] S. Osentoski, G. Jay, C. Crick, B. Pitzer, C. DuHadway, and O. C. Jenkins, “Robots as web services: Reproducible experimentation and application development using rosjs,” in *IEEE International Conference on Robotics & Automation (ICRA)*, 2011.