Mathematical and Computational Applications

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Editorial

Advanced Mathematics and Computational Applications in Control Systems Engineering

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Control-systems engineering is a multidisciplinary subject that applies automatic-control theory to design systems with desired behaviors in control environments. Automatic-control theory has played a vital role in the advancement of engineering and science. It has become an essential and integral part of modern industrial and manufacturing processes. Today, control-precision requirements are higher, and real systems are more complex, including higher-order, discrete, hybrid, time-delayed linear and nonlinear systems, and systems without a mathematical model and uncertainties.

In control engineering, parallel to all other engineering disciplines, the impact of advanced mathematical and computational methods is rapidly increasing. Advanced mathematical methods are needed because real-world control systems need to comply with several conditions related to product-quality and -safety constraints that have to be considered in problem formulation. Conversely, the increment in mathematical complexity impacts computational aspects related to numerical simulation and practical implementation of algorithms. A balance must also be maintained between implementation costs and the performance of the control system.

This special issue aims to present recent advances in developing and applying advanced mathematics and computational applications in control-systems engineering. It comprises nine high-quality papers, summarized below.

Alhato and Bouallègue [1] present an advanced metaheuristic optimization algorithm—thermal-exchange optimization—in order to optimize the gains of proportional–integral (PI) controllers applied to outer loops in the classical vector control scheme of doubly fed induction-generator-based wind-turbine systems. The authors considered the PI controllers' gain tuning as an optimization problem under nonlinear and nonsmooth operational constraints to improve the precision of the proposed control technique in reference tracking.

Kas and Das [2] provide a new theoretical approach of controlling resistance spot welding processes with the aim of avoiding inconsistent weld quality and inadequate nugget size. The proposal is based on a dynamical analytical model and an adaptive tracking controller that continuously adjusts welding voltage given the estimation of unknown process parameters.

Lara-Ortiz et al. [3] developed a hybrid active disturbance rejection controller for the regulation of the gait cycle of a mobile worm-bioinspired robot. The controller considers the maximal and minimal angles of each of the six links that conform the worm structure. An extended state observer estimates the unknown dynamics to actively compensate for it in a closed loop. Both numerical and experimental results validated the strategy.

Rodríguez-Mata et al. [4] present an approach based on Streeter–Phelps contaminant-distribution models and state-estimation techniques to monitor water-quality conditions. They designed a novel fractional-order high-gain observer to estimate dissolved- and biochemical-oxygen demand, which are variables that difficult to measure with physical sensors. Experimental results of its application in a river are presented.

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López-Estrada et al. [5] studied the case of a mechanical crane transporting a load of which the control objective was to attenuate swing load while tracking a reference. They propose a convex quasilinear parameter-varying approach with a $\mathcal{H}_\infty$ criterion that guarantees robustness against measurement noise and partial faults.

Pulido-Luna et al. [6] discuss a method to synchronize unidirectionally coupled heterogeneous chaotic systems, and its implementation in reconfigurable hardware. The controller uses Lyapunov theory with state feedback for this purpose. Lastly, it was implemented in a field-programmable gate array (FPGA) to test its performance.

Heras-Cervantes et al. [7] dealt with a DC–DC buck–boost power converter to control the heat of a resistance located in the boiler of a distillation column. Three different models of the converter (switching, nonlinear, and fuzzy Takagi–Sugeno) and two different fuzzy observers (with and without sliding modes) to estimate the inductor current and the capacitor voltage were compared in order to determine the best performance option.

Santos-Ruiz et al. [8] propose a method to simultaneously estimate the head loss and roughness of a serpentine pipe through the use of nonlinear optimization. The authors optimized the error of the Colebrook–White equation for an operating interval using the pressure and flow measurements at the pipeline ends.

Ramírez-Cárdenas and Trujillo-Romero [9] focus on sensorless speed tracking of a brushless direct-current motor using a neural network. The neural network had two layers; it was trained using the backpropagation method, and the velocity values and control signal from a proportional–integral–derivative control. The neural network could hold constant and variable load pairs, as is numerically demonstrated.

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