The ICRA 2017 Robot Challenges

By Keng Peng Tee and Herman van der Kooij

The 2017 IEEE International Conference on Robotics and Automation (ICRA) robot challenges aimed at advancing innovations in robotics through solution benchmarking on challenging problems motivated by real-world use scenarios. We tried to make the challenges accessible to all members of the robotics community so as to encourage participation from around the world and to ensure that the challenges were closely relevant to the technical scope of the conference.

Proposals for organizing robot challenges were solicited through open calls as well as invitations to prospective organizers from industry. For them, running a robot challenge is a good opportunity to work with world-class teams in robotics to understand the gap between state-of-the-art robotics technology and real-world needs and find potential solutions to problems in a short time frame.

Based on considerations of relevance, originality, feasibility, and the implementation plan for the proposed challenges, four robot challenges were confirmed and held at ICRA 2017 on 30–31 May 2017:

- the Dà-Jiāng Innovations (DJI) RoboMaster Mobile Manipulation Challenge (RMMC)
- the 2017 Humanitarian Robotics and Automation Technology Challenge (HRATC)
- the 2017 Mobile Microrobotics Challenge (MMC)
- the Soft Material Robot Challenge (SMRC).

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Of these challenges, the HRATC and MMC are familiar, having run annually at ICRA since 2014 and 2010, respectively. This year, the HRATC introduced a new outdoor environment and a new robot platform with low-cost sensors for autonomous landmine detection, and the MMC introduced a new microarena for the autonomous navigation of microrobots. The RMMC is a new challenge sponsored and organized by DJI, the world's leading company in the civilian-drone industry. This industry-sponsored and organized challenge follows in the tradition of ICRA 2015, with the Amazon Picking Challenge, and ICRA 2016, with the Airbus Shopfloor Challenge. Another new addition is the SMRC, which is timely, considering the growing interest and excitement in the emerging area of soft robotics.

All the robot challenges were successfully hosted, and the winners were announced during the awards ceremony on 2 June 2017. Additional details about the RMMC, MMC 2017, and SMRC, including the objectives, descriptions, judging criteria, and winners, can be found in the following sections. HRATC 2017 will be covered in a separate piece on humanitarian technology, which will appear in a future issue. To summarize the results of HRATC 2017, none of the finalists, despite their valiant efforts, managed to achieve the minimum requirements of detecting more than 50% of the number of mines correctly to be declared a winner. Details about the challenge rules, difficulty level, and the teams' performances will be shared in the upcoming article.

The robot challenges chairs are grateful to the IEEE Robotics and Automation Society Competition Committee for providing travel support to the finalist teams and the organizers. The support and cooperation of the ICRA 2017 organizing committee and the challenge organizers are also acknowledged and deeply appreciated. For more information about each of the challenges, please visit http://www.icra2017.org/conference/robot-challenges.

The DJI RoboMaster Mobile Manipulation Challenge

DJI initiated RoboMaster in 2015 as an educational robotics competition for students around the globe. The annual competition attracted teams who competed in building ground robots that used shooting mechanisms to battle with other robots, and the performance of the robots was monitored by a specially designed judging system. The competition was designed not only to entertain but also to draw more attention from the general public to robotics. To encourage more participation in shaping the future of robotics, RoboMaster 2017 included, as a special event, the RMMC at the 2017 IEEE ICRA.

The RMMC was a ground robot challenge that examined the application and competence of technologies that include positioning, object grasping, force control, target identification, and system stability. The teams were challenged to develop a lightweight mobile manipulator that could autonomously pick, transport, and stack building blocks. The winners were determined on the basis of completion time and assembly height, and the

Figure 1. The finalist teams of the DJI RMMC.

mobile manipulator developed by each team was required to meet weight and size specifications.

