Scanning the Issue*

Relaxing Integrity Requirements for Attack-Resilient Cyberphysical Systems (17-2070)

Ilija Jovanov and Miroslav Pajic

A cyberattacker in a cyberphysical system could remotely affect control performance by tampering with sensor measurements delivered to the controller. In response to this, the authors consider linear estimators equipped with a general type of residual-based intrusion detectors and show that, even when integrity of sensor measurements is enforced only intermittently, the attack impact is significantly limited. Specifically, either the state estimation error is bounded, or the attacker cannot remain stealthy. On three automotive case studies, the authors show that even with less than 10% of authenticated messages one can ensure acceptable control performance in the presence of attacks.

Observers for Linear Systems by the Time-Integrals and Moving Average of the Output (18-0417)

Laura Menini, Corrado Possieri, and Antonio Tornambè

It is shown that, under some mild assumptions, it is possible to design observers for linear, time-invariant systems by feeding classical linear observers with the successive integrals and the moving average of the measured output. The main interest in these observers relies on the fact that both the integral and the moving average exhibit low-pass behaviors, thus, allowing the design of observers less sensitive to high-frequency noise. Examples to corroborate the theoretical results and to highlight the improved filtering properties of the proposed observers are reported.

SuperMann: A Superlinearly Convergent Algorithm for Finding Fixed Points of Nonexpansive Operators (18-0382)

Andreas Themelis and Panagiotis Patrinos

The paper proposes SuperMann, a universal framework to globalize Newton-type methods for finding fixed points of nonexpansive operators. SuperMann allows to robustify against ill conditioning and considerably accelerate popular convex optimization algorithms, such as the ADMM or the extremely versatile Vũ-Condat splitting. The method is based on a novel hyperplane projection tailored for nonexpansive mappings. A modified Broyden scheme is shown to enable superlinear convergence rates even when the set of solutions is not a singleton. The effectiveness of SuperMann is illustrated through numerical experiments on linear model predictive control.

Analysis and Control of a Continuous-Time Bi-Virus Model (17-0944)

Ji Liu, Philip E. Pare, Angelia Nedich, Choon Yik Tang, Carolyn L. Beck, and Tamer Basar

This paper studies a distributed continuous-time bi-virus model in which two competing viruses spread over a network consisting of multiple groups of individuals. Limiting behaviors of the network are characterized by analyzing the equilibria of the system and their stability. Specifically, when the two viruses spread over possibly different directed infection graphs, the system may have, first, a unique equilibrium, the healthy state, second, two equilibria including the healthy state and a dominant virus state, or, third, at least three equilibria including the healthy state and two dominant virus states.

Stealthy Adversaries against Uncertain Cyberphysical Systems: Threat of Robust Zero-Dynamics Attack (18-0743)

Gyunghoon Park, Chanhwa Lee, Hyungbo Shim, Yongsoon Eun, and Karl H. Johansson

The authors construct a robust stealthy attack that compromises uncertain cyberphysical systems having unstable zeros. In contrast to conventional strategies, they isolate the actual zero-dynamics from the plant's input–output relation and replace them with auxiliary nominal zero-dynamics. Hence, the knowledge of the exact model is not required anymore, at the price of utilizing input and output signals. The authors also show that a disturbance observer can be employed by the adversary when there is a lack of model knowledge. Finally, they validate the results using a hydro-turbine power system model.

Structural Controllability of a Networked Dynamic System With LFT Perturbed Subsystems (18-0921)

Yuan Zhang and Tong Zhou

This paper discusses the controllability of networked dynamical systems (NDSs) with unknown parameters both in their subsystems (heterogeneous) dynamics and in their interconnections. Using a linear fractional transformation (LFT) approach, the authors obtain necessary and sufficient conditions for controllability of LFT-parametrized plants and derive similar conditions for controllability of the overall NDS. The proposed methodology elucidates the way in which the controllability of an NDS is influenced by the topology and structural properties of its subsystems and allows one to optimize the number of interconnections while preserving NDS controllability.

On Fundamental Limitations of Dynamic Feedback Control in Regular Large-Scale Networks (18-0690)

Emma Tegling, Partha Mitra, Henrik Sandberg, and Bassam Bamieh

We study fundamental limitations on the performance of distributed feedback control in large-scale networked dynamical systems. Specifically, we address the question of whether dynamic feedback control can alleviate known limitations to localized static state-feedback control that, for example, prevent coherent behaviors in large-scale string formations. We model distributed linear consensus and vehicular formation control problems over toric lattice networks and develop a framework for evaluating asymptotic scalings (in network size) of global performance bounds.

Digital Object Identifier 10.1109/TAC.2019.2952442

Event-Triggered Quantized Control for Input-to-State Stabilization of Linear Systems With Distributed Output Sensors (18-1792)

Mahmoud Abdelrahim, Victor Sebastiaan Dolk, and W. P. M. H. Heemels

This paper deals with the joint design of event-triggering mechanisms and dynamic quantizers for linear time-invariant systems subject to unknown external disturbances. The triggering mechanism only depends on output measurements of the plant, which are collected by distributed sensors and transmitted to the controller in an asynchronous manner. The proposed approach ensures an input-to-state stability property of a size-adjustable set around the origin and prevents Zeno behavior. The tradeoff between transmissions and quantization is characterized in terms of the design parameters. The method is feasible for any stabilizable and detectable linear plant.

