Guest Editorial Special Section on Emerging Information Sharing and Design Technologies on Robotics and Mechatronics Systems for Intelligent Manufacturing

ROBOTICS and mechatronics systems have been extensively employed for manufacturing automation for decades. Utilizing the emerging information sharing and design technologies, their performances will be further enhanced and augmented so that they can play a greater role in today's intelligent manufacturing. For a single robotics or mechatronics system, the information sharing technology helps to improve its design, analysis, and control. For multiple robotics and mechatronics systems in a complex manufacturing system, the information sharing technology enhances the system's coordination, working efficiency, and productivity. For the applications that require the robots and mechatronics systems interacting with human and environment, the information sharing technology helps to improve the systems' perception, cognation, and adaptation to human and environment. In general, the introduction of new design concepts in robots and mechatronics systems, with fusion of low-cost sensors, novel ways of information sharing, and intelligent control, will create great potentials for intelligent manufacturing.

This special section aims to gather the latest research and development works on design, sensing, and intelligent control of robotics and mechatronics systems resulting from the emerging information sharing and design technologies. Many papers presenting the state-of-the-art research achievements within the section scope have been received. After a strict evaluation process by peer reviewers, ten papers have been accepted to appear in this special section. These papers can be categorized into three themes, i.e., *information sharing within individual robots or mechatronic systems, information sharing among multiple robots or mechatronic systems*, and finally, *information sharing for robotics and mechatronics systems interacting with human and environment.*

The works on *information sharing within individual robots or mechatronic systems* cover multiobjective smart sensing by an eddy-current sensor, multiaxis coordinated motion control for a flexible robotic arm, a dual-drive gantry stage with flexible joints, and a mobile robot with four independent driving wheels.

The paper by Lee *et al.* presents methods to develop a novel eddy-current sensor for simultaneous measurement of displacement, thickness, and electrical conductivity of a nonferrous electrically conductive workpiece. Unlike traditional eddy-current sensors based on principles of lumped-parameter impedance, the eddy current generated magnetic flux density can lead to a more accurate, analytical impedance model. The design criteria for developing a multiparameter eddy-current sensor are established.

The paper by Liu *et al.* presents methods to improve the contact force estimation in a flexible robot arm by information acquired from joint-torque sensor. By the torque sensor feedback, the dynamics on the link side can be separated from that on the motor side. In this sense, the end-effector force estimation becomes attractive since it only requires computing partial dynamics on the link side during compliant control. To achieve smoother human–robot interaction, the neural network (NN) is used to approximate observed residual value during free motion, which can be considered as the friction dynamics. By analyzing the properties of the friction force in detail to select appropriate excitation trajectory, accurate approximation using global basis function in NN is achieved by using only limited training data.

The paper by Ma *et al.* presents methods to synthesize the decentralized controller for a dual-drive gantry stage with flexible joints. Such a stage is one of the simplest, but typical parallel mechanism, for which the accurate system identification is usually difficult due to strong interaxis coupling. In addition, the decentralized control is desired for implementation of motion control in kinematic level. By transforming such a problem to an H_2 guaranteed controller synthesis problem, a simple cutting plane method is developed to efficiently synthesize the controller parameters using iterative linear programming.

The paper by Liao *et al.* presents methods to design the coordinated control for a mobile robot with four independent driving wheels in the dynamic sense. The conventional control scheme based on its kinematic model is incapable to achieve precise interwheel coordination and vibration suppression of the loading, especially during start and stop phases. By including the inertial information, a model-based coordinated adaptive robust

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controller is developed. In this way, the robustness to model-uncertainty, interwheel coordination, and antislip of wheel are concurrently achieved.

The works on *information sharing among multiple robots or mechatronic systems* include base-frame calibration of the cooperative dual-robot systems, and design and control of a composite-axis acquired pointing and tracking (APT) system for multitarget laser communications.

The paper by Wang *et al.* presents the method to perform the base-frame calibration on the cooperative dual-robot systems. The conventional calibration methods suffer the drawbacks such as insufficient accuracy and low efficiency. Here, by viewing the cooperative dual-robot systems as a closed chain, a projection-based calibration method is proposed, by which only two calibration points are required. The accuracy is improved by 45% as the experimental validation.

The paper by Li *et al.* presents a new design of the composite-axis APT system. It consists of a gimbal mirror and a fast steering mirror (FSM) for information acquisition, so the system is able to achieve high rate and large capacity communication with cluster UAVs. To ensure the robustness to the model uncertainties, the cascade control and H-infinity control schemes are proposed for these two subsystems accordingly. The least squares support vector machines are used to compensate the error due to hysteresis effect of piezoelectric materials used in FSM, and the pruning error minimization method is applied to reduce its computational cost.

The works on *information sharing for robotics and mechatronics systems interacting with human and environment* cover the multiple peg-in-hole assembly process, the multiwire slider, the multichannel robot-assisted single port access surgery (SPAS), and the autonomous operation of car part spray painting.

The paper by Xu *et al.* discusses automatic completion of multiple peg-in-hole assembly tasks by robots. This problem remains a formidable challenge due to unavailability of analysis in a simple contact model. This work formulates this assembly task as a Markov decision process. A model-driven deep deterministic policy gradient algorithm is proposed to accomplish the assembly task through the learned policy without analyzing the contact states. The feedback exploration strategy and a fuzzy reward system are utilized to address the data efficiency and guarantee the stability.

The paper by Fang *et al.* addresses the measurement and control issues on the wire sending process in the multiwire slider system, which are crucial for consistent wire tension and the quality of the silicon wafer. The measurement strategy for wire sending state is proposed based on two tensometers readings near the wire sending point and the tension adjusting unit, respectively. The smooth wire sending control is realized through a position adjusting unit and a novel feedforward multiconditioned P controller. A self-tuning fuzzy controller is proposed to further suppress the wire tension vibration.

The paper by Li *et al.* discusses on robot-assisted SPAS, which remains a challenge task due to the limited incision size and requirements in precision, load capacity, and dexterity. The multichannel SPAS robotic system consists of two channels of 5-degree-of-freedom (DOF) flexible manipulators and an endoscope channel. The design of flexible manipulator by integrating a 3-DOF parallel mechanism and a universal joint, take care of both flexibility and safety considerations with a simplified structure. Flexible shafts are used to achieve the remote operation, which is essential for patients' safety. The tests of the manipulator's stiffness, accuracy, and peg-transfer capability validate the effectiveness of this design.

The paper by Lin *et al.* addresses the issues on autonomous operation of car-part spray painting robot. To achieve minimum human supervision through this process, a set of novel object detection and pose estimation algorithms is developed. The principal component analysis is applied to compress three-dimensional (3-D) point cloud to 2-D binary image during object detection for real-time cognition. Subsequently, the iterative closest point algorithm is used together with the genetic algorithm, to estimate the pose difference of the auto part with respect to the camera reference frame, while preventing local minimum entrapment.

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