Launched in December 2016, the RMMC received 40 entries from around the world. Based on the merits of the technical proposals submitted by the teams, 13 finalist teams from six countries were shortlisted to participate in the challenge at ICRA 2017 (Figure 1). Each team could opt to use its own mobile platform (subject to the weight and size requirements) or the RoboMaster platform that was provided to the team. The teams submitted a progress report in April 2017 to ensure that their progress was on track, and the teams who showed good progress were eligible to receive travel sponsorship from DJI.

Over the two days of the RMMC at the ICRA 2017, each team performed three attempts to achieve the tallest stack in the shortest time (Figure 2). The scores for all of the attempts were then aggregated, and the winners were determined. The champion, and also the winner of the Outstanding Performance Award, was Team T-DT from Northeastern University, China. The team won the US$20,000 cash prize, and each team member received a DJI Phantom 4 Pro drone. The other winners were Team Duxing (runner-up) from Xi'an Jiaotong University, China, and Team RobotPilots (third place) from Shenzhen University, China, and they returned home with cool drones and gadgets from DJI.

The RMMC was an exciting showcase of technology, engineering, and innovation coming together to solve a particular mobile manipulation problem. It fulfilled its goal as an educational robotics competition to encourage student participation in robotics, foster robotics research, and attract public interest in robotics. Its competitive nature pushes students to develop autonomous systems that have fast speed and reaction ability. Future editions of the main RoboMaster competition may see the addition of engineering robots with mobile manipulation capabilities to further push the limits and challenge the contestants.

—Shuo Yang and Chunshao Xu

Figure 2. A robot attempts to pile a stack of blocks on top of another in the race to achieve the tallest assembly.

The 2017 Mobile Microrobotics Challenge

Since its inception in 2010, MMC has been held at the IEEE ICRA every year, and it involves microrobots that must fit within a 500-μm-diameter sphere or, roughly, the diameter of a human hair. The microrobots for this competition operate in a controlled setup under a microscope and are actuated using advanced control systems.

MMC 2017 challenged teams to face off in tests of autonomy, accuracy, and assembly. The competing teams were required to furnish their own microrobots and microarenas as well as equipment for powering, operating, and controlling the microrobotic devices. The detailed specifications on the requirements for the microrobots and the microarenas were provided in advance to the prospective teams at the launch of the challenge in October 2016.

Based on an evaluation of the proposals and video submissions that demonstrated the functionality of the teams' microrobots, four finalist teams qualified for live competition at ICRA 2017: Team UVT (Valahia University of Targoviste, Romania), Team NOMAD (Centre for Nanosciences and Nanotechnology, Paris Sud University, France), Team Micro Robot Lab (King Mongkut's University of Technology Thonburi, Thailand), and Team NGS (University of Louisville, Kentucky). The teams participated in up to three challenges.

The Autonomous Mobility and Accuracy Challenge

Microrobots navigated within a grid of waypoints, with the winner being the fastest and most accurate. The microarenas used for this event were furnished by the teams, and they consisted of a substrate with clearly defined boundaries and a grid of waypoints [Figure 3(a)]. At the competition, each team was given a list of waypoints to hit (targets) and waypoints to avoid (obstacles). The objective was to hit the most targets and avoid the most obstacles while moving as rapidly as possible. As an example, a representative trajectory is shown in Figure 3(b).

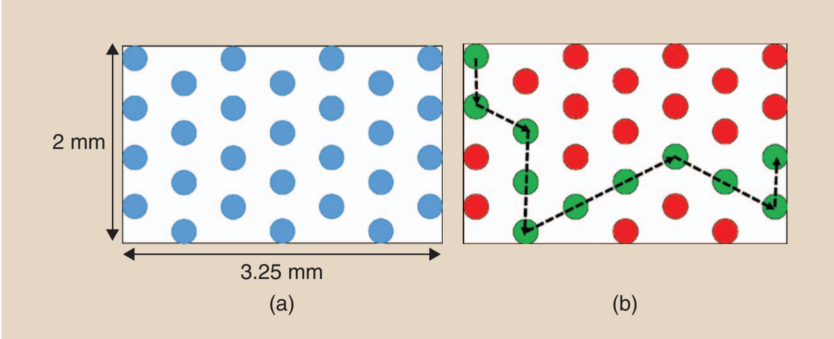

Figure 3. (a) The microarena and (b) the representative trajectory (dashed line) for the autonomous mobility and accuracy challenge. The targets are green, and the obstacles are red.

