Tri-Co Robot: a Chinese robotic research initiative for enhanced robot interaction capabilities

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Since the invention of the first industrial robot in 1959, the missions of robots have evolved from basic mechanical transfer or assistance to a diverse range of tasks through close interactions with environment, their human counterparts and robot peers. Through adaptation to uncertain and dynamic environments, legged robots can achieve coordinated locomotion in rough terrain, even at high speed [1]. By interpreting human motives from bio-signals and neuro interfaces and providing sensory feedback to the wearer, robotic prosthetic devices can potentially emulate the missing limb or other body parts [2]. Autonomous robots operated in large groups could cooperate through local interactions governed by collective control algorithms and decentralized information exchange [3]. Those scenarios demonstrate that the functionalities of advanced robotics rely highly on their capabilities of effective interactions with the environment and other agents, either people or robots. Endowing robots with such capabilities will require extensive research efforts in order to develop: (i) sensing techniques and cognitive mechanisms for perceiving and interpreting environment states, human physiology and behavior, and status of other agents in the multi-robot systems; (ii) models and control strategies for robots to be able to recognize, track, infer the task actions and proactively plan their actions for adaptation to task contingencies in collaborative interaction scenarios; (iii) actuation and execution mechanisms and structures for dexterous manipulation and natural interfacing with humans with safety and effectiveness. In seek of research on the fundamental science, technologies and integrated systems required to fulfill this vision, the National Natural Science Foundation of China (NSFC) has launched the Tri-Co Robot (i.e. the Coexisting-Cooperative-Cognitive Robot) major research program in 2017 (Fig. 1). Coexisting ensures robotics technology to be ubiquitous for enrichment of quality of life and work for human beings in an inherently safe manner. Cooperative enables robots to collaborate and coordinate effectively with other agents (e.g. people or robots) through communication and interplay. Cognitive emphasizes the capabilities of robots to perceive and predict the behavior and intent of the environment and other agents through information gathering, and respond adaptively through machine learning, control and planning algorithms.

Enhanced interaction capabilities of robots with environment, humans and robots are targeted deliverables of this major research program. A range of research themes are fundamental to achieve the overall vision, such as the following aspects:

(i) Robot structure design and control. Future robots are coupled systems composed of rigid, flexible and soft materials and motion mechanisms. Rigid components ensure necessary force, power and responsiveness of actuation for motion tasks, while flexible and soft parts facilitate natural interactions with humans and provide the capability of adaptation, sensitivity and agility [4,5]. Research efforts are needed to

Figure 1. The Tri-Co (Coexisting-Cooperative-Cognitive) Robot for enhanced robot interactions with the environment, humans and robot peers.
understand the characteristics of the rigid-flexible-soft hybrid system configuration and its mechanical behavior, to reveal the action-deformation principles of the multi-body coupling mechanism driven by internal and external force and environmental constraints. The development of rigid-flexible-soft robot system dynamic models and efficient solution methods is desirable to achieve the adaptation of the robotic structure of variable stiffness design to environmental uncertainty and compliant interactions with humans or robots.

(ii) Multi-mode dynamic perception and natural interactions. In order to achieve highly effective perception and situation understanding in an unstructured environment, multi-mode information acquisition through vision, hearing and tactile sensing mechanisms and data fusion are critical and the development of intelligent perception systems through integrations of sensing, data processing and interpretation is necessary [6]. Meanwhile, seamless human-robot interactions require robots to be able to recognize human motives through bio-signal collections and autonomous learning [7]. Therefore, it is imperative to understand the characteristics of human physiological signals in time, spatial and frequency domains and propose corresponding autonomous and adaptive learning methods for accurate perception of human behavior.

(iii) Swarm intelligence in multi-robot systems and system architecture. To design multi-robot intelligent aggregation mechanisms and operation platforms, research efforts are required to propose coupled behavioral models of individual autonomy and swarm intelligence, reveal the population topology evolution by exploring the mechanisms of information propagation during independent individual interaction and perception, and establish the models for cooperative cognition and action. On the other hand, due to the polymorphic and distributed nature of multi-robot systems, it is desirable to explore adaptive frameworks and system architecture for resource management in geographically distributed robots of heterogeneous networks, as well as distributed control strategies for coordinated collaborations [8].

