Robot Challenge

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The 2012 IEEE International Conference on Robotics and Automation (ICRA) Robot Challenge again proved to be an exciting venue where researchers showcased the latest state of the art in robotics. In addition to this year's challenges, the conference also featured a special session where the 2011 teams were able to present and discuss their competition-related research. The challenge has grown to include five individual events, 28 teams, and close to 100 participants. Each of the events is detailed below.

The Virtual Manufacturing Challenge (VMAC) made its fourth consecutive appearance and had the highest number of teams participating ever. The competition included two events, a mixed palletizing and an intrafactory mobility challenge. Mixed palletizing is an example of the three-dimensional (3-D) cutting stock problem, a variant of the combinatorial nondeterministic polynomial-time hard (NP-hard) knapsack problem. Teams were required to generate a pallet-stacking plan from order files and constraints provided by an industry partner. The team's palletstacking plans were evaluated by National Institute of Standards and Technology (NIST)-developed metrics for pallet quality, which included criteria such as the pallet's center of gravity, density, and package interlocking.

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Figure 1. Team members from the DARwIn-OP Humanoid Application Challenge.

The intrafactory mobility challenge aimed to address the need for factory robots to operate in unstructured environments amongst dynamic obstacles, as seen in numerous assembly plants and distribution centers. Teams were tasked with docking a rear-wheeled Ackerman steered robot with a conveyor system, picking up packages for transport, and then delivering these packages to unloading stations in the factory.

Six teams from five institutions and four countries participated in VMAC. The winner of the mixed palletizing challenge was the team from Jacobs University, Bremen, Germany, while Drexel University, Philadelphia, USA received an honorable mention. The team from the University of Zagreb, Croatia, won the intrafactory mobility challenge.

Another first from VMAC this year was the organization of a guest lecture during the last day of the competition. Erik Nieves, technology director at Yaskawa Motoman Robotics, gave a very interesting talk: "The Challenges of Robotics in Logistics—An Industrial Perspective." This event was cosponsored by the IEEE Robotics and Automation Society's Washington, DC/Northern Virginia Chapter. This is the

Figure 2. Team members from the Mobile Microrobotics Challenge.

start of a new tradition that will reinforce and further promote VMAC's ties with industry, research, and government partners.

The Dynamic Anthropomorphic Robot with Intelligence-Open Platform (DARwIn-OP) Humanoid Application Challenge is based on developing creative research and novel applications for humanoid robots in an open-source community for cooperative research. This year was the first open challenge using DARwIn-OP, and nine teams from across the United States, Canada, and Spain participated (Figure 1).

Each team's 20-min presentation was composed of a demonstration of their application followed by a question and answer session open to judges, the audience, and fellow participants. The challenge was peer reviewed based on creativity (40%), technical skills (30%), and overall completeness (30%).

The winner was a team from the University of Manitoba, Canada. Their entry featured Jennifer—the first member of their robotic ice hockey team. Even though superficially similar to soccer, ice hockey provides several unique challenges that make it a very interesting research topic. First, movement on skates on ice is very different from walking. New walking gaits that emphasize side-to-side movement needed to be developed. Second, the movement of the puck requires more accurate and complex movement than dribbling a ball, since the stick needs to move the puck from side to side. Third, the blob detection needed to be replaced with a region-based segmentation and shape-detection algorithm. The winner was awarded one DARwIn-OP humanoid robot, LabVIEW Robotics Software, and Webots Pro.

The challenge also featured an online competition. The winner from Purdue University featured two tic-tac-toe playing DARwIn-OPs. The goal of this entry was to take advantage of the capabilities of DARwIn-OP, engage the ICRA audience with artificially intelligent robotic game play, and contribute to the DARwIn open-platform community. Their

Figure 3. A student from Johns Hopkins University builds a robot from a kit of parts in the Modular Robotic Challenge.

research includes robot-to-robot interaction, image recognition and processing, possible robot-to-human interaction, robotic movement, and the development of the artificial robotic adversarial personalities. All finalists were awarded a Bioloid Premium Kit, a LabVIEW Robotics Module, or a Webots Edu.

The Mobile Microrobotics Challenge (MMC) is focused on driving innovation in the design and control of robots that are smaller than a millimeter. Applications for this technology include medical diagnostics and therapeutics, mobile sensor networks, and micro- and nanomanufacturing. The challenge was started in 2007 by the NIST and has been held as part of the ICRA Robot Challenges since 2010. The challenge goal is to accelerate the adoption of this technology by industry by solving critical technical barriers through structured competitions. Previous challenges have focused on basic functionalities, including robot speed and microassembly of components using simple fixturing. In 2012, the challenge had two independent tasks—the mobility task, in which the microrobot must navigate a figure-eight course in the shortest time, and the microassembly task, where the robot has to assemble groups of triangular components without the use of fixtures.