Lattice Filter-Based Multivariate Autoregressive Spectral Estimation With Joint Model Order and Estimation Bandwidth Adaptation (17-0905)

Maciej Niedzwiecki, Michal Stanislaw Meller, and Damian Chojnacki

This paper considers the problem of parametric, autoregressive model-based estimation of a time-varying spectral density function of a multivariate nonstationary process. It is shown that estimation results can be considerably improved if identification of the autoregressive model is carried out using the two-sided doubly exponentially weighted lattice algorithm, which combines results yielded by two one-sided lattice algorithms running forward in time and backward in time, respectively. It is shown that the model order and the estimation bandwidth can be efficiently selected using a suitably modified Akaike's final prediction error criterion.

Robust Fault Detection and Set-Theoretic UIO for Discrete-Time LPV Systems With State and Output Equations Scheduled by Inexact Scheduling Variables (17-1660)

Feng Xu, Junbo Tan, Ye Wang, Xueqian Wang, Bin Liang, and Bo Yuan

A novel robust fault detection (FD) approach is proposed, along with a set-theoretic unknown input observer (SUIO) for linear parameter-varying systems with both state and output equations scheduled by inexact scheduling variables. The proposed robust FD method is obtained by combining set theory with the unknown input observer, which considers the bounds on the measurement errors of the scheduling variables to generate the FD-oriented sets. Next, the unknown input decoupling condition of SUIO for the considered LPV systems is given, and an SUIO design method is proposed under such condition.

A Smooth Distributed Feedback for Formation Control of Unicycles (18-1174)

Ashton Roza, Manfredi Maggiore, and Luca Scardovi

This paper discusses formation control for a group of kinematic unicycles, where the goal is convergence to a desired formation with the unicycles in parallel headings and zero speeds. The authors propose a distributed control law, viewing the problem as one of consensus on a set of offset vectors and headings that describe the desired formation shape. Formation members are required to sense their displacements and heading angles relative to neighbors, along a connected, undirected, time-invariant sensing graph. The effectiveness of the proposed approach is demonstrated in simulations.

Generalized Dual Dynamic Programming for Infinite Horizon Problems in Continuous State and Action Spaces (17-1721)

Joseph Warrington, Paul Nathaniel Beuchat, and John Lygeros

This paper describes a nonlinear generalization of dual dynamic programming theory and its application to deterministic control problems over continuous state and action spaces in a discrete-time infinite horizon setting. The approach is based on a Benders-type argument to generate global lower bounds on the optimal value function; these bounds are in general expressive nonlinear functions reflecting the problem data. The paper provides an algorithm that, under certain assumptions, achieves an arbitrarily low Bellman optimality tolerance at preselected points in the state space in finite iterations. The algorithm is demonstrated on linear and nonlinear systems.

Resilient Reinforcement in Secure State Estimation Against Sensor Attacks With *A Priori* Information (18-0499)

Takumi Shinohara, Toru Namerikawa, and Zhihua Qu

Motivated by cyberphysical systems security and the internet of things, the paper studies the resilient state estimation of a linear time-invariant system under attack under the hypothesis of prior information about the states. The authors show that this information, of which diverse types are considered, can be leveraged in order to enhance state reconstruction, both in the noise-free and noisy cases. Under certain conditions the authors obtain a convex formulation for their estimator.

LMI Stability-Constrained Parameter Identification for Composite Adaptive Internal Model Control (18-0880)

Zeng Qiu, Jing Sun, Mrdjan Jankovic, and Mario Santillo

Internal model control (IMC) explicitly incorporates a plant model and a plant inverse model in its control architecture. Within an IMC framework, we propose composite adaptive IMC (CAIMC), which simultaneously identifies the plant and its inverse models to minimize modeling errors and further reduce the tracking error. Existing stability-constrained identification methods do not guarantee boundedness and continuity properties of the estimated parameters, causing problems for closed-loop stability of CAIMC. To address this problem, a modified stability-constrained parameter identification method is proposed. Closed-loop stability and asymptotic performance of CAIMC are then established.

Supervisory Control of Probabilistic Discrete Event Systems Under Partial Observation (18-0851)

Weilin Deng, Jingkai Yang, and Daowen Qiu

The supervisory control problem for probabilistic discrete event systems (PDESs) under partial observation is considered. Notions of probabilistic controllability and probabilistic observability are introduced for probabilistic specification languages. It is then proved that probabilistic controllability and probabilistic observability are necessary and sufficient conditions for the existence of a probabilistic supervisor, which is more powerful than a deterministic one for PDESs. Furthermore, as an achievable approximation of a given specification language, the infimal controllable and observable superlanguage is calculated.