Guest Editorial
Automation in Automotive Manufacturing

AUTOMOTIVE manufacturing is at a critical point. Not only does it have to fight against the impact of global recession, but also it needs to face the difficulty of adapting to dramatic change in the manufacturing sector, as well as emerging issues in product safety and quality. This provides both challenges and opportunities. Improving productivity, quality, and flexibility and reducing cost are the necessary steps in responding to these challenges and seizing these opportunities. Therefore, automation—a primary tool for making these improvements—is more relevant than ever in achieving these goals in all aspects of automotive manufacturing, from process and equipment control that reduces variations, ensures safety and increases productivity, to system and operation management that improves efficiency and quality, and application of new technologies, such as RFID.

Automation research in automotive manufacturing has attracted substantial effort from researchers in both academic and industrial communities for decades. Their goal has been to provide efficient scientific and engineering solutions for process and quality control, production planning and operation, and supply chain management. In recent years, significant advances in technology, the fast growing economy and rapidly changing markets have generated numerous opportunities for innovation in automation. At the same time, many new challenges have emerged in applying and implementing these innovations. Such advances have significantly expanded the scope of traditional automation research for automotive manufacturing.

The central theme of this Special Issue is *advances in automation science and engineering for automotive manufacturing*, with modeling, analysis, control and optimization as the focus areas. The purpose is to show the state-of-the-art research and applications in the general area of automation in automotive manufacturing, by bringing together researchers and practitioners from both academia and industry, to expose the significant advances, uncover and address the unsolved challenging problems, present the needs for integration of existing practice with new technologies, and provide visions for future research and development. We intend to provide original, significant and visionary automation research results describing scientific methods and technologies that improve efficiency, productivity, quality and flexibility in automotive manufacturing, with both solid theoretical development and practical importance.

The contributions in this Special Issue can be divided into four categories in automotive manufacturing: variation reduction on the process level; productivity or quality analysis and improvement on the system level; information and control problems in manufacturing environment, such as in painting, assembly and welding processes; and finally, RFID applications.

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The first part of this Special Issue focuses on variation reduction in automotive manufacturing processes. Zhong *et al.* propose a feed-forward control strategy for a multistage assembly process to reduce dimensional variation by taking into account the uncertainties of the model coefficients explicitly. Such a system-level control strategy is able to minimize the end-of-line product variance, which is propagated from upstream manufacturing stages, even when significant changes of process parameters occur from their nominal values such that the designated model will be different from that of the actual process.

Huang and Kong carry out yield based sensitivity analysis for design evaluation of a multistage assembly process and present three analysis algorithms. The yield, i.e., conformity to product specifications, formulated as a high dimension probability integral over a specification region, is a transparent index for process capability evaluation. The sensitivity of such an index can provide valuable information on conformity to product specifications in the design stage.

Chase *et al.* analyze the variation of tooth engagement and loads in involute splines used in transmissions. A simple closed-form solution has been developed to allow designers to predict the load in spline teeth based upon the characteristics of the spline.

The second part of the Special Issue is devoted to analysis and improvement of manufacturing systems. Arinez *et al.* describe the design and implementation of a continuous improvement project at an automotive paint shop, where quality/quantity coupled operations exist in production systems. An integrated approach addressing such coupling is developed to evaluate system performance and identify both throughput and quality bottlenecks. Implementation of this project has resulted in substantial improvement on the factory floor.

Zhao *et al.* introduce an efficient simulation method for general assembly lines with material handling systems. Such a method is based on aggregated event-scheduling approach with a two-level framework, where the global event list is divided into small sizes in top-level simulation, and max-plus algebra is applied in bottom-level local simulation to further reduce local event lists. Such a method can mimic real production lines quickly and accurately within a reasonable computation effort.

Wang *et al.* study the impact of product sequencing on quality in flexible manufacturing systems with batch operations, such as vehicle sequencing in automotive paint shops where vehicles with same colors are grouped into batches to improve quality and reduce cost. A Makov chain model is presented to evaluate quality in such systems, and an analytical method is introduced to determine the appropriate sequencing and batch policies, and select the optimal sequence that leads to the highest quality.

Lennartson *et al.* introduce an integrated framework for product, process and automation design to obtain a unified information flow from early product design to final production.

The framework is based on the sequences of operations and includes a formal relation between product properties and process operations. A set of sequences of operations (SOP) is generated from this information and a formal graphical language for hierarchical operations and SOPs is then introduced and defined based on automata extended with variables. In this way, the inter-operability between different engineering disciplines is improved.

Control problems are addressed in the third part of this special issue. From and Gravdahl present a real-time algorithm to determine the optimal paint gun orientation in spray paint applications. Such a method can increase the speed at which a standard industrial manipulator can paint the surface so that a higher constant velocity throughout the trajectory can be maintained and uniform paint coating can be guaranteed.

Lee *et al.* develop a safety measurement to help ensure smooth control mode switching of an intelligent assist device (IAD), that is, Skill-Assist, a force-control-based robotic device that enables a human operator to handle heavy modules. Applying the proposed safety measurement enables the Skill-Assist to recognize the reaching gesture of an operator when the control mode is switched, so that control mode switching without abrupt deceleration can be achieved, and collision and serious injuries to a human operator can be avoided.

Li and Zhang introduce the interval model control of a new welding process, the Consumable Double-Electrode Gas Metal Arc Welding, which can double the travel speed for automobile welding. Interval models are developed and a prediction-based interval model control algorithm is implemented to control the resultant models.

The last section of this Special Issue addresses the application of RFID in manufacturing. Lin and Lin propose an efficient estimation and collision-group based anticollision algorithms for dynamic frame-slotted ALOHA in RFID networks. Such an anticollision algorithm can identify all tags within a small number of time slots to improve efficiency.

The Guest Editors would like to thank all the authors and the anonymous reviewers for their outstanding work. We would also like to thank Editor-in-Chief Emeritus Peter Luh, Editor-in-Chief N. Viswanadham, Editor Mengchu Zhou, Editor Y. Narahari, Editorial Assistant Amit Chakravarty, and many others for their efforts devoted to this Special Issue.

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