Figure 4. The PR2 robot being used by the world team in the 2012 ICRA Mobile Manipulation Challenge to clear a table.

Nine teams from four countries (Canada, the Czech Republic, France, and the United States) participated in the challenge, making it the largest MMC event to date. (Figure 2). The demonstrated microrobot technologies included laser-controlled bubble robots and robots actuated using dielectrophoresis as well as the more common electromagnetic microrobots. A team composed of members from the Institut des Systèmes Intelligents et de Robotique, Franche-Comté Electronique Mécanique Thermique et Optique—Sciences et Technologies (FEMTO-ST), and the Centre National de la Recherche Scientifique. France, won the mobility task with an electromagnetic microrobot that completed the "figure-eight" track in less than 0.5 seconds. Every team was able to complete the figure-eight track, indicating that this functionality is now a solved problem.

The microassembly task was won by Carnegie Mellon University (CMU) using an electromagnetic microrobot that was able to place at least two triangles into an assembly in all three of the trials. Unlike the mobility task, the microassembly task remains an open problem and will likely appear in future challenges.

The Modular Robotic Challenge has run four times since 2008. The rules are fairly simple with an unknown robotic task to complete in roughly 4–6 hours. Competitors can bring anything they want that fits in 64 linear in (e.g., a suitcase) and weighs less than 50 lb total. This constraint includes robot modules, power supplies, tools, computers, raw materials, duct tape—everything.

This challenge develops, tests, and validates

1) rapid robot prototyping and design methodologies
2) software for rapid teleoperation and new programming paradigms
3) adaptability/generality of robotic hardware and software
4) user interfaces (both hardware and software).

In 2012, three teams participated: Harvard University, Johns Hopkins University, and the University of Colorado at Boulder (Figure 3). All three teams used CKBot robotic modules supplied by the GRASP lab, University of Pennsylvania. This year's challenge shared the same task as the Mobile Manipulator challenge: serving sushi. The only differences were that the robots had to be constructed on site and could be teleoperated. Points were awarded for placing food and utensils and busing tables. Points were lost for dropping items.

In the end, the three teams were successful in building a robot to carry out human-scale tasks and served three plates of maki, three plates of nigiri, two cups, and two utensils as well as busing six items (plates, cups and spoons). Unfortunately, they also dropped a dozen plates (nine of them with real sushi). Building a robot capable of human-sized tasks in 4 hours was the most difficult part, yet all teams succeeded in this. The area needing most work was reliable control and manipulation of the items even when teleoperated.

The Mobile Manipulation Challenge, also called the "Sushi Challenge," was held for the first time. Yesterday's Sushi was a sushi restaurant operated by autonomous robots. The robots were expected to clean dirty dishes off tables, set dishes and silverware on a clean table, and serve sushi. The intent of this challenge was to push the state of the art in autonomous mobile manipulation, integrating the state of the art in perception, manipulation, navigation, and other capabilities. The teams participated in the challenge using the PR2 robots supplied by the organizers (Figure 4).

Interested participants were first invited to take part in a preparatory workshop for the Challenge at the University of Freiburg. Over 30 participants from around the world took part in this workshop, where they were able to program the robots to stack and unstack dishes, clear tables, lay place settings, and pick up objects off a rotating turntable sushi boat, building on a base of software built by researchers from Willow Garage, the PR2 Beta Program, and the robot operating system (ROS) community.

The participants in this workshop got together to form two teams for the ICRA Challenge: a world team (including students from Technische Universität München (TUM), Brown University, and KU Leuven) and a team of graduate students from the University of California, Berkeley. Both teams performed admirably, successfully performing a subset of the tasks, including recognizing common kitchen objects, navigating autonomously while carrying objects, and tracking and picking up moving objects. A team from Willow Garage, including interns from the Massachusetts Institute of Technology, the University of Southern California, the University of Pennsylvania, and CMU also demonstrated a complete integrated demonstration carrying out all the tasks outlined in the challenge. The software implemented by participants in the challenge, providing capabilities in 3-D navigation, semantic mapping, object recognition, and manipulation, is available open source from the challenge Web site (mobilemanipulationchallenge.org).

The teams and organizers are looking forward to continuing these competitions at ICRA 2013. In addition, we anticipate that a special session will be held to showcase competition technologies. For more information, visit the ICRA 2013 Web site at www.icra2013.com.