

2014 Humanitarian Robotics and Automation Technology Challenge

By Raj Madhavan, Lino Marques, Edson Prestes, Prithviraj Dasgupta, Gonçalo Cabrita, David Portugal, Bruno Gouveia, Vitor Jorge, Renan Maffei, Guilherme Franco, and Jose Garcia

Robotics and automation (R&A) technologies have the potential to transform and improve the lives of people around the globe by addressing the world's toughest challenges. The IEEE Robotics and Automation Society (RAS) Special Interest Group on Humanitarian Technology (SIGHT) is engaging the academic and nonacademic community to propose viable solutions in R&A to address relevant world problems through the Humanitarian Robotics and Automation Technology Challenge (HRATC). The HRATC is an unprecedented opportunity for IEEE Members from around the world to collaborate using their skills and education to benefit humanity. The problems (challenges) are framed with the environmental, cultural, structural, political, socioeconomic, and resource constraints so that solutions can be developed, deployed, and sustained.

RAS is the first and only IEEE Society to have a SIGHT. The mission of the RAS SIGHT is the application of R&A technologies for promoting humanitarian causes around the globe and to leverage existing and emerging technologies for the benefit of humanity and toward increasing the quality of life in underserved, underdeveloped areas in collaboration with existing global communities and organizations.

According to the United Nations Mine Action Service, land mines kill 15,000–20,000 people every year (mostly children) and maim countless more across 78 countries. Demining efforts

cost US\$300–1,000 per mine, and, for every 5,000 mines cleared, one person is killed and two are injured. Thus, clearing postcombat regions of land mines has proven to be a difficult, risky, dangerous, and expensive task with enormous social implications for civilians. Motivated by these considerations, the first HRATC edition took place at the 2014 International Conference on Robotics and Automation (ICRA) in Hong Kong and remotely in Coimbra, Portugal. It focused on promoting the development of new strategies for autonomous land mine detection using a mobile (ground) robot.

Initially, 14 teams from eight countries submitted their entries. Based on the description papers where teams were asked to describe their experience and strategies, ten teams were short-listed to move forward with the three stages of HRATC 2014: simulation, testing, and finals. The 2014 edition was the first HRATC event where teams from around the globe had the chance to participate and remotely develop autonomous demining strategies for detection and classification in a physical outdoor robotic platform, the field and service robotics (FSR) Husky, as shown in Figure 1. This is an all-terrain, four-wheeler, skid-steering autonomous robot built around a Clearpath Husky A200 base, comprising several sensors, such as stereo cameras, a laser range finder, a global positioning system (GPS), an inertial measurement unit (IMU), and a

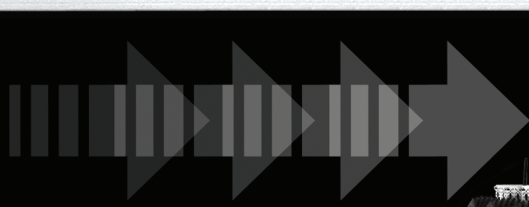


Figure 1. The HRATC 2014 robot platform.

two-degrees-of-freedom (2-DoF) mine clearance arm equipped with a Vallon VMP3 metal detector.

For the simulation stage (March–April 2014), a software framework (hereafter referred to as the *HRATC framework*) that runs on a Linux-based operating system and uses the robot operating system (ROS) to communicate with the client and the robot was developed. Figure 2 presents the software architecture. In the simulation, as shown in Figure 2(a), the framework provides the simulated data to the client. The Gazebo Simulator, through the Husky modules, provides the data of the robot sensors, cameras, and its localization, while a custom simulator provides the metal detector readings based on data sets collected with the real metal detector. In the core of the framework is the HRATC Judge, which extracts several performance measures, such as the number of detected mines, false detections, and exploded unknown mines as well as the covered area and coverage time, and computes the scores of

