EDITORIAL

Analysis and synthesis of control systems over wireless digital channels[1]

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With the development and integration of theories of information, communication and control, large-scale and spatially distributed control systems over wireless digital channels are now widely applied in intelligent transportation, industrial automation and advanced manufacturing, for instance. The use of wireless networks in control systems allows for modular and flexible system design, e.g., distributed processing and interoperability, simple and fast implementation, e.g., reduced wiring and powerful configuration tools, and reduced installation and maintenance costs. However, the analysis and design of such systems pose new challenges due to packet loss, data quantization, channel fading, communication delay, asynchronous sampling and so on. In the past decades, although some fundamental aspects have been studied, there are several open issues that still need to be addressed such as the performance analysis of networked systems, the modeling and congestion control of wireless networks, co-design of wireless networked control systems, distributed estimation and control.

Different than a number of well-established journals in the areas of information processing, communication networks and control theory, the primary objective of this Special Issue in Journal of The Franklin Institute is to bring together the latest approaches to understanding, analyzing and controlling systems over wireless digital channels in a quantitative way and to identify critical issues and challenges for future investigation on network modeling for wireless networked systems; congestion control of wireless networks; stabilization of wireless networked systems; analysis of networked systems over digital fading Channels; distributed estimation and control under communication constraints; co-design of networks and control systems, for instance. Based on this focus the special section has accepted fourteen high-quality papers after rigorous peer-review processes, the contents of which are summarized as follows.

Within the context of model-predictive-control, Gautam et al. in the work entitled '*Communication–computation tradeoff in distributed consensus optimization for MPC-based coordinated control under wireless communications*' developed an analysis of the tradeoff between repeated communications and computations for a fast distributed computation of global decision variables in a model-predictive-control (MPC)-based coordinated control scheme. The authors considered a coordinated predictive control problem involving uncertain and constrained subsystem dynamics and employ a formulation that presents it as a distributed optimization problem with sets of local and global decision variables where the global variables are allowed to be optimized over a longer time interval. Considering a modified form of the dual-averaging-based distributed optimization scheme, the authors explored convergence bounds under ideal and non-ideal wireless communications and determine the optimal choice of communication cycles between computation steps in order to speed up the convergence per unit time of the algorithm. Finally, the authors applied the algorithm for a class of dynamic-policy based stochastic coordinated control problems and illustrated the results with a simulation example.

In the work done by Amine Sid et al. (*Medium access scheduling for input reconstruction under deception attacks*), the authors developed a novel approach of state filtering scheme and the sensor scheduling co-design for cyber-physical systems subject to random deception attacks. Such cyber attacks are switching disturbances that affect the input information transmitted from the controller to the plant through a constrained communication network. The cyber-physical system dynamics can be modelled as an augmented state model, while the unknown input reconstruction is obtained from a modified Kalman filter recursions under communication constraints. To deal with limited bandwidth constraint, a periodic sensor scheduling strategy is proposed in order to ensure the minimization of disturbances and cyber-attack effects.

In the work done by Rezaee and Abdollahi (*Discrete-time consensus strategy for a class of high-order linear multiagent systems under stochastic communication topologies*), the authors studied the problem of achieving consensus in a class of high-order discrete-time multiagent systems. It is supposed that the network topology is dynamic and the existence of a communication link between each two agents is stochastic. Based on the concept of discrete-time super-martingales, the authors proposed a Lyapunov-based high-order protocol which guarantees achieving almost sure consensus in the network in the presence of some conditions. The main contribution of the paper compared with existing results for consensus control of high-order multiagent systems under stochastic networks is that the proposed consensus protocol in this paper requires no knowledge on the set of feasible topologies (topologies with nonzero probabilities), and can be designed without computing the eigenvalues of the coupling matrices associated with the feasible topologies. In this condition, the computational costs of the consensus protocol design will be decreased significantly. The results are finally validated via a numerical example.

For the work done by Song et al. (*Robust finite-time dissipative control subject to randomly occurring uncertainties and stochastic fading measurements*), the authors investigated the finite-time dissipative control problem for a class of discrete stochastic systems under the circumstance of wireless communication networks, in which both randomly occurring uncertainties and stochastic fading measurements are involved. A modified stochastic Rice fading model with disturbance-dependent Gaussian noise is put forward to better reflect the fading phenomena in complex wireless communication networks. By introducing a novel concept of finite-time stochastic exponential dissipative, this work designs a state-feedback controller such that the closed-loop system is finite-time stochastic bounded with a prescribed exponential dissipativity performance. Moreover, some parameters-dependent sufficient conditions on the existence of the finite-time dissipative controller are derived and the corresponding computation algorithm is given. A numerical example is finally provided to illustrate the effectiveness of the proposed design approach.

