Guest Editorial

VARIABLE-STRUCTURE systems with sliding modes are currently among the most important research topics within the control engineering domain. Therefore, several special issues of the leading control journals on the recent advances in the theory of variable-structure systems have been published within the last decade. On the other hand, recently, a number of important applications of the systems in the fields of power electronics, motion control, automotive engine regulation, and robotics have also been reported. Therefore, this Special Section of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS is dedicated to the significant latest developments in engineering applications of sliding-mode control (SMC), and its objective is to stimulate further research in this field.

This Special Section consists of 29 papers. It begins with four contributions devoted to various issues in control of induction motors. In the first paper, Veselic *et al.* apply discrete-time sliding-mode methodology in order to develop induction motor position controller for high-performance applications. In addition to the main discrete-time position controller, they also introduce a control structure including an active disturbance estimator which helps improve system robustness and accuracy. In the second paper, Plestan *et al.* combine an adaptive observer and a higher order sliding-mode framework to control induction motors without mechanical sensors. Then, Ryvkin *et al.* develop the sliding-mode approach to control an induction motor fed by a three-level voltage source inverter. In the next paper, Comanescu *et al.* discuss current decoupling and controller design for sensorless vector-controlled induction motor drives. They present a new method, which does not require speed estimation, for decoupled current control based on integral sliding mode.

Another contribution concerned with electric drive control is the paper by Pisano *et al.*, which presents a novel cascade control scheme, based on multiple instances of a second-order SMC algorithm for the speed/position control of permanent-magnet motors. Even though electric drives are of primary interest to the readers of this Special Section, a remarkable alternative solution is also studied in the next paper by Aschemann and Schindele. They give results of the application of nonlinear cascaded trajectory control for a new linear axis driven by pneumatic muscles. That solution may be considered as a viable alternative to electric direct linear drives.

Sliding-mode systems are a feasible option not only for electric drive regulation but also for power converter control. This issue, i.e., control of electronic power converters, is addressed in papers by Ramos *et al.* and Shtessel *et al.* Ramos *et al.* introduce a quasi-SMC algorithm for the control of a modular dc–ac power conversion system comprising multiple single-phase parallel-connected inverter modules. On the other hand, Shtessel *et al.* develop an SMC algorithm for the three-phase ac/dc boost power converter with full-bridge hardware configuration. The developed control strategy helps achieve a power factor close to unity and ensure efficient load voltage regulation in the presence of disturbance and parameter uncertainty. Furthermore, sliding-mode observers are applied to estimate variations of load and phase resistances.

The next four papers cover a broad range of SMC topics in automotive applications. Yagiz *et al.* propose a robust fuzzy sliding-mode controller for active suspension of a nonlinear half car model. Then, Butt and Bhatti address the development of second-order sliding-mode method using real twisting algorithm for parameter estimation of the naturally breathing gasoline engine model. In the next paper, Pan *et al.* discuss the issue of the electronic throttle valve position control and design for that purpose a variable structure controller using the backstepping approach and a sliding-mode observer. In another contribution directly related to automotive applications, Vecchio *et al.* consider the vehicle yaw control using yaw rate feedback and a rear active differential. The proposed control structure consists of a reference generator, designed to improve vehicle handling, a feedforward compensator, which enhances the transient system response, and a second-order sliding-mode controller, designed to ensure robust stability in the presence of disturbances and model uncertainties inevitable in automotive applications.

The next two contributions present some interesting issues related to the challenging task of SMC of piezoactuators. In the first of these papers, Xu and Abidi develop a discrete-time output integral sliding-mode controller for high-precision tracking control of a piezomotor-driven linear motion stage. Then, in the second paper, a similar problem is considered by Chen and Hisayama. They discuss the fusion of the Prandtl–Ishlinskii hysteresis model with adaptive control methods, which do not require the parameters of the stage to be either measured or identified. In another contribution referring to ultrahigh-precision positioning and force measurement, Jalili and Saeidpourazar present the development and real-time implementation of a robust nonlinear control strategy for piezoresistive nanomechanical-cantilever-based force tracking. The results of this paper may be applied to high-resolution imaging and also to very precise manipulation tasks.