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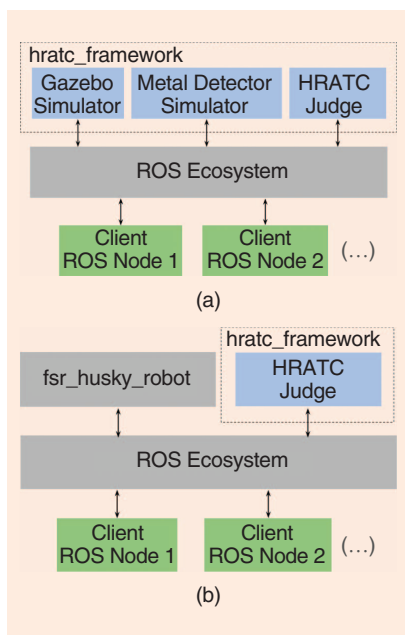


Figure 2. The software architecture for (a) the simulation and (b) the testing phase.

the teams. During experiments, these measures can be visualized in the HRATC framework main window, as

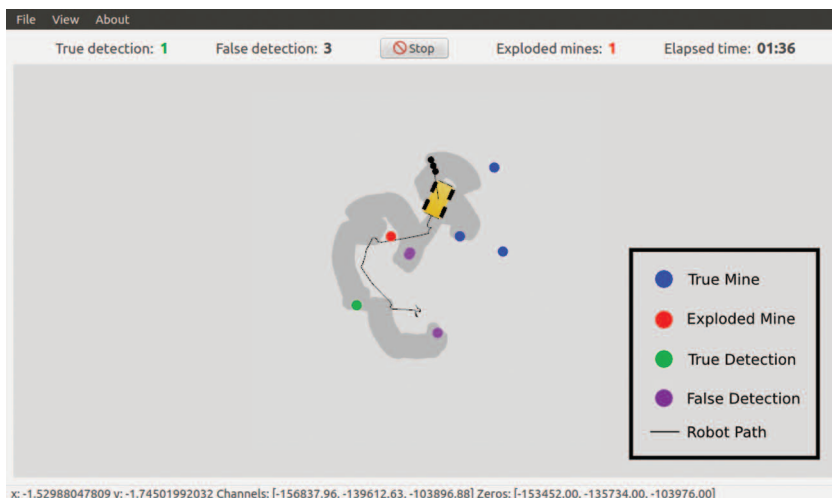


Figure 3. An HRATC framework main window.

shown in Figure 3, along with some additional information, such as the robot path.

The scoring metric used to evaluate the performance of the teams is a composition of three different components: the mine detection score, the total time score, and the swept area score. The mine detec-

tion score—the one with the largest weight of the three—is a ratio between the number of true detections and all guesses made by the competitor, and, therefore, each mistake decreases this score. In addition, mistakes considering previous knowledge (e.g., explosions of detected mines) are worse than mistakes without

