# Editorial for the JFR special issue on "Multiple Collaborative Field Robots"

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The deployment of multiple robots can lead to important operational benefits in many field applications, for either exploration, surveillance and intervention missions. With respect to a single robot, teams of robot are obviously less prone to failures, able to simultaneously operate over larger areas and to convey a more and larger variety of payloads. But deploying multiple robots also yields benefits to the robots themselves: the robotics literature has already proposed numerous multi-robot schemes in which robots not only cooperate to achieve a given mission, but assist each other to palliate encountered difficulties. Robots can act as communication relays, locate others or merge maps to improve the spatial consistency of maps, carry smaller robots, evolve information to ensure safer or quicker motions, etc.

Several contributions of multiple field robot systems have been proposed in a former special issue of the Journal of Field Robotics in 2007[1]. Research on such systems has much evolved since, and in 2010 an ambitious challenge has been set up in Adelaide, Australia, in which several teams competed to achieve a surveillance mission with more than a dozen of robots. Six articles of this special issue report on this Multi-Autonomous Ground-robotic International Challenge (MAGIC) sponsored by the The Defence Science & Technology Organization (DSTO) in Australia and the Research Development & Engineering Command (RDECOM) in the United States of America. The MAGIC 2010 contributions highlight the technical challenges in planning, perception, and command and control that has been overcome to operate successfully in the field. In contrast, the last two contributions of this Special Issue report on field experiments conducted with a team of field robots in environments that were directly and indirectly damaged by the 2011 Tohoku earthquake in Sendai, Japan.

To lay the foundation for the MAGIC 2010 competition, Finn et al. depict the metrics defined to assess the performance of the MAGIC competitors. After a summary of the scenarios and missions in which numerous heterogeneous robots have to detect an "neutralize" static and mobile targets in a large scale rurban environment, the article depicts the various criteria used to measure the performance of the robot teams. The task is not an easy one, as mission-level

[1] Journal of Field Robotics, special Issue on Teamwork in Field Robotics. Volume 24, Issue 11-12, Nov. – Dec. 2007

operational criteria have to be mixed with systems level criteria, that include human robot interactions, and technological criteria pertaining to single robots. The robotics community is paying more and more attention to evaluation metrics, which are naturally essential to assess robotics systems: here a thorough work on evaluating robot teams interacting with operators in a realistic scenario is proposed – and has been exploited to rank the MAGIC competitors.

With the rules clearly outlined, the issue segues into the various teams' efforts. While different approaches were taken, common themes emerge. For one, the use of commercial off-the-shelf components as the foundation of each team's effort coupled with the development of a unifying system architecture. Boeing et al. outline team MAGICian's approach towards developing a unified system architecture with the necessary sensing, planning, navigation, and mapping capabilities needed to address the competition's demands. Key to their success was an agile development methodology that took advantage of commercial off-the-shelf hardware and software components which enabled the team to focus on system integration. A similar approach taken by team RASR as described by Lacaze et al. In these two contributions, a common theme is the use of commercial off-the-shelf hardware and software components to minimize risk in the design phase and to identify focus areas. In addition, team RASR incorporated a distributed coordination strategy which focuses on minimizing communications between the various robots.

A second theme that emerges is the emphasis on the human and robotic team command and control interface. Butzke et al. describe the University of Pennsylvania entry in MAGIC. The article presents how the authors engineered a hierarchical architecture to interleave mapping, localization, exploration and target management processes within each UGV, and emphasizes the way two operators can operate a team of nine robots endowed with this architecture. Olson et al. describe their teams approach towards developing the winning MAGIC 2010 system. In this article, Team Michigan presents their general design approach which focused on minimizing the efforts required by the human operators when commanding and controlling a team of fourteen autonomous vehicles. Specifically, the team describes their ability to maintain a consistent global map by developing fast loop-closing, map optimization, and communications algorithms. These developments, in conjunction with a centralized planning architecture that enabled robots to execute their individual tasks in a centrally coordinated fashion, were the key to their success.

A third and common theme is the need for a careful management of communications. Guivant et al. describe their team's approach which centered on the development of the interface between the communication and processing modules to achieve a flexible control architecture that can support traditional teleoperation to point-and-click autonomy. In this work, the authors describe how careful management of the available system bandwidth enabled their teams to achieve long-range communication while still providing real-time map data.

If one views the MAGIC 2010 contributions as a celebration of the recent achievements in the field of collaborative robotic systems, the two last contributions should be viewed as challenges that must be overcome. Murphy et al.

reports on the experience of two deployments of heterogeneous unmanned marine vehicle teams at the 2011 Great Eastern Japan Earthquake response and recovery by the Center for Robot-Assisted Search and Rescue (USA) in collaboration with the International Rescue System Institute (Japan). This work reports on the teams successes and failures. Specifically, Murphy et al. showed how their planned multi-robot systems did not fall into traditional taxonomies and the resulting challenges. Lastly, Michael et al. reports on their deployment of a team of aerial and ground robots for collaborative mapping of an earthquake-damaged building. Specifically, the team reports on the experiments that were conducted in a structurally compromised building at Tohoku University in Sendai, Japan that was damaged during the 2011 Tohoku earthquake. The team shows the ability of the team of heterogeneous robots in providing 3-D maps of the building and discuss future challenges from their experiences.

It has been a great pleasure working with all the contributing authors and the numerous reviewers in bringing together this special issue. In many ways, this issue is a small microcosm of the various developments in the field of collaborative field robotic systems. We hope you will enjoy these articles as much as we have.