Guest Editorial
Networking, Sensing, and Control for Networked Control Systems: Architectures, Algorithms, and Applications

The accelerated integration and convergence of communications, computing, and control over the last decade has inspired researchers and practitioners from a variety of disciplines to become interested in the emerging field of networked control systems (NCS). In general, an NCS consists of sensors, actuators, and controllers whose operations are distributed at different geographical locations and coordinated through information exchanged over communication networks. Some typical characteristics of those systems are reflected in their asynchronous operations, diversified functions, and complicated organizational structures. The widespread applications of the Internet have been one of the major driving forces for research and development of NCS. More recently, the emergence of pervasive communication and computing has significantly intensified the effort of building such systems for control and management of various network-centric complex systems that become more and more popular in process automation, computer-integrated manufacturing, business operations, as well as public administration.

Control over a communication network is not a new concept in automation. From teleoperation for space and hazardous environments to process regulation with distributed control systems, control systems with communications have already been developed and utilized in applications of real-world problems for almost 30 years [1]. There are many factors that distinguish the current NCS and previous control with communications. Two of them are the most significant: 1) in the previous control with communications, the network is specialized and dedicated for the timeliness of information exchange and stability of process operation, while in the current NCS the network is general-purpose and public for various irrelevant yet concurrent applications, and thus real-time communication and stable operation are no longer ensured and 2) the functionality of the NCS from the previous to current has been diversified tremendously, from pure control to a variety of control and management or administrative functions, ranging from resource allocation, event scheduling, to task organization, etc., involving concept and methods from control and communication engineering, operations research, computer science, and management science.

Demands on diversity, complexity, and real-time performance for networked operations have brought new technological challenges to NCS. Today, many fundamental questions regarding the stability of interconnected dynamical systems, the effects of communication on the performance of control systems, etc., remain open and to be answered. Even from the perspective of control aspect alone, we need to think about what the new direction for research and application in this age of connected world would be. One potential approach is to extend the concept of “programming on demand” with agent programming to “control on demand” with agent-based control (so-called ABC) [2]. In other words, can we liberate control algorithms that are fixed to controlled plants to control agents that are free and mobile in a connected world? Once this is accomplished, various innovative methods based on connectivity can be employed for control and management, e.g., using “local simple, remote complex” principle to design low-cost yet high-performance and intelligent NCS that require less computing power, small memory space, and few upgrades [3], [4]. Indeed, there are many new, exciting, and challenging ideas and problems in the field of NCS.

This special issue is dedicated to address some of the questions and problems discussed above. The eight papers can be divided into three groups. The first group consists of three papers that deal with issues directly related to control over the Internet, especially fuzzy control, predicative control, and multirate control of NCS. The second group has two papers for design and evaluation of network architectures for service delivery and operation control. The third group discusses intelligent control algorithms and techniques that might have great potential for applications in NCS.

The special issue starts with the paper by Zhang, Yang, and Chai on the guaranteed cost networked control (GCNC) for T–S fuzzy systems with time delay, where the state feedback controller with GCNC using the Takagi–Sugeno (T–S) method is developed for NCS and its stability is established and validated through computer simulations. In the second paper, Liu, Xia, Rees, and Hu discuss issues in the design and stability analysis of networked predictive control systems with random delay in the feedback. After adapting the principle of predicative control to network-based control to overcome the effects of time delay, the authors establish necessary and sufficient conditions for the stability of closed-loop NCS. Yang and Yang address the architectural and procedural aspects of using multirate control in Internet-based control systems. In their paper, a two-level hierarchy with remote and local controllers is used for the Internet-based control systems where two compensators are placed in the feedback and feedforward channels, respectively.

Intelligent home systems can be significant for potential applications of NCS. Wu, Liao, and Fu investigate the protocol and architectural issues for service-oriented smart homes and
the process of service delivery with the protocol defined by the Open Services Gateway initiative (OSGi) Alliance. Based on the multiple OSGi platforms and mobile agent technology, the authors propose a service-oriented smart home architecture for dynamical service delivery and peer-to-peer operations. In their paper on fairness and dynamic flow control, Yang, Cao, Tan, and Yi focus on the rate control problem of feedback-based sessions in the coexistence of both unicast and multiroute multicast traffic architecture networks. A strategy called “reasonable consumption” is proposed for achieving the fairness, and a Lyapunov approach is used for accomplishing the stable multiroute control for flow congestion in multicast services.

Wu, Hu, and Xie present a new intelligent control method based on an intelligent characteristic model for a kind of complicated plant with nonlinearities and uncertainties, whose controlled output variables cannot be measured online continuously. The basic idea of their method is to utilize intelligent techniques to form the characteristic model of the controlled plant, and then to present a new design method of intelligent controller based on this characteristic model. The application result in the aluminum electrolytic process is really impressive and convincing. In their paper on distributed simulation of differential algebraic systems, Rum and Gordon investigate the optimal solution of differential algebraic equations over a network of processors using optimal sliding mode control to address the sensor and network time delays associated with communications. In a connected world, cars will be mobile offices and homes where networked control and operation will become important and central. One of the most active current research topics in intelligent vehicles is robust vehicular vision systems for driving safety and comfort. In their paper on a novel robust in-car digital image stablization, Hsu, Liang, Pu, and Lin propose a technique that can stably remove the unwanted shaking phenomena in the image sequences captured by in-car video cameras without the influence caused by moving objects in the image or intentional motion of the car. Their technique can be of important practical implication on future mobile visual systems for wireless networked applications.

Finally, as the guest editors of the special issue, we would like to express our sincere appreciation to all reviewers for their time and effort, and to the editorial assistants of this Transactions for their patience and great help.

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