The 2017 Humanitarian Robotics and Automation Technology Challenge

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Since 2014, the IEEE Robotics and Automation Society's Special Interest Group on Humanitarian Technology (RAS-SIGHT) has been organizing the Humanitarian Robotics and Automation Technology Challenge (HRATC). The main goal of the HRATC is to develop reliable robotic solutions for detecting landmines and unexploded ordnance, especially for communities where, due to these explosives, people live in fear of losing limbs or even their lives. Consequently, these communities have reduced access to agricultural lands for growing crops, which severely restricts their sustenance and livelihood. While other solutions exist, they are prohibitively expensive and are not practical for the developing world, where the bulk of these mines are buried. The emphasis of the HRATC from the beginning has been the development of cost-effective and sustainable solutions for such communities. More details on previous editions of the challenge are available in [1]–[3].

In the 2017 edition of the HRATC, one of the objectives was to design an affordable robot that could be built and deployed for mine detection. To that end, the first change in the robot was the utilization of a Pioneer P3-AT mobile base instead of the Clearpath Husky used in past editions. The robot, shown in Figure 1, consists of the Pioneer P3-AT base and fixtures used to keep the electronics fully described on the RAS-SIGHT GitHub [4]. The second physical modification to the robot compared to the previous edition is the selection of lower-cost sensors for localization and obstacle detection, as these are two of the main technical challenges. The robot's sensor suite consisted of two laser rangefinders: a SICK Tim-551 facing forward, for localization, and a Hokuyo URG-04LX positioned below the SICK rangefinder, for detecting obstacles; an MTK3339-based GPS module and a CH Robotics UM6 inertial measurement unit were for positioning. A custom robot operating system (ROS) package was built with all the necessary files for start-up and operation of the robot (the *hratc_robot* package [4]) and was executed remotely in a Raspberry Pi 2 Model B through a laptop computer connected to the robot's Wi-Fi network. The third physical change compared to the other HRATC editions is that the metal detector (attached to the front of the mobile base, as shown in Figure 1) was built from scratch with commonly available parts based on an existing design [5].

Figure 1. The HRATC 2017 robot platform and sensor suite.

Similar to past editions of HRATC, the teams' main challenge was to successfully translate their solution from the simulation phase to a real-world environment during the testing phase. The participating teams were required to develop their solutions in the ROS framework, which would then run in the laptop after starting up the robot. The tests were performed in a controlled area of approximately 360 m^2, where mock mines were buried. The robot localization challenge was simplified in the past iterations of the HRATC because the robot used a real-time kinematic GPS and the test scenario was on even terrain in an open field with good GPS availability. However, in this edition, the robot used a simpler GPS module, and the scenario had occlusions from trees and a nearby building. Though a more realistic scenario, this proved to be challenging for the teams, who had to develop solutions not completely reliant on GPS. Moreover, the terrain irregularities caused the laser rangefinders to sway, compounding errors in localization.

The participating teams integrated and tested several localization techniques based on sensor fusion, e.g., extended Kalman and particle filters and simultaneous localization and

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Figure 2. The finalists and co-organizers of HRATC 2017 in Singapore at ICRA.

mapping (SLAM) techniques. However, these solutions came mostly in the form of standard ROS packages designed for indoor operation and, thus, performed poorly in the highly dynamic outdoor scenario. As there was no reliable information on the robot position, the teams had difficulties navigating the arena and were unable to detect a satisfactory number of mines. The organizing team realized that the testing area did not have a sufficient number of unique features for the teams' SLAM algorithms and so augmented it with artificial obstacles. However, the problem of obstacle detection and avoidance became aggravated, as some teams could not detect the artificial obstacles and would crash into them, ending their test run. This issue was mainly caused by all teams using only the top laser rangefinder and not using the downward-tilting rangefinder placed specifically to detect smaller obstacles. Teams primarily did this because most navigation software, such as the ROS navigation stack, does not require this second laser, and the teams decided not to use it because it would require major changes in the software.

