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Editorial

Realizing the promise of robotic self-x systems

Consider a robot trying to accomplish a mission in an unfamiliar, hostile, and dynamic environment. As the robot encounters a seemingly insurmountable obstacle, it quickly reconfigures itself into two smaller robots, and with the aid of a nearby puddle of water, these two robots conduct self-detection procedures to confirm successful reconfiguration. One robot then calibrates itself using its reduced sensor suite and begins climbing over the obstacle, whilst the other robot folds itself into a compact structure and finds a crevice it can use to bypass the obstacle. But when the obstacle shifts, both robots send signals to a base to warn of impending mission failure. A copy of the original robot, located at the base, receives these warning signals and initiates a rapid self-replication process by assembling available resources. The resultant robotic offspring are then ready to continue the mission when called upon.

The above vision, once wildly futuristic, is closer to becoming reality thanks to the sophisticated technologies described in this special issue on *Robotic Self-X Systems*. Self-x systems are systems that are capable of self-assembly, self-assessment, self-calibration, self-detection, self-organization, self-reconfiguration, self-repair, self-replication, or self-reproduction. Such systems have the important capacity to operate optimally in the presence of uncertainty, learn about and adapt to changes in the external environment, and respond rapidly to applied disturbances and disruptions to internal system states. Furthermore, the widespread applicability and versatility of self-x technology implies that these systems hold immense promise for advances in such diverse areas as autonomous manufacturing, bioengineering, evolutionary software, search and rescue, space colonization, and many others.

The fields of self-x systems and robotic self-x systems have experienced tremendous recent growth. This is indicated by the increasing number of groups actively researching these topics, as well as the broad variety of new results and applications being reported. Although there have been a few special issues devoted to the subject (see refs. [1,2]), the Editor-in-Chief felt that the time was right for the robotics community to take another close look at robotic self-x systems, and we delightfully agreed.

Twenty-two manuscripts were submitted for possible inclusion in this special issue. We are very grateful to all authors who contributed their work in response to our call for papers. We would also like to sincerely thank the editorial and publishing staff for facilitating the special issue process. And we are immensely indebted to the many dedicated reviewers who evaluated and suggested excellent refinements to the submissions; as a result of three rounds of their efforts, this issue contains eleven high-quality papers that reflect the cutting-edge of robotic self-x systems technology.

The issue is organized around three broad self-x themes: self-assessment, self-reconfiguration, and self-replication. Stoytchev kicks-off the special issue with a paper on autonomous self-detection, where a robot classifies different visual stimuli to distinguish between its own body and the external environment. Tavakoli *et al*. follow this work with their approach to increasing the positioning accuracy of a robotic arm on a mobile base through a repeated self-calibration algorithm; the approach utilizes low-cost sensors, and is independent of external observers, engineered shapes or symbols, and external mechanisms and devices.

Moving to the topic of self-reconfiguration of modular robots, Schultz *et al*. present their implementation of a scripting language that executes self-reconfiguration sequences on ATRON robot modules in a distributed manner. The result is robustness to partial failures, as well as the reversibility of a self-reconfiguration sequence. Next, Aloupis *et al*. propose two algorithms for the reconfiguration of n-atom crystalline robots in a way that respects certain physical constraints. The algorithms have linear time complexity $O(n)$ when performed using $O(n)$ parallel steps, and are also worst-case optimal. Larkworthy and Ramamoorthy then explain the structure of a subspace of the reconfiguration space of a self-reconfiguring robotic system that is desirable for efficient motion planning in that subspace.

Motion planning is also the subject of the paper by An *et al*.; however, the focus here is on a self-folding sheet (which is a novel type of programmable matter) rather than a self-reconfigurable modular robot. The paper showcases an algorithm that can fold a single sheet into multiple origami patterns. This is followed by the work of White *et al*., who explore means of quickly ascertaining the load-bearing ability of a configuration of programmable matter or a configuration of modular robots, to inform searches for desirable shape configurations.

On the third theme, Kabamba *et al*. describe fundamental requirements for self-reproduction using Generation Theory, and demonstrate their work with a self-assembly application. Hierarchical assembly is the goal of Kaloutsakis and Chirikjian's paper, which presents the development of a stochastic robot that is capable of both self-replication in an unstructured environment and cooperation with similar robots to form aggregations. Stevens discusses a simulation environment for a self-replicating programmable constructor that, unlike cellular automata, accounts for material parts and also models system features that depend on component motion and connectivity. Lastly, Jones *et al*. provide an account of the success of their replicating rapid prototyper from inception to the present day.

This special issue undoubtedly provides a rich and varied take on current topics in robotic self-x systems, and offers a glimpse of several challenging problems that are still open. It has been a great pleasure for us to put this issue together. We do hope that you enjoy the selection contained herein, and, if you are not already a member of the robotic self-x community, we hope that you are inspired enough to join us in our endeavors.

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1. *IEEE/ASME Transactions on Mechatronics*, Special Issue on Self-Reconfigurable Robots, Vol. 7, No. 4, December 2002.
2. *IEEE Robotics and Automation Magazine,* Self-X: Toward Robotic System Autonomy, Vol. 14, No. 4, December 2007.

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