Hindawi
Mathematical Problems in Engineering
Volume 2018, Article ID 5078027, 4 pages
https://doi.org/10.1155/2018/5078027

Editorial

Advances in Modelling, Analysis, and Design of Delayed Systems

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Received 29 April 2018; Accepted 29 April 2018; Published 29 May 2018

In feedback control systems, delay as a generic part of many processes, including industrial [1], communication [2], economical [3], traffic [4], automotive technology [5], and biological [6] ones, is a phenomenon which unambiguously deteriorates the quality of a control performance. Delay has inter alia a decisive impact on control system stability, and the studying of this influence is not usually mathematically simple. Modern control theory has been dealing with this problem since its nascence; the well-known Smith predictor [7] has celebrated six decades of being known and applied a year ago.

Modern and advanced control theory is confronted with higher and higher requirements on quality and performance of control systems in industry as well as in everyday reality [8]. It is well known that control of such processes often represents a very complex problem and they are hardly controllable by conventional control methods. Many related problems are unsolved and many questions remain unanswered. The aim of this special issue has been to highlight the most significant recent developments on the topics of Time Delay Systems (TDSs), their modelling and identification, stability analysis, various control strategies, and interesting academic and real-life applications.

The attractiveness of the special issue has been proved by the number of 58 submitted manuscripts collected by the editors from the authors from Argentina, Chile, China, Czech Republic, Iran, Malaysia, Mexico, Pakistan, Republic of Korea, Saudi Arabia, Sweden, Taiwan, Tunisia, Vietnam, United Kingdom, and USA (i.e., 16 countries in total). The acceptance rate has been only of 29%; that is, 17 papers have been eventually published, which indicates a high level of the review process concerning the technical quality and originality of the works.

Regarding the content and subject manner of the special issue, the broad scope of topics has been covered. Namely, in five papers, spectral and stability analysis is made, or stability conditions and criteria are developed. Asymptotic or H_2 stabilization, observer or filter design, and adaptive or robust control of TDSs using linear matrix inequalities (LMIs) tools and Lyapunov theory are addressed in four papers. Two papers are devoted to automotive technology problems; namely, optimal control of a car suspension system and improved car-following model that include the influence of strong wind are investigated. A single paper deals with associative memories for memristive neural networks with deviating argument; it is worth noting here that five papers use or incorporate neural networks. The following delay-related tasks are also represented by a single paper in the special issue: PID control design, digital predictive control design, feedback carbon emission reduction, the stationary probability density functions of an oscillator, and the passivity of delayed neural networks. A concise characterization of all papers included in the special issue follows.

In the paper titled "Delay-Dependent Stability Analysis of TS Fuzzy Switched Time-delay Systems" by N. Aoun et al., a new approach to deal with the problem of stability under arbitrary switching of continuous-time switched TDSs represented by Takagi-Sugeno (TS) fuzzy models [9] is proposed. A specific state space representation, called arrow form matrix, is used first. Then, sufficient asymptotic stability conditions are obtained through the application of Borne and Gentina practical stability criterion [10] and by constructing a pseudo-overvaluing system. The eventual stability criteria are algebraic and easy to use and permit avoiding the problem of existence of a common Lyapunov-Krasovskii functional.

Stability characteristics of Delay-Differential Equations (DDEs) with multiple time-periodic delays are proposed by G. Jin et al. in the paper titled "A Method for Stability Analysis of Periodic Delay-Differential Equations with Multiple Time-Periodic Delays". Stability charts are produced here for two typical examples of time-periodic DDEs about milling chatter, including the variable-spindle speed milling system with one time-periodic delay [11] and variable-pitch cutter milling system with multiple delays [12]. The proposed method further provides a generalized algorithm, which possesses a good capability to predict the stability lobes for milling operations with variable-pitch cutter or variable-spindle speed.

F.-D. Li et al. deal with the stability analysis of genetic regulatory networks with interval time-varying delays in the paper titled "Stability Analysis of Delayed Genetic Regulatory Networks via a Relaxed Double Integral Inequality". Firstly, the Wiringter-type double integral inequality (WTDII) [13] is established to estimate the double integral term appearing in the derivative of Lyapunov-Krasovskii functional with a triple integral term. Then, by applying the WTDII to the stability analysis of a delayed genetic regulatory network, together with the usage of the information of regulatory functions, several delay-range- and delay-rate-dependent (or delay-rate-independent) criteria are derived in terms of linear matrix inequalities.