This major initiative will be implemented for the next eight years and research proposals will be solicited and evaluated annually. Regular projects will be supported for three years with budgets around ¥800,000, while the priority projects selected will be awarded ¥2,500,000 to ¥3,500,000 in four years. The actual number of awards every year may vary, depending on the budget. The program aims to develop robots for applications in various industrial sectors, rehabilitation assistance, military missions and extreme environments. Outcomes of particular interest include:

(i) ‘craftsmen’ type of robots for intelligent manufacturing. Craftsman robots are equipped with light-weight structure and drives of variable stiffness for highly dexterous manipulations and their control with high compliance to the manufacturing operations is facilitated by process knowledge learning and multi-mode sensing mechanisms. One example is the multi-robot system for manufacturing of thin-walled structures of large size and complex surface, such as gas turbine blades and aircraft structural components. Multi-agent craftsman robot systems can enable more effective manufacturing processes than conventional approaches due to the integration of vision and tactile sensing components, actuation units of adaptation, as well as control and planning algorithms for coordinated collaborations;

(ii) ‘smart and considerate’ rehabilitation robots. These kinds of robots are composed of bio-inspired, soft and compliant structures for compatibility with human motion, and multi-mode sensing capabilities for natural human machine interactions;

(iii) robot clusters for special missions. For instance, heterogeneous networks of robots with high autonomous mobility and coordinated cluster formation operated in different fields, such as air, ground and sea water, can find great utility in inspection, rescue and military missions.

Following China’s robotics research and development efforts for more than four decades, the goal of this major research program is to foster cutting-edge research to push the boundaries of robot functionalities and capabilities. As representatives of robotics research institutes in China, Huazhong University of Science and Technology, Shanghai Jiao Tong University, Harbin Institute of Technology, etc., have been consistently supported by NSFC to carry out fundamental investigations in emerging research areas, such as soft robotics, artificial intelligence, electronic skin for robots, rehabilitation robotics, space and underwater robotics, unmanned fleet, etc. Chinese roboticists’ endeavors have resulted in successful developments of advanced robotic systems, examples of which include those for applications in extreme environments (e.g. submersible vessel Jiaolong for deep-sea exploration) and robot clusters for entertainment (UBTECH Robotics) [9].

In addition to supporting fundamental research, the Tri-Co Robot initiative also aims to provide driving forces to accelerate the growth of the Chinese domestic robot industry. China has also been the largest industrial robot market in the world due to the boom of manufacturing industries over the past few decades. However, Chinese domestic robot manufacturers are lagging behind their foreign counterparts due to limited capability in manufacturing high-performance mechatronic parts and maintaining system reliability for desirable lifetime. Due to the rise of labor costs, the nation is now transitioning into an economy that relies more on innovation and highly value-added products, which creates the demand and opportunity for rapid growth of the robot industry. To boost the
contributes of the robot workforce to the overall manufacturing industry upgrade in China, the Tri-Co Robot initiative encourages collaborations between academia and industry to establish interactions between fundamental science, engineering, technology development and deployment and the industrial use of robots. Those expectations are in line with the goals of robotic research programs initiated by other nations, such as the National Robotics Initiative by the USA, the Horizon 2020 or SPARC Robotics projects by European Union, etc., while the Tri-Co Robot initiative particularly highlights the demand, directions, as well as actions required to realize enhanced interaction capabilities of robots since those are believed to be the major weaknesses to fulfill the functionalities of advanced robotics.

Chinese roboticists have a proven record of successful collaborations with international colleagues, such as the development of DLR-HIT-Hand by joint efforts from the German Aerospace Center and Harbin Institute of Technology [10]. The Tri-Co Robot research initiative also encourages collaborations with the international robotics community and we anticipate more in-depth understanding of China’s dedication and strategies for robotics development from the international community through communication and collaborations.

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