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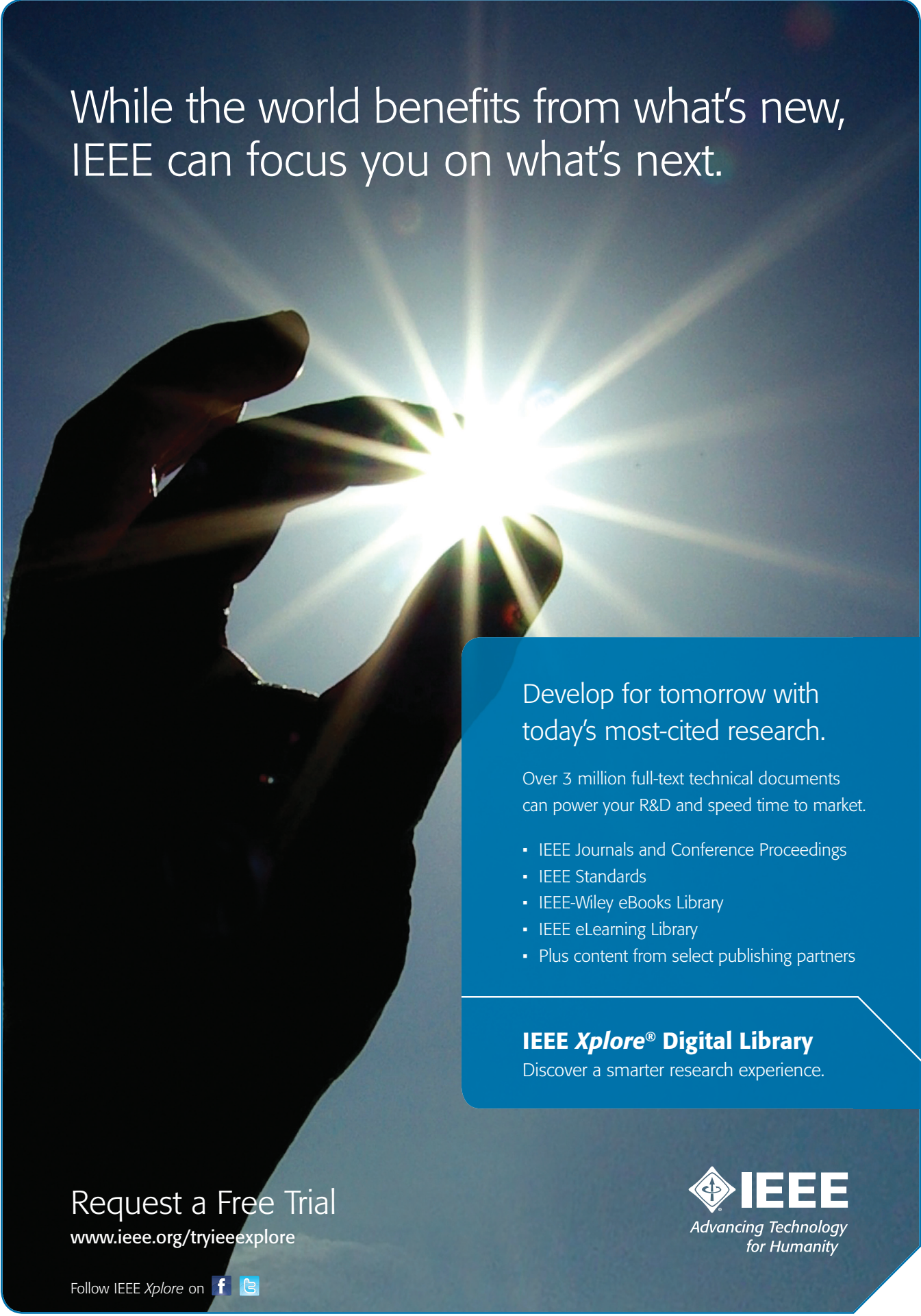
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Figure 4. A challenge environment.

prior knowledge (e.g., explosions of undetected mines), and receive a large penalization. The swept area score, i.e., the percentage of the total area of the environment covered by the robot sensors, is of great importance since one of the goals in demining is cleaning the largest area. However, its importance is much smaller than the mine detection score because a large coverage without a good mine detection strategy can be useless and even dangerous. Finally, the total time score, although important, is not as critical as correct detection and, therefore, only adds a small contribution to the final score.

In the testing stage, as shown in Figure 2(b), the real robot is used through the `fsr_husky_robot` ROS metapackage. For consistency, in both stages, the same ROS topics are used to publish the data, which means that the code generated by the teams during the simulation stage can also work on the testing stage without major modifications. During the testing phase, which took place over the first three weeks of May 2014, each team had the possibility to refine its field coverage and mine detection strategies using ROS to control the FSR Husky. Flexibility was a priority, as the participants could make use of all of the robot's sensors as they saw fit to develop their own algorithms. The testing phase took place in an outdoor arena covered by low grass and ditches, as shown in Figure 4. A few surrogate mines, composed of a small plastic box with a metal sphere inside, were buried at a shallow depth, together with other metal debris, e.g., coke cans, metal pieces, and large screws. Three separate trials were allowed (staggered by a week each) for each team to evaluate and adjust their strategy. Participants had access in real time to precise localization

data fed by GPS, IMU, and odometry. In addition, during the trials, a data set for the teams to assess the sensibility of the metal detector over different types of soil was also provided, as well as several examples on how to control the robot and the sweeping arm with the ROS. Feedback, data sets, and video footage with the robot behavior were sent to all teams