The papers by Floquet *et al.*, Pisu *et al.*, Liang *et al.*, and Chwa *et al.* are also concerned with the problem of motion

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steering, but they focus on the control of larger mechanical devices. Floquet *et al.* consider the control of a group of autonomous wheeled mobile robots. They develop a coordinated control scheme based on a leader–follower approach to achieve formation maneuvers. For that purpose, they design a second-order sliding-mode controller using only the measurement of relative configurations between the controlled robots. In the next paper, Pisu *et al.* present and experimentally verify a new model-based fault detection and isolation scheme for rigid robot manipulators. The scheme—based on the concept of second-order sliding modes, inverse dynamics approach, and generalized observer scheme—can detect a single sensor fault or multiple actuator faults at a time. In another contribution concerned with rigid manipulator steering, Liang *et al.* combine Takagi–Sugeno fuzzy system modeling with SMC technique in order to design computationally efficient, yet fast and robust, controller for a class of n, possibly coupled, second-order systems. Furthermore, they demonstrate that their result may be successfully applied to the classical problem of robot manipulator control. Then, Chwa *et al.* introduce an adaptive fuzzy sliding-mode controller for the robust antisway trajectory tracking of 2-D overhead cranes, with actuator deadzone nonlinearity. It is demonstrated that the considered cranes can be effectively controlled, even though they are subject to parameter variations and external disturbance.

In another contribution presented in this Special Section, Chen and Saif study the output-feedback control design problem for a class of multi-input–multi-output nonlinear systems with smaller number of inputs than the outputs. The proposed output-feedback controller uses high-order sliding-mode differentiators to estimate the derivatives of the outputs required in the control law design. Similarly to Chwa *et al.*, Chen and Saif also successfully apply the proposed controller to the problem of crane control. In particular, they test their controller on a commercially available 3-D laboratory-scale crane system. Next, Orlov *et al.* propose a second-order sliding-mode controller for a class of two-degree-of-freedom underactuated mechanical systems with dry friction. They impose stronger friction on the unactuated joint than on the actuated one, which allows simple decoupling of the hybrid synthesis procedure. The proposed approach is experimentally verified on a planar horizontal two-degree-of-freedom pendulum. Then, Ashrafiuon *et al.* consider another underactuated system—a surface vessel with two actuators and three degrees of freedom. They introduce, implement, and experimentally verify a visual-feedback-based SMC strategy which ensures good quality of the straight line and circular system demand trajectory tracking.

In the next contribution, Ignaciuk and Bartoszewicz address the issue of congestion control in connection-oriented communication networks. They propose a discrete-time sliding-mode controller which eliminates data loss in the network and simultaneously ensures full bottleneck link bandwidth utilization.

Then, Yu and Tseng analyze the problem of sliding-mode modulation in switch-mode power amplification. They introduce a feedback modulation scheme which, at the same time, minimizes the accumulated quantization error and in-band modulation error while converting a continuous input signal into a coarsely quantized signal. The scheme is applied to build a class-D audio power amplifier.

The last five papers present results which may be applied in various practical control problems related to industrial applications. Edwards and Yan develop an online fault reconstruction scheme for a class of nonlinear multi-output systems with uncertain parameters. They illustrate the proposed scheme with an example of magnetic levitation system. Then, Cunha *et al.* focus on the synthesis of first-order filters which generate approximations for upper bounds of some signals often needed in SMC laws and demonstrate that the filters are a feasible option for the velocity control of a dc motor connected to a large inertia through reduction gears and a flexible link. Next, Choi analyzes the nontrivial issue of output-feedback sliding-mode controller design for a class of multivariable uncertain systems. He proposes linear-matrix-inequality-based design methods applicable to systems with both matched and mismatched uncertainty. In the penultimate paper, Wang *et al.* analyze the effect of zero-order-hold discretization on high-order SMC systems. They verify the presented theoretical results with a simulation study of a vehicle suspension system. Finally, Chang proposes a new algorithm for linear discrete-time multi-input–multi-output system state and disturbance estimation and applies the estimates given by the algorithm in the feedback control process.

In conclusion, the main objective of this Special Section is to present a broad range of well-worked-out recent application studies in the field of SMC. We believe that, thanks to the authors, reviewers, and the editorial staff of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, this ambitious objective has been successfully accomplished. The editors and authors would like to thank Prof. Marian P. Kaźmierkowski, the past Editor-in-Chief, and Prof. Bogdan M. Wilamowski, the current Editor-in-Chief, of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS for allowing the preparation of this Special Section to proceed. It is hoped that the result of this joint effort will be of true interest to the control community working on various aspects of nonlinear control systems and, in particular, to those working in the variable structure systems community.

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