The teams were given 5 min to complete each trajectory. The team scores were computed based on the microrobot size, the number of targets hit, the number of obstacles avoided, and the time for completion of a trajectory. The lower the scores, the better.

The winner of this challenge was Team NOMAD with a score of 5.2, followed by Team NGS in second place with a score of 20.1, Team UVT in third place with a score of 119.7, and Team Micro Robot Lab in fourth place with an unfinished session.

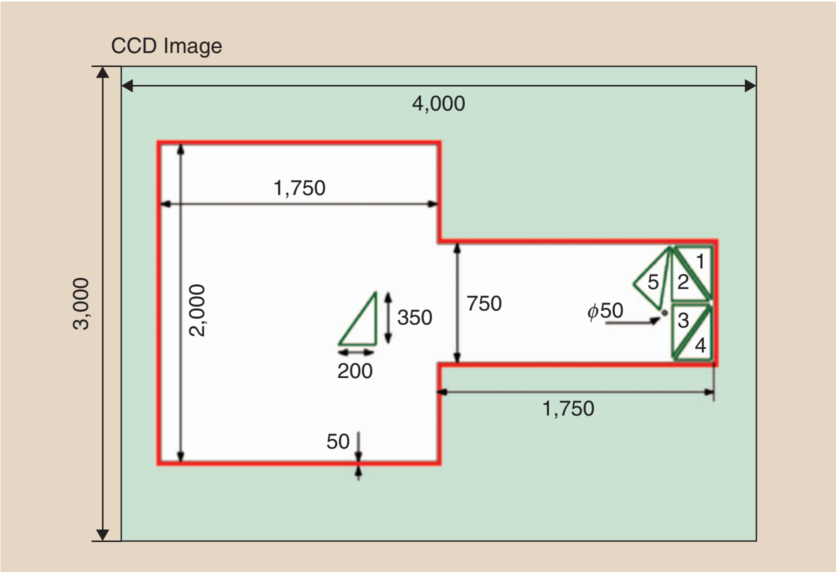

Figure 4. The microarena for the microassembly challenge. CCD: charge-coupled device.

Figure 5. The MMC 2017 participants.

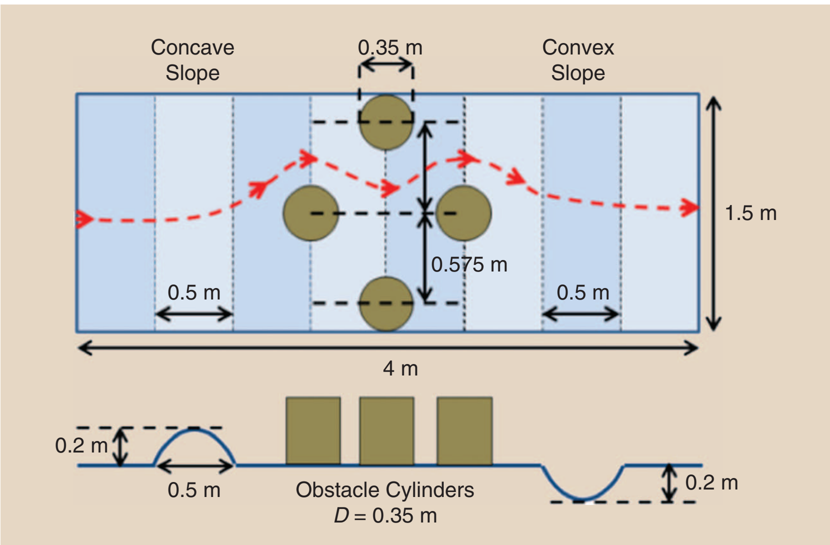

Figure 6. The obstacle course for the SMRC speed challenge.