In the paper titled "New Stability Criterion for Takagi-Sugeno Fuzzy Cohen-Grossberg Neural Networks with Probabilistic Time-Varying Delays" by X. Wang et al., a new global asymptotic stability criterion is derived, in which the diffusion item can play its role. Owing to deleting the boundedness conditions on amplification functions, the main result is novelty to some extent. The positive definite form of p powers for Lyapunov-Krasovskii functional, which is different from those of existing literature [14], is another novel contribution of this method.

The existence of stability switches and Hopf bifurcations for the scalar DDE of the form $\ddot{x}(t) + a\dot{x}(t - \tau) + bx(t) = 0$ with complex (not real in general) coefficients is studied in the paper titled "Stability Switches and Hopf Bifurcations in a Second-Order Complex Delay Equation" by M. Roales and F. Rodríguez, by means of results published in [15].

In the paper titled "Observer Design for Delayed Markovian Jump Systems with Output State Saturation" by G. Wang and B. Feng, the observer design problem of continuous-time delayed Markovian jump systems with output state saturation [16] is considered. The probability distributions of two states are described in the observer design by exploiting the Bernoulli variable. Sufficient conditions for the designed observe with three kinds of output saturations are provided with LMI forms.

In the paper titled "Delayed Trilateral Teleoperation of a Mobile Robot" by D. Santiago et al., the stability of nonlinear, varying-time, and delayed system represented by a trilateral teleoperation system of a mobile robot is analyzed. The stability analysis is based on Lyapunov-Krasovskii theory where a functional is proposed and analyzed to get conditions for the control parameters (for three PD controllers under a position master/slave velocity strategy [17]) that assure a stable behavior, keeping the synchronism errors bounded. In the paper, a practical verification of the theoretical result is given to the reader as well.

The neural network and disturbance observer are designed to tackle the uncertainties and external disturbance for a class of nonlinear TDSs with output prescribed performance constraint in the work "Adaptive Constrained Control for Uncertain Nonlinear Time-delay System with Application to Unmanned Helicopter" by R. Li et al. In addition, prescribed performance function is constructed for the output prescribed performance constrained problem. Then the robust controller is designed via the adaptive backstepping method, and the stability analysis is considered by using Lyapunov-Krasovskii functionals [18]. The proposed method is eventually employed into the unmanned helicopter system with time delay aerodynamic uncertainty [19].

H.-J. Yu et al. focus on the generalized H_2 filtering of static neural networks with a time-varying delay in their paper "Improved Generalized H_2 Filtering for Static Neural Networks with Time-Varying Delay via Free-Matrix-Based Integral Inequality". A full-order filter such that the filtering error system is globally asymptotically stable with guaranteed H_2 performance index is designed. An improved delay-dependent condition for the generalized H_2 filtering problem is established in terms of LMIs, by constructing an augmented Lyapunov-Krasovskii functional and applying the free-matrix-based integral inequality [20] to estimate its derivative.

In the paper titled "An Improved Car-following Model Accounting for Impact of Strong Wind" by D. Liu et al., an enhanced car-following model based on the full velocity difference model is developed in order to investigate the effect of strong wind on dynamics of traffic flow. Wind force, lift force, and side force are considered in the model. Stability condition of the improved model is derived, and numerical analysis is made to explore the effect of strong wind on spatial-time evolution of a small perturbation. Moreover, the effect of strong wind to the stability of traffic flow and car driving safety in strong wind by comparing the lateral force under different wind speeds are studied. The fuel consumption of a vehicle in strong wind condition is explored as well.

The determination of coordinate values of articulated geometry for a double-wishbone independent suspension with two unequal length arms based on structural limitations and constraint equations of alignment parameters is presented in the paper titled "An Improved Genetic Algorithm to Optimize Spatial Locations for Double-Wishbone Type Suspension System with Time Delay" by Q. Li et al. The sensitivities of front wheel alignment parameters are analyzed using the space analytic geometry method with insight module in ADAMS software [21]. The multiobjective optimization functions are designed to calculate the coordinate values of hardpoints with front suspension since the effect of time delay because wheelbase can be easily obtained by vehicle speed. The kinematic and compliance characteristics are investigated using genetic algorithm solutions [22] in the simulation environment. Experimental results are also provided to the reader.

