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Editorial

# Editorial Overview: Advances in Robotic Technologies

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Since the late 1950s, great progress has been achieved in robotic technologies due to advances in mechanics, electronics, sensing technologies, computing and information technologies, control theory, and so forth. The fields of robot application are expanding into all aspects of our daily lives. Examples include industrial robots that perform constrained and repetitive tasks such as welding and painting; space and underwater robots that perform scientific exploration in environments where humans cannot reach; anti-terror and mining robots that execute delicate but dangerous operations; household and field robots that complete household chores and agricultural operations in order to free up the human host's time for recreation and entertainment; medical robots that enhance the abilities of disabled and elderly people in order to enable them to live independently, or that assist doctors to perform minimally invasive but complex surgeries; and automatic driving vehicles that have the potential to increase users' safety, mobility, and satisfaction along with providing a significant reduction in traffic collisions.

The versatility of robot applications is largely attributed to the significant improvements that have been made in mechanical structure design, sensing capability, computing performance, and control theory. However, as robots become increasingly integrated into human society, the challenges increase: It becomes necessary for such robots to have higher robotic capabilities of understanding uncertain environments and human intentions, adapting to dynamic tasks, and interacting safely with their agent counterparts, which include humans and other robots. In some industries, such as electronic manufacturing and car manufacturing, robots operating within a fixed area are required to have a certain amount of flexibility to adapt to dynamic production tasks, as the product life and production period of electronics become shorter than ever before. Personal service robots, which intimately interact with humans, must have the comprehensive capability to precisely understand and perceive a human's intentions and behaviors, recognize the action and task that must be fulfilled, and coordinate and collaborate with humans safely and effectively. Prosthesis robots must be able not only to correctly interpret the human host's intentions through biological signals, but also to perform the required action in such a way as to biologically and accurately coordinate with the host.

Enhancing robots with such capabilities requires extensive research efforts, and this endeavor has attracted considerable attention. In order to achieve such a goal, research activities must be carried out from many directions. These include: biomimetic and compliant structure design for compatibility with human motion; multi-mode sensing and dynamic perception, which are achieved through the fusion of multi-mode information acquired with a variety of sensor modalities such as cameras, radar, lasers, and tactile sensors, and which permit natural interactions with human intentions and behaviors; and modeling theories, planning algorithms, and control strategies that adapt to the new design, actuation, and perception of robots to permit coordinated collaboration. In addition, machine learning techniques play a significant role in robotic perception, cognition, and learning. In particular, the deep learning technique has dramatically enhanced robotic learning capabilities from offline visual data and online visual information, due to the resource availability of large computation power and big data.

In recent years, advances in relevant research fields, such as materials science, nanotechnology, bioengineering, brain science, and manufacturing technology, have triggered the emergence of many new types of robots. With the benefit of highly compliant materials and three-dimensional (3D) printing technology, soft robots with structure deformability possess natural adaptability to their surroundings and increased flexibility. Micro/nano robots can perform tasks on a tiny scale—as small as micrometers or nanometers—and have great potential for medical applications including noninvasive surgery, early diagnosis, and targeted drug delivery. Bio-syncretic robots, which are also called "bio-bots" or "bio-hybrid robots" by various researchers, consist of both living biological materials and non-living systems. These robots are becoming a topic of great interest, and significant progress has been achieved in their development over the past decade. By integrating electromechanical systems with biological materials at various scales (i.e., molecules, cells, and tissues) with desirable functions, bio-syncretic robots may offer advantages such as high energy-transformation efficiency, intrinsic safety, high sensitivity, and self-repairing capabilities. Thus, they offer a possible way to

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enhance the comprehensive capabilities of robots in order to improve their interactions with their surrounding environment and with other agents.

It is timely for *Engineering* to create a special issue on robotics. This issue gives overviews of industrial robots and bio-syncretic robots, and reports on new results for exoskeleton robot, moving robot, and automatic driving vehicles. This information is delivered from the perspectives of structure design, control and actuation, planning and navigation strategies, and system integration. We hope that this special issue will provide a set of reference coordinates for current and future research directions in the field of robotics. Although the field of robotics began in the 1950s, it is still a young research field. Considerable room for growth exists in various research dimensions, including robotic structure design and fabrication, actuation and control, sensing and perception, planning and navigation, and even robotic application. The field of robotics has bright prospects in science, technology, engineering, and applications.