The Microassembly Challenge

This task simulates anticipated applications of microrobotic microassembly for medical or micromanufacturing applications. The arena for the microassembly challenge consisted of a starting region connected to a narrow channel (see Figure 4). A set of triangular microfabricated components was placed in the starting region with the microrobots. Within 2 min, the microrobot needed to assemble the components into the far end of the channel. The components had to be densely packed so that no gap between the components, or between components and the channel wall, was larger than 50 μm.

Team UVT won this challenge with an average of 2.3 triangles assembled, followed by Team NGS in second place with an average of one triangle assembled.

The MMC Showcase and Poster Session

Each team was given an opportunity to showcase and demonstrate the advanced capabilities and functionalities of their microrobot system, and each was allowed one vote to determine the best in show, which was awarded to Team NOMAD.

Every year, the MMC event helps to highlight and advance the current state of the art in microrobotics. The organizers would like to congratulate the winners and thank all participants for making MMC 2017 a success (Figure 5). We look forward to MMC 2018 at ICRA 2018 in Brisbane, Australia. More information about MMC 2017 can be found at https://sites.google.com/site/mobilemicrorboticschallenge/.

—Aaron T. Ohta, Igor Paprotny, and David J. Cappelleri

The Soft Material Robot Challenge

The SMRC, held for the first time at the 2017 IEEE ICRA, aimed to promote and showcase research in and encourage the development of soft robots for field applicability. The SMRC consisted of a speed challenge for robots driven by soft actuators as well as a technology showcase challenge for participants to demonstrate the novelty, functionality, replicability, and significance of their soft component technologies.

Figure 7. The finalists and organizers of the SMRC.

Soft Robot Speed Challenge

This was a challenge to find the team with the fastest robot, driven by soft actuators, for moving through a given obstacle course. To compete in the challenge, the robot had to be smaller than a 1-m cube, and its body had to be made of soft materials.

The soft robots were required to traverse a given obstacle course in the shortest time possible. As the track consisted of vertical undulations and obstacles, the robots were required to maneuver down the path and around the obstacles. The side and front views of the obstacle course are shown in Figure 6.

The evaluation criteria for the speed challenge included the following factors:

1) The length, width, and height of the robot were measured, and the largest dimension of the robot was noted as the body length.
2) The speed was noted as the number of body lengths traveled by the robot per second.
3) For each obstacle that the robot came in contact with, 1% of the final score was deducted.
4) The robots with onboard power supply (untethered robots) or robots that were completely driven by soft actuators were awarded a bonus—5% of the final score.
5) Each team was able to take three trial runs, and the best of the three runs was recorded as the team's score.
6) The robots that could not complete the race path were awarded no points.
7) If none of the robots completed the race path, the robot that traversed the maximum distance would be declared the winner.

After the consideration of these factors by a panel of judges, the team with the highest score would become the winner.

There were five finalists for the SMRC speed challenge (Figure 7): Team WPI Salamander (Worcester Polytechnic Institute, Massachusetts), Teams ZJUnoomy and Soft Challenger (Zhejiang University, China), and Teams SoRollBot NUS and WormBot NUS (National University of Singapore). After an intense competition (Figure 8), WPI Salamander was the fastest, with ZJUnoomy coming in a close second. However, ZJUnoomy obtained a bonus for completely driving its robot with soft actuators, while WPI Salamander did not receive this bonus. Finally, the panel of judges, after some debate, reached the decision that both ZJUnoomy and WPI Salamander would be tied for first place.

Figure 8. The SMRC soft robot speed challenge.

