Guest Editorial
Special Section on Computationally Intelligent Methodologies and Sliding-Mode Control

VARIABLE-STRUCTURE systems (VSSs) with a sliding mode were first proposed in the early 1950s. However, due to implementation difficulties of high-speed switching, it was not until the 1970s that the approach received the attention it deserved. Sliding-mode controllers (SMCs) nowadays enjoy a wide variety of application areas, such as in general motion control applications and robotics, in process control, in aerospace applications, and in power converters. The main reason for this popularity is the attractive properties that SMCs have, such as good control performance for nonlinear systems, applicability to multi-input multi-output systems, and well-established design criteria for discrete-time systems. The most significant property of an SMC is its robustness.

In practical applications, a pure SMC suffers from the following disadvantages. Firstly, there is the problem of chattering, which is the high-frequency oscillations of the controller output, brought about by the high-speed (ideally, at infinite frequency) switching necessary for the establishment of a sliding mode. In practical implementations, chattering is highly undesirable because it may excite unmodeled high-frequency plant dynamics, and this can result in unforeseen instabilities. Secondly, an SMC is extremely vulnerable to measurement noise since the input depends on the sign of a measured variable that is very close to zero. Thirdly, the SMC may employ unnecessarily large control signals to overcome the parametric uncertainties. Last, but not least, there exists appreciable difficulty in the calculation of what is known as the equivalent control. A complete knowledge of the plant dynamics is required for this purpose.

The technological developments of the recent decade have increased the use of high-speed computers in control applications. It is now possible and economically feasible to use complex model-based control paradigms in practical applications, using advanced control strategies derived from adaptive, nonlinear, and robust control theories. This has resulted in the development of the "intelligent control" field and a host of new control approaches based on fuzzy logic, neural networks, evolutionary computing, and other techniques adapted from artificial intelligence have come into common use. These methodologies provide an extensive freedom for control engineers to exploit their understanding of the problem, to deal with problems of vagueness, uncertainty, or imprecision, and to learn by experience and, therefore, they are good candidates for alleviating the problems associated with SMCs discussed above.

In recent years, there has been a growing interest in theory and applications of the fusion of computationally intelligent methodologies with sliding-mode control systems. Neural networks, fuzzy logic systems, and evolutionary computing strategies are synergetically combined with SMCs in numerous studies reported in the control systems literature. Some studies focus on combination schemes that serve to alleviate implementation problems inherent in sliding-mode control systems via the use of computational intelligence. Others address problems in the design and stability analysis of computational intelligence methods and employ the well-defined stability design tools of sliding-mode control systems for the formulation of stable architectures for intelligent controllers.

The first paper in this "Special Section on Computationally Intelligent Methodologies and Sliding-Mode Control" of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, by Kaynak, Erbatur, and Ertugrul, presents a literature survey on the fusion of computationally intelligent methodologies in sliding-mode control. Guidelines in sliding-mode control and computational intelligence in control systems are briefly reviewed and fusion methodologies are classified. Selective examples from the literature and many references are cited.

The second paper, by Berstecher, Palm, and Unbehauen, discusses a new adaptive fuzzy SMC. A linguistic adaptation algorithm is proposed and detailed analysis of that scheme is presented. The performance of the adaptive control method is demonstrated by experiments on a two-link robotic arm.

Wong, Leung, and Tam discuss a fuzzy SMC for nonlinear systems in the third paper. In this method, a fuzzy logic controller combines an SMC with a proportional plus integral control system. The advantages of the two control methodologies are kept, whereas the disadvantages are removed. A proof of the system stability is provided and the controller is tested via simulations on an inverted pendulum system.

Design of robust control systems using sliding-mode control with a fuzzy tuning technique is presented in the fourth paper, by Ha, Nguyen, Rye, and Durrant-Whyte. The control law is a superposition of the equivalent control, switching control, and fuzzy control. Simulation and experimental results with a hydraulically actuated mini-excavator are used to demonstrate merits of the proposed control scheme.

In the fifth paper, Hwang, Jan, and Chen propose an intelligent variable-structure control to cope with implementation difficulties in the control of piezomechanic systems. Firstly, a neural network learns the dynamics of the piezomechanic system. Together with a forward control based on this learned model, a discrete-time variable-structure control is applied for performance improvement. Lyapunov analysis indicates the stability of the overall system. The effectiveness of the algorithm is confirmed by experimental investigations.

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In the sixth and final paper, by Lin and Wai, the dynamic response of a sliding-mode-controlled slider–crank mechanism driven by a permanent-magnet synchronous motor is studied. A sliding-mode controller is designed and a fuzzy neural network (FNN) is employed to adjust the control gain in the switching control law. To guarantee the convergence of the tracking error, a Lyapunov approach is followed in determining the varied learning rates of the FNN. Numerical and experimental results indicate robustness of the developed system in the face of parameter variations and disturbances.

I would like to thank all of the authors of these papers for their valuable contributions to this Special Section, and the reviewers for their comments, time, and effort. Thanks are also due to Prof. J. Holtz, the Past Editor-in-Chief of this TRANSACTIONS, for the opportunity to present this Special Section.

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Okyay Kaynak (M’80–SM’90) received the B.Sc. (first class honors) and Ph.D. degrees in electronic and electrical engineering from the University of Birmingham, Birmingham, U.K., in 1969 and 1972, respectively.

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