Guest Editorial
Focused Section on Hysteresis in Smart Mechatronic Systems: Modeling, Identification, and Control

I. Introduction

HYSTERESIS nonlinearity invariably appears in various smart mechatronic systems, such as smart material-based actuators, smart material-based sensors, mechatronic systems with friction, and electromagnetic systems [1]–[5]. This nonlinearity yields undesirable responses, which limit the tracking performance or introduce oscillations that may compromise the stability of the closed-loop systems [6], [7]. For example, the presence of hysteresis in smart material-based actuators, which are used widely in micro/nanopositioning applications, results in a considerable tracking error and compromises the positioning precision [8], [9]. Significant continuing efforts are thus being made to seek effective compensation of hysteresis nonlinearity in different smart mechatronic systems [10]–[12]. Recently, advances have been made in various aspects of mechatronic systems with hysteresis: modeling, inverse compensation or feedforward control, feedback control, and stability and performance analysis. In the meantime, this subject continues to pose research challenges that invite innovative solutions in modeling, control, and analysis.

The primary objective of this Focused Section on Hysteresis in Smart Mechatronic Systems: Modeling, Identification, and Control is to highlight some recent accomplishments in the modeling and control of smart mechatronic systems with pronounced hysteresis, and to motivate new ideas from the community to address outstanding challenges. There were a total of 24 papers submitted to this Focused Section. After a rigorous peer-review process, six papers were accepted. The contributions of these accepted papers are highlighted below.

II. Contributions of The Focused Section

The six papers included in this Focused Section comprise both theoretical and experimental contributions detailing new advances in modeling, identification, and control of hysteresis in mechatronics. The variety of mechatronic systems addressed spans piezoactuated systems, magnetorheological dampers, and electromagnetic actuators. These papers can be roughly classified into two groups. The first group focuses on the modeling and model identification for systems with hysteresis, while the second group deals with hardware and algorithmic solutions to the control of hysteretic mechatronic systems.

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A. Modeling and Identification

In this Focused Section, three papers deal with the hysteresis modeling and identification. These approaches include an observer for ferromagnetic hysteresis modeling, describing function-based investigation of hysteresis in magnetorheological dampers, and a modified Maxwell-slip model for characterizing asymmetric hysteresis loops in piezoceramic actuators.

MacKenzie and Trumper present a method for real-time estimation of the hysteresis in an electromagnetic actuator in the presence of a changing air gap. The actuator is modeled with a lumped parameter model. This enables to model the ferromagnetic hysteresis with the Preisach model separately from the air gap reluctance. Experiments performed to illustrate the proposed approach in a real-time system.

Ha *et al.* consider modeling of the hysteresis of nonlinearities in the magnetorheological (MR) dampers using describing functions. Such nonlinearities limit the performance of the MR dampers when used in smart structures. In this study, describing functions obtained from the experimental measurements of an MR damper were identified to model the hysteresis nonlinearities. Experiments were conducted to illustrate the proposed approach.

Liu *et al.* propose a modified Maxwell-slip model to characterize the asymmetric hysteresis loops in piezoceramic actuators. A generalized elastoslide operator (ESO) is constructed to replace Maxwell-slip elements. Each ESO is characterized with the spring extension stiffness constant, maximum extension, compression stiffness constant, and maximum compression. Simulation and experimental results show that the proposed model is capable of reproducing convex and/or concave asymmetric hysteresis loops.

B. Control of Systems With Hysteresis

The next three papers contribute to the control of systems with hysteresis. These studies range from the design of new charge drives for hysteresis mitigation to the development of an efficient inverse scheme for hysteresis compensation in piezoactuated mirrors, to nonsmooth model predictive control of Wiener systems with backlash-like hysteresis.

Rios and Fleming present the design of a charge drive for reducing the hysteresis exhibited by a piezoelectric bimorph bender. A new charge drive circuit is implemented to linearize the input–output relationship of the bender. This circuit consists of four major components, including a high-voltage amplifier, a differential amplifier, a piezoelectric load, and a proportional integral feedback controller. An isolation amplifier is used to achieve differential amplification with a high common-mode rejection ratio. The effectiveness of the proposed charge drive in hysteresis mitigation is demonstrated experimentally.

Mynderse and Chiu report the development of an efficient hysteresis control scheme for a piezo-based dynamic mirror system. The proposed two-degree-of-freedom control strategy consists of a low-computation inverse model for hysteresis compensation and an LQR feedback controller for mitigating the impact of the inversion error. Experimental results are presented to support the proposed control approach.

Dong *et al.* propose a nonsmooth predictive control method for Wiener systems with backlash-like hysteresis, where the hysteresis is connected in series with a preceding linear system. The proposed control scheme incorporates a nonsmooth receding horizon strategy that addresses the challenge of gradient evaluation at nonsmooth points of the objective function. A simulation study on a mechanical transmission system characterized with a nonsmooth Wiener system is presented to validate the proposed control approach.

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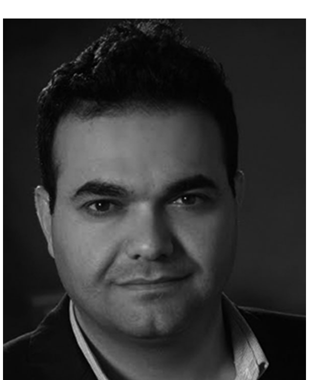

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