Novel Emerging Sensing, Actuation, and Control Techniques for Haptic Interaction and Teleoperation

HAPTICS is a field of study that deals with perceiving, transmitting, and reproducing human haptic sense. Auditory and visual sensations are unilateral, whereas haptic sensation is bilateral via the principle of action and reaction. Haptic technologies have been applied, with ever increasing potential, in manufacturing, medicine, entertainment, and defense.

With the advent of new functional materials, smart actuators and sensors, embedded computers, and the latest advance in real-time intelligence, machine learning, cognitive science, and augmented reality/virtual reality/mixed reality, a lot of more novel, intelligent, user-friendly haptic devices are emerging. At the core of these devices are essentially the sensor that perceives remote contact with real world in various physical forms, the transmission that transfers remote contact sensation to haptic interface, the actuation that reproduces the haptic sense perceivable by a human operator and the bilateral control that closes the loop of haptic feedback.

Due to the small size requirement for wearable devices, the many degrees of freedom from the use of soft, stretchable sensors and actuators, the embodiment of actuators, sensors and controllers and the level of intelligence, speed, precision or compliance required, unique challenges emerge concerning the design and realization of novel haptic interaction and teleoperation.

IEEE Transactions on Industrial Electronics has published a considerable amount of works on haptics in recent decades, in parallel to the IEEE Transactions on Haptics and other journals with varying scopes. So far, no journal has devoted yet a special issue or special section to novel emerging sensing, actuation, and control techniques for haptic interaction and teleoperation.

Indeed, there have been other journals publishing various special issues on the haptics related themes; however, almost all of them were on the novel applications of haptics rather than the technologies enabling haptics. Those published special issues were intended to promote more applications of haptics.

Novel sensing, actuation, and control methods and technologies that enable haptics are the themes of this special section. The call for papers was well responded. A total of 48 submissions were received and 20 papers were finally accepted after a rigorous peer reviewing process. The special section has a collection of five, seven, and eight papers in sensing, actuation, and control, respectively.

Digital Object Identifier 10.1109/TIE.2019.2927784

The novel emerging sensing techniques shown in the special section include a universal tactile sensing technology for imaging pressure distribution on an object based on electromechanical boundary impedance tomography in [item 1) in the Appendix], a piezoelectric sensing array with pin-type modules for surface topography measurements in [item 2) in the Appendix], multiple soft sensors optimally placed across the back of the hand to recognize hand gestures by estimating skin strain in [item 3) in the Appendix], a soft sensor glove based on novel inertial sensor fusion algorithm for three-dimensional real-time hand gesture measurements in [item 4) in the Appendix], and a novel haptic texture authoring algorithm to synthesize new virtual textures by manipulating the affective properties of already existing real life textures in [item 5) in the Appendix].

The novel emerging actuation techniques shown in the special section include a soft electroactive actuator for vibration generation in haptics in [item 6) in the Appendix], a cable-driven actuation for exoskeleton device to perform passive range of motion exercises and teleoperation rehabilitation in [item 7) in the Appendix], an electrical motor controlled in voltage mode for haptic devices in [item 8) in the Appendix], a novel modular wearable interface for cutaneous and kinesthetic interaction in haptics and teleoperation in [item 9) in the Appendix], a soft and transparent visuo-haptic interface compatible with flexible devices and wearable gadgets, which is composed of a touch-sensitive visual display based on polymer waveguides and a dielectric elastomer microactuators array in [item 10) in the Appendix], a curvature reproduction approach where the finger pad is extruded by a flat plate to generate skin and muscle deformation in [item 11) in the Appendix], and an ultrasound phased array technique for mid-air haptic interface to display vibro-tactile feedback in [item 12) in the Appendix].

The novel emerging control techniques shown in the special section include a globally stable adaptive fuzzy backstepping control in human–machine interaction-based cooperative operation systems in [item 13) in the Appendix], a fine sensorless force control considering static friction in human–robot interaction and teleoperation in [item 14) in the Appendix], a fine load-side acceleration control for remote operations with haptic feedback in [item 15) in the Appendix], an internal force control for bimanual robotic teleoperation with varying time delay in [item 16) in the Appendix], a dynamic interconnection and damping injection control for rendering bilateral teleoperation in [item 17) in the Appendix], a proportional pattern recognition control using myoelectric signal of arm muscle for prosthetic manipulation in [item 18) in the Appendix], a successive force augmentation approach to enhance the rate-hardness of haptic interaction while maintaining stability in [item 19) in the Appendix], and a bilateral control for a stable and transparent haptic rendering for simulations involving interaction between a rigid tool and deformable objects in [item 20) in the Appendix].

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Acknowledgement

The guest editors would like to thank all the authors and the reviewers for their time, efforts, and patience in the review-and-revise process. We would also like to thank Prof. L. G. Franquelo, the past Editor-in-Chief of the IEEE Transactions on Industrial Electronics, and S. Jacobs, the TIE Administrator, who provided professional advices and guidance for which we are sincerely grateful.

Appendix
Related Work

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