The work entitled '*Mixed time/event-triggered distributed predictive control over wired-wireless networks*' by Zou et al. investigated the problem of mixed time/event-triggered dual-mode distributed predictive control (DPC) for constrained large-scale linear systems subject to bounded disturbances. Considering the effects of two different communication modes and introducing a prediction error between the current actual state and predicted state, the event-triggering condition is derived for each event-triggered subsystem. Based on this, a mixed time/event-triggered dual-mode DPC algorithm is proposed in view of the asynchronous coordination among subsystems. Furthermore, the sufficient conditions to ensure the recursive feasibility and closed-loop stability of mixed triggered DPC are developed. Finally, a multi-vehicle control system was provided to verify the effectiveness of the proposed approach.

The work entitled '*Observer-based decentralized event-triggered H_∞ control for networked systems*' by Zhang et al. investigated the problem of observer-based decentralized event-triggered H_∞ control for networked systems. The system measurements and control inputs are grouped into several nodes. An event-triggered transmission scheme is introduced to choose those necessary signals to be transmitted from the plant to the observer and from the controller to the actuator, where signals from control input nodes and from measurement nodes are released not necessarily synchronously. Under the decentralized event-triggered transmission scheme, H_∞ performance analysis for the resultant closed-loop system is made, and an algorithm to designing suitable observers and controllers is presented as well. Moreover, a sufficient condition is derived such that the inter-event time is strictly greater than zero. Finally, two examples are given to show the effectiveness of the method proposed in this paper.

For the work done by Yan et al. (*Distributed event-triggered* H_∞ *state estimation for T–S fuzzy systems over filtering networks*), the authors investigated the problem of distributed event-triggered H_∞ filtering over sensor networks for a class of discrete-time nonlinear system modeled by a set of linear Takagi–Sugeno(T–S) fuzzy models. In the filtering network, every individual filter receives the measurement information from the nonlinear plant, meanwhile, each filter can exchange the information with the other filters. Event-triggered communication scheme is applied to determine whether or not the current instant information should be transmitted to the quantizer. Distributed fuzzy filters are designed to guarantee the H_∞ disturbance attenuation level for the error estimation of the filtering network. Finally, a simulation example was provided to illustrate the effectiveness of the proposed filter design approach.

For the work done by He et al. (*Finite-time synchronization of cyclic switched complex networks under feedback control*), the authors studied the problem of global finite-time synchronization between two cyclic switched complex dynamical networks via feedback control. Based on the cyclic dwell time approach, finite-time stability theorem and some inequality techniques, several sufficient criteria are proposed to ensure finite-time synchronization for a class of cyclic switched complex networks (CSCNs) with and without coupling delay. The obtained criteria not only provide a feasible approach to design state feedback controllers but also fully reveal the trade-off among the cyclic dwell time, the finite convergence time and the initial state. Finally, numerical simulations are given to illustrate the effectiveness of the proposed results.

In the work done by Yao and Li (*Input–output finite-time stabilization of a class of nonlinear hybrid systems based on FSM with MDADT*), the authors studied the problem of input–output finite-time stabilization for a class of nonlinear impulsive hybrid systems based on finite state machine (FSM). First, the concept of input–output finite-time stability (IO-FTS) is extended for such hybrid systems, then, the stability analysis is given by combining the multiple Lyapunov functions (MLFs) method and mode-dependent average dwell time (MDADT) technique, the corresponding sufficient conditions are derived and proved. Furthermore, a state feedback controller is designed to stabilize the hybrid systems. Finally, a numerical example has been given to show the feasibility and effectiveness of the proposed controller.