After the simulation and testing phases of the challenge, three teams qualified as finalists: Team Dhruva (India), Team National University of Singapore, and Team RCMakers (Turkey). At the finals, held in conjunction with the International Conference on Robotics and Automation (ICRA) in Singapore, teams were asked to send in their code to be run on the remotely stationed robot in Brazil (see Figure 2 for a photo of the finalists and the co-organizers of HRATC 2017). After two trials for each team, it was decided that there would be no winner this year because, according to the rules of the challenge, a winning team is required to reliably detect more than 50% of the number of buried mines.

After four years of the HRATC, we undertook an honest self-assessment to evaluate how well the challenge is fulfilling its original objectives. During these four years, a total of 53 teams representing 18 countries from the Americas, Europe, and Asia have participated. The most positive aspects have been 1) increasing the awareness of the robotics community for the humanitarian demining problem and the possibility of addressing it using robots in a cost-effective fashion as a viable alternative and 2) engaging students at the educational level toward developing a robust framework supporting cooperative remote field robotics trials.

The HRATC is the only mine detection event in the world that provides free access to a state-of-the-art robot platform and sensors to participants from all over the globe, thereby promoting the education of roboticists from developing countries with advanced tools. This has resulted in significantly lowering the entry barrier for students and researchers, who otherwise do not have a practicable way to participate in an international robotics challenge geared toward the benefit of humanity. Thanks to its sponsors, IEEE-RAS SIGHT and the IEEE ICRA Challenges Committee, travel support has been provided for the challenge's finalists so they could attend a premier robotics conference and network with attendees of the ICRA.

In terms of measuring the success of the event from a technical point of view, the inclusion of additional sensors for determining the robot's ground-truth would be beneficial as it could be used to evaluate the quality of the teams' localization solutions. There is a tradeoff between realism and accessibility in the testing phase, which the organizing team had to consider when selecting a test arena. An intermediate localization phase could be useful for the teams to focus on and solve localization issues before the testing phase. In this phase, the organizers could provide data sets of all the robot sensors for several trajectories, including its ground-truth. The teams would then implement and enhance their localization solutions, and those having the positioning error below a certain threshold would be allowed to proceed to the testing phase. In the current setup, the laser rangefinder proved to be insufficient for the selected scenario as the robot could not detect enough features for localization purposes. Perhaps a more affordable sensor, such as Sweep Scanner [6], could be a better option due to its reduced cost and longer range.

We are considering the development of performance indices that would be independent of the environment so the progress of the teams could be compared year after year, even if the operating environment is drastically altered. Continual adjustments will be made to ensure more sustainable progress in the challenge's outcomes and eventually reach the point where state-of-the-art advances can be quantified, leading to practical deployment. One of the most challenging aspects for the teams has proven to be the reliable detection of the buried mines. It is our observation that, after four iterations of the challenge, the teams are not fully utilizing the robot's capabilities; for instance, in previous editions, they were not integrating the robot's vision capabilities or properly controlling the arm height to maximize the probability of detecting landmines. With respect to the metal detector in the 2017 challenge, it worked quite well considering its production costs; however, timing issues associated with its operation could lead to false negatives. A detector design with a single large coil, instead of two small coils, would be more desirable.

We have observed that the fact that most teams were made up entirely of students who have no extensive background in robotics is directly reflected in the teams' performance during all phases of the challenge. This is not entirely surprising because it is necessary that the participants have a good grasp of robot navigation aspects such as motion planning, localization, nonlinear signal processing, and ROS. One possible problem with the HRATC format could be the steep learning curve the participating teams need to undergo given the relatively short time span of the challenge, especially if they are competing for the first time. Perhaps a longer period of involvement would provide the time necessary for tangible advances to occur. Additionally, starting with the 2017 Challenge, we have devised a standard documentation practice that would be adopted to make a team's code reusable for other teams. Although the progress has been incremental and slower than anticipated, we remain optimistic about the potential of such challenges to solve the humanitarian problem of detecting and extricating landmines. We continue to explore and investigate ways to make the challenge a closer match to foster the development of innovation needed to improve the quality of lives for thousands of people who continue to live and experience the devastation of the remnants of war on a daily basis.

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