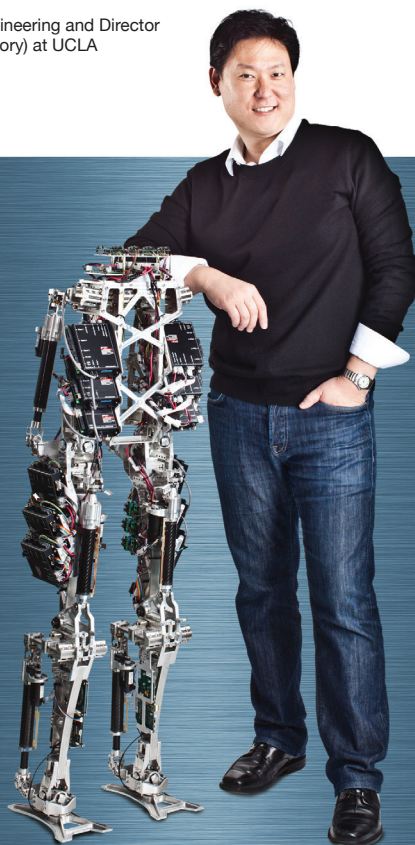
after each trial. This phase was crucial to allow the participants to have a "feel" of the differences between controlling a simulated platform, which they used for development and the real robot used in the finals. These differences mainly were in the localization system and the arm control. Likewise, the testing phase was a fundamental learning process for the

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Figure 5. From left, Raja Chatila, RAS president; Sandesh Gowda and Dan Popa (winners from team ORION); and cochairs of HRATC 2014: Raj Madhavan (chair, RAS SIGHT and vice president, RAS Industrial Activities Board), Lino Marques, Edson Prestes, and Prithviraj Dasgupta.

challenge organization, as it allowed for checking the robustness of the robot in numerous field trials and during long periods of time, as well as optimizing the arm sweeping controlling parameters, carrying out timely replacement of hardware and pieces, and assessing weaker points of the platform so as to improve in upcoming trials.

After the testing phase, four teams participated in the finals at ICRA in

Hong Kong, consisting of two runs on 31 May and 1 June, which were video-streamed live over the Internet from Coimbra, Portugal. The final challenge environment was an open wooded area with a size of 10×5 m, as shown in Figure 4, and delimited by four GPS coordinates. The challenge area was marked by plastic tape for visualization purposes, and a virtual fence was deployed to stop the robots from going outside the chal-

lenge area. Five surrogate mines were buried in the field in addition to metal debris. The teams were evaluated according to the scoring metric on their best run.

Team ORION of the University of Texas at Arlington was declared as the grand winner. The second- and third-place finishers were the Team Geeks of the Square Table (University of Bremen, Germany) and Team USMiners (University of Southern Mississippi). Thanks to IEEE SIGHT sponsorship, the three best-ranked teams received a cash prize (US\$1,000, US\$500, and US\$250, respectively) together with a certificate and a plaque.

We see this challenge as a multiyear effort at the end of which it is our hope that, with the help of the academic and industrial communities, a sustainable, cost-effective, and meaningful solution would become available to this problem that has plagued several worldwide communities for a long while. In the next HRATC edition that will take place during ICRA 2015 in Seattle, Washington, we will continue to refine the development of new strategies for autonomous land mine detection.

In addition, the RAS SIGHT is currently investigating new challenges for the R&A community. If you are interested in participating and/or proposing a challenge, please send an e-mail to raj.madhavan@ieee.org. Additional information regarding challenges, deadlines, and a subscription for the next edition will be posted at <http://www.ieee-ras.org/educational-resources-outreach/humanitarian-efforts>. The challenge organizers thank Clearpath Robotics, Inc., the FP7-TIRAMISU project (<http://www.fp7-tiramisu.eu/>), the RAS Competitions Committee, and the RAS SIGHT for their support and partnership in organizing HRATC'14.

The HRATC 2014 organizers were Raj Madhavan (chair, RAS SIGHT), Lino Marques (University of Coimbra, Portugal), Edson Prestes (Federal University of Rio Grande do Sul, Brazil), and Prithviraj Dasgupta (University of Nebraska-Omaha). For more information and details on the challenge and scope, please visit <http://www.isr.uc.pt/HRATC2014/>. 

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