For the work done by Sakthivel et al. (*Adaptive reliable output tracking of networked control systems against actuator faults*), the authors studied the reliable adaptive observer-based output tracking control problem for a class of networked control systems subject to actuator faults and external disturbances via equivalent-input disturbance technique. Notably, the reliable control design based on adaptive mechanism is implemented to compensate the on-line actuator faults automatically and an observer-based controller is introduced through communication networks to drive the output of controlled plant to track the output of a reference model. Moreover, due to the effect of network-induced delays and packet dropouts in the controller-to-actuator channel, the inputs of controlled plant and observer-based tracking controller are updated in an asynchronous way. Then, based on the asynchronous characteristic, the resulting closed-loop networked control system is formulated with two interval time-varying delays for obtaining the required result. In particular, the equivalent-input disturbance approach improves the disturbance rejection performance and it does not require any prior knowledge of the disturbances. By constructing a suitable Lyapunov–Krasovskii functional and using free-weighting matrix approach, a new set of sufficient conditions for the solvability of the addressed problem is derived in terms of linear matrix inequalities. At last, the proposed result is validated through two numerical examples and also a comparison study is presented which shows the effectiveness of the developed control scheme over some existing conventional control schemes.

In the work by Zhang et al. (*Output feedback control of networked systems with a stochastic communication protocol*), the authors addressed an output feedback control problem for a class of networked control systems (NCSs) with a stochastic communication protocol. Under the scenario that only one sensor is allowed to obtain the communication access at each transmission instant, a stochastic communication protocol is first defined, where the communication access is modelled by a discrete-time Markov chain with partly unknown transition probabilities. Secondly, by use of a network-based output feedback control strategy and a time-delay division method, the closed-loop system is modeled as a stochastic system with multi time-varying delays, where the inherent characteristic of the network delay is well considered to improve the control performance. Then, based on the above constructed stochastic model, two sufficient conditions are derived for ensuring the mean-square stability and stabilization of the system under consideration. Finally, two examples were given to show the effectiveness of the proposed method.

In the work done by Gu et al. (*Adaptive event-triggered control of a class of nonlinear networked systems*), the authors investigated an adaptive event-triggered communication scheme (AETCS) for a class of networked Takagi-Sugeno (T-S) fuzzy control systems. It is shown that the threshold of event-triggering condition has great influence on the maximum allowable number of successive packet losses. Different from the conventional method, the threshold, in this study, is dependent on a novel adaptive law which can be achieved on-line rather than a predefined constant, since the threshold with fixed value is hard to suit the variation of the system. The stability and stabilization criteria are derived by using a new Lyapunov function. Finally, an example has been provided to demonstrate the design method.

The work entitled '*Multi-instant switching control of nonlinear networked systems under unreliable wireless digital channels*' by Xie et al. studied a new multi-instant switching controller design for nonlinear networked systems under unreliable wireless digital channels. The proposed controller can be viewed as an improvement of previous results concerned with the homogenous polynomials approach, since it presents a denser subdivision of the joint space of multi-instant normalized membership functions and therefore essentially yields an efficient multi-instant switching mechanism for the first time. As a result, more efficient results can be obtained in the study. Finally, an illustrative example has been provided to demonstrate the effectiveness of the multi-instant switching controller.

In the work by Wang et al. (*Transmission power allocation of NCSs with Markov channel assignment*), the authors studied networked control systems (NCSs) where the sensors communicate with the remote controller via a wireless fading channel. Each time the channel can accommodate just one sensor for communication and the access to the channel of the sensors is driven by a random event. When a sensor is triggered to send its measurement, it can choose to use a high power or a low power to save energy. The power level of the sensor determines the probability of successful packet reception at the controller. This work aims to find an appropriate transmission power allocation method for the sensors jointly with a system controller so that the NCS is stabilized with a given energy budget. By introducing a Markov chain model for the medium-access constraint and modeling the packet dropout as a Bernoulli process, the authors derived a new model and stability conditions for the NCSs, which are given in terms of the transition probabilities of the Markov chain and different packet reception rates. An interesting power scheduling policy is obtained and two kinds of controller design schemes are given depending on whether the medium-access status of the sensors is acknowledged to the controller or not. The results are then extended to the case of large-scale systems and an optimal co-design methodology which can stabilize the whole set of systems with largest stability margin is proposed. The effectiveness of the presented method is demonstrated by numerical simulations.

Finally, it is understood that the selected topics and papers are not a comprehensive representation of the area of this special section on modelling, analysis and synthesis of control systems over wireless digital channels. Nonetheless, they represent the rich and many-faceted knowledge that we have the pleasure of sharing with the readers. We would like to express appreciation to the authors for their excellent contributions, to the reviewers for the quality check of the special issue, and to the Journal of The Franklin Institute Editor-in-Chief, Journal Manger and the Editorial office staff for their great support.

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