J.-E. Zhang in his paper "Analysis and Design of Associative Memories for Memristive Neural Networks with Deviating Argument" investigates associative memories for memristive neural networks with deviating argument [23]. Firstly, the existence and uniqueness of solution for memristive neural networks with deviating argument are discussed. A derivation of sufficient conditions for this class of neural networks to possess invariant manifolds follows, and a global exponential stability criterion is presented. Next, analysis and design of autoassociative memories and heteroassociative memories for memristive neural networks with deviating argument are formulated, respectively.

In the paper titled "Proportional Retarded Controller to Stabilize Underactuated Systems with Measurement Delays: Furuta Pendulum Case Study" by T. Ortega-Montiel et al., the design and tuning of a simple feedback strategy with delay to stabilize a class of underactuated mechanical systems with dead-time are presented. A linear time-invariant model with time delay of fourth order represented by the Furuta pendulum [24] (that is a standard two-degree-of-freedom benchmark example from the class of underactuated mechanical systems) and a proportional retarded controller are considered. A step forward to obtain a better understanding of the effect of output delays and related phenomena in mechatronic systems is presented in the paper, making possible designing resilient control laws under the presence of uncertain time delays in measurements. The configuration under study includes an inherent output delay due to wireless communication used to transmit measurements of the pendulum angular position. The approach offers a constructive design and a procedure based on a combination of root-loci and Mikhailov methods [25] for the analysis of stability. An experimental comparison with a standard linear state feedback control law is also presented.

A combination of identification and discrete-time control procedures aimed at precise control of systems with any time-delay value is presented by S. Talaš and V. Bobál in the paper titled "Predictive Control Adapting to Fractional Values of Time Delay". Suggested strategy allows the predictive controller to adapt its parameters to a value of the time delay identified during the control process. The system flexibility resides in the ability to work precisely even with time-delay values that are not integer multiples of the sampling period. The authors prove by example that the designed approach represents a very precise method to control systems with both static and variable cases of time delay.

A nice study from the field of environmental engineering is presented in the paper titled "The Feedback Mechanism of Carbon Emission Reduction in Power Industry of Delayed Systems" by X. Yu et al. The paper proposes a carbon market feedback mechanism to power market, comprehensively considering the influence of generation structure, carbon intension, and technological progress on carbon emission reduction in power industry, and builds a potential model based on dynamic system. It is shown by operation system results that the increasing trend of carbon emission can be controlled effectively; however, it is always with a lag. Moreover, sensitivity analysis results show that carbon emission reduction of at most 32% and 60% can be realized by adjusting power structure and improving technological level, respectively.

In the paper titled "Response of Duffing Oscillator with Time Delay Subjected To Combined Harmonic And Random Excitations" by D. N. Hao and N. D. Anh, the stationary probability density functions of the Duffing oscillator with time delay [26] subjected to combined harmonic and white noise excitation are investigated by the method of stochastic averaging and equivalent linearization. The paper shows that the displacement and the velocity with time delay in the Duffing oscillator can be computed approximately in non-time delay terms. The transformation based on the fundamental matrix of the degenerate Duffing system is used here. Then, the stochastic system with time delay is transformed into the corresponding stochastic non-time delay equation in Ito sense. The approximate stationary probability density function of the original system can be found by combining the stochastic averaging method, the equivalent linearization method, and the technique of auxiliary function [27]. The response of Duffing oscillator is also investigated in the paper.

Several conditions for passive performance, based on appropriate Lyapunov-Krasovskii functionals and some inequalities, are established via LMIs in the paper titled "Passivity of Memristive BAM Neural Networks with Probabilistic and Mixed Time-varying Delays" by W. Wang et al. More precisely, the passivity problem of memristive bidirectional associate memory neural networks with probabilistic and mixed time-varying delays (including the leakage and distributed delays) is solved by applying random variables with Bernoulli distribution [28].

Acknowledgments

We appreciate the authors for their contributions to this special issue. Special thanks go also to the reviewers for their valuable feedback, which helps improve the quality of the submitted papers. We would like to express our gratitude to the European Regional Development Fund and to the Ministry of Education, Youth and Sports of the Czech Republic that financially supported the editors' work under Project CEBIA-Tech Instrumentation no. CZ.1.05/2.1.00/19.0376 and under the National Sustain-ability Programme Project no. LO1303 (MSMT-7778/2014), respectively.

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