Multi-Robot Systems

Nora Ayanian, Robert Fitch, Antonio Franchi, and Lorenzo Sabattini

The Technical Committee (TC) on Multi-Robot Systems (MRS) was founded in 2014 to create a focal point for the wide and diverse community of researchers interested in multi-robot systems. Since then, we have gained over 350 members from over 40 countries and maintain a high level of activity in sponsoring workshops, summer schools, special issues, and a new conference (with technical co-sponsorship from IEEE). Our TC aims to identify and constantly track the common characteristics, problems, and achievements of MRS research in its multiple domains. We envision the TC as a principal gathering place and communication catalyst among all researchers and practitioners working on MRS and related fields.

Researchers interested in MRS represent an inherently diverse community, since several competences are needed in this field, including control systems, mechanical design, coordination, cooperation, estimation, perception, and interaction. The TC promotes cross-fertilization between these communities to identify common characteristics of multi-robot problems in different domains, facilitating the definition of standard methods and practices for development and validation of algorithms in multi-robot applications.

Research Activities

MRS research comprises three broad research areas. These areas of interest are:

- **Modeling and control of MRS.** The modeling aspect seeks to uncover principles that inform the choice of how to represent a given MRS mathematically, such as simplicity versus completeness, level of fidelity in modeling dynamics, and level of abstraction for sensor models. The control aspect then asks how to design controllers that act on these models, and involves questions regarding architecture (e.g., centralized or decentralized) and control objectives (formation control, flocking, coverage, force control, and others).
- **Planning and decision-making for MRS.** Classical robotics planning problems have rich, unique analogues in the multi-robot setting due to the possibility of complex interactions between robots. Examples of problems of interest include motion planning and coordination, task planning and allocation, perception with multiple robots, and cooperative/collective learning.
- **Applications of MRS, and technological and methodological issues.** MRS offer strong opportunities for solving real-world problems at large scales. Developing applications of MRS involves important challenges such as mechatronic and software design for robots that work together in interesting ways, communication in real-world environments, design of realistic simulation tools, and principled experimental and evaluation methodologies.

Capabilities of MRS and related algorithmic advances have been validated on a wide variety of demonstrators, from research platforms to real-world implementations, in many different domains; examples are shown in Figs. 1–5. Mature results have been commercialized, and TC members include industry practitioners from companies such as Elettric80 S.p.A. (Italy), whose robots are shown in Fig. 6, SwarmFarm Robotics (Australia), and Amazon Robotics (USA).

TC Activities

The MRS TC sponsors many activities that bring our members together, both in-person and online. Our flagship achievement to date is the founding of a new conference dedicated to multi-robot and multi-agent systems: the International Symposium on Multi-Robot and Multi-Agent Systems. The inaugural meeting of this conference will be MRS 2017, to be held later this year at the University of Southern California (USA). The conference will be held biennially thereafter.

We regularly promote MRS research topics in conference workshops. In the two-year period of 2015-2016, we promoted and sponsored 8 workshops at IEEE ICRA, IEEE/RSJ IROS, IEEE IV, and RSS.

Our educational activities include summer schools and IEEE CEMRA projects. We organized a MRS summer school at NUS (Singapore) in June 2016, attended by 72 students from all IEEE geographical areas. We supported the successful CEMRA project "Autonomous mobile robot programming using ROS on a remote web-based real robot lab", also in 2016. Both received financial support from the IEEE.

Finally, we are also proud of a new best paper award category for MRS that will debut at this year's ICRA conference. The award is generously supported by Amazon Robotics.

Further information about the TC mission, organization, membership, and supported activities, as well as many other actions related to the MRS community, can be found on the continuously updated TC website http://multirobotsystems.org/.

Future Directions

We look forward to a blossoming of new activities, interest, and research questions in MRS. Ideas developed by the research community over the past decades are already evident in MRS that perform real work in the real world, and we envision challenging new problems in all three of our main areas of interest. These challenges will be addressed by a growing body of MRS researchers that we, as a TC, hope to continue to support through our activities for many years to come.

ACKNOWLEDGMENTS

Special thanks to the many research groups who actively contribute to the TC website growth and provided research highlights and photos of their impressive work.

(a) (b)

Fig. 1. A system of many small aerial vehicles that coordinate their motion from the Autonomous Coordination of Teams Laboratory and the Robotic Embedded Systems Laboratory at USC.

Fig. 2. Two autonomous vehicles used for research in autonomous mining, from the Australian Centre for Field Robotics (ACFR) at The University of Sydney.

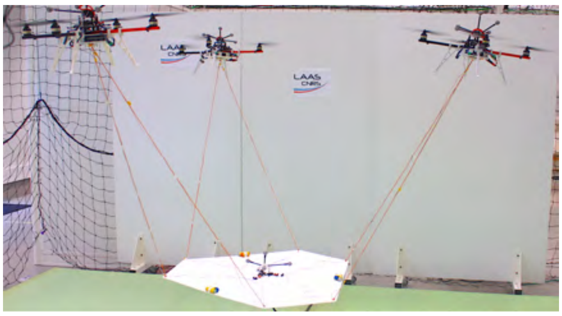

Fig. 3. An example of multi-robot aerial manipulation: the FlyCrane system from LAAS-CNRS. The system comprises three quadrotors connected to a load via six cables and is able to precisely and robustly control the full-pose (position and orientation) of the load.

Fig. 4. Three mini autonomous surface vehicles in a multi-robot testbed coherent flow tank in the Scalable Autonomous Systems Laboratory at the University of Pennsylvania. The white particles are flow tracers used to image the surface flows created in the tank.

Fig. 5. A heterogeneous multi-robot system, composed of a ground and an aerial robot, used for vineyard monitoring, from the University of Modena and Reggio Emilia.

Fig. 6. A fleet of automated guided vehicles from Elettric80, used for logistics operations in automated industrial warehouses.