The Soft Component Technology Challenge

This challenge aimed to showcase newly developed actuator, sensor, or other component technologies that advance the field of soft robotics. The entries were evaluated based on their significance, originality, functionality, and quality of documentation. They were challenged to contribute to solving pertinent issues in soft robotics, be original compared to existing literature, be based soundly on experimental data and benchmarked against the state of the art, and be properly documented in terms of the design, modeling, fabrication, and testing.

A total of 23 entries from nine countries were received, and 18 were shortlisted as finalists, who demonstrated their prototypes to a panel of judges at ICRA 2017 (Figure 9). The teams were scored by the judges based on the evaluation criteria. After two days of intense presentations and questions and answers, Team EPFL-LIS-1 (École Polytechnique Fédérale de Lausanne, Switzerland) emerged victorious with their work "Dual-Stiffness Frame for Collision Resilient Quadcopters" and won the first prize of US$1,000.

In addition, two second prizes of US$500 each were awarded to Team Soft Pioneers (Zhejiang University,

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each is doing fabulous work in the local community. It is therefore important to create opportunities for networking and meeting one another. Each of us can bring a unique perspective that makes the whole so much stronger and more vibrant, diverse, and interesting.

Being an active member of the network is extremely important for personal and professional growth, and it is important to create opportunities for meeting and sharing ideas and challenges. To be part of the network, don't be shy, don't be afraid of your ideas and vision, and be ready and proactive for discussion. Sharing our ideas and putting them out there for review is fundamental to becoming stronger.

Another lesson learned is the importance of moving out of our comfort zone. We must not be afraid of change; it is going to happen anyway. Change is part of our life, in both the personal and professional spheres. So be ready for any change, and take it as an opportunity for improvement and growth.

It is important to maintain our own private space, anyway, and our personal time for family, friends, and hobbies. It is therefore fundamental to learn to say no when necessary. We don't have to think that saying no betrays a lack of responsibility or a is sign of insufficiency. These are the major lessons I've learned.

I see a positive future for robotics, and in particular for women in robotics. The new trends that have shaped robotics as a multi- and cross-disciplinary science are attracting more and more women to the field, and their role in bringing robots to society could be fundamental. The ability to collaborate, excite with passion, reach consensus, listen empathetically, bring together disparate ideas, and stimulate support and enthusiasm are all skills that are particularly strong in women and essential for pioneering new changes.

Developing the ethical, legal, and social aspects of robotics and using robots as educational tools are fundamental for increasing robots' acceptability and creating an environment in which humans and robots can operate symbiotically. I believe that the areas that serve to bring robots closer to humans, in contrast to the older vision of using them only in industrial and other limited contexts, will continue to attract more women to work in the field.

The Society will continue to promote women's leadership and involvement in the organization of conferences and special issues. I expect more women on the IEEE RAS Administrative Committee; in the next ICRA, IROS, and CASE conference boards; and in other symposia. The change is happening already.

COMPETITIONS *(continued from page 19)*

Figure 9. The SMRC soft component technology showcase challenge.

China) for their work on "Fast Moving Soft Electronic Fish" and Team uSkin (Waseda University, Japan) for "uSkin, a Soft Distributed 3-Axis Skin Sensor System and Its Implementation on a Robotic Fingertip."

Finally, three third prizes of US$300 each were awarded to Team DeployableSoro Seoul National University, Korea for their "Deployable Soft Bending Actuator," Team Origami Robot NUS (National University of Singapore) for their "Soft Origami Robot Driven by Electrostatic Force," and Team TacTip BRL (University of Bristol, United Kingdom) for "TacTip."

The first SMRC at the ICRA was successful. The large number of participants was highly encouraging, the interactions and exchange of ideas were stimulating, and it was a great opportunity to demonstrate the progress in the emerging area of soft robotics. We look forward to organizing future editions of the SMRC. More information about the SMRC 2017 can be found at https://sites.google.com/view/softrobotchallenge2017.

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