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Editorial

Control under limited information: Special issue (Part I)

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1. INTRODUCTION

In recent years, new applications have changed the way that systems interact and communicate: users working across the Internet, people communicating with cell phones, entire manufacturing facilities that share real-time data for product tracking, and wireless systems to network computers. New technologies have brought extraordinary advantages to the developers of control systems including the simplification in wiring and maintenance as well as cost reduction for teleoperation, automobile applications, multi-robot systems, etc. The introduction of these technologies into the control systems, however, has also brought about new challenges. Control theorists have usually assumed perfect flow of information among the different devices (sensors to controllers, controllers to actuators). In the new control systems, however, dedicated and unconstrained communication channels have been replaced by shared communication systems or very constrained communication links. Perfect communication links are now the shared networks that suffer from traffic congestion and limited communication bandwidth. Such communication media feel the quantization effects, the potential loss of information, and random delays.

These different aspects in the feedback control loop are what we refer to ‘control under limited information’. Control engineers are thus forced to expand their application domain by incorporating the communication infrastructure into their designs, and by considering the impact of link capacity, latency, and packet loss on the performance of feedback control systems. The need for new paradigms for control design is particularly evident in large-scale interconnected multi-agent systems. For such systems, signals need to flow quickly and efficiently, but interconnected

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components may not be able to store and manipulate the complete state of the system. Although complexity barriers render the design of controllers for high-dimensional systems impractical, the ability to reason about global network properties based on locally available information enables the design of decentralized control laws. These topics are receiving a lot attention and researchers are bringing important contributions to the area [1–4]. The objective of this Special Issue (and its companion) is to present the latest developments in the field of control systems with limited information and to stimulate further research within the community.

2. SPECIAL ISSUE CONTENT

The first article in this first special issue is titled 'Kalman Filtering over Unreliable Communication Networks with Bounded Markovian Packet Dropouts', by Xie, Xiao, and Fu. This work addresses the peak covariance stability of a time-varying Kalman filter. The main contribution is that it assumes the presence of packet losses in transmitting measurement outputs to the filter when a packet-based network is used for the transmissions. The main assumption is that the packet losses are bounded and driven by a finite-state Markov process. This work uses the observability index of the discrete-time linear time-invariant (LTI) system under investigation as well as the system dynamics and the probability transition matrix of the Markov chain to establish conditions for the peak covariance stability of the Kalman filter. The validity of the results is demonstrated by numerical simulations.

The second article is titled 'Average Consensus On Networks with Quantized Communication' by Frasca, Carli, Fagnani, and Zampieri. This article presents a contribution to the solution of the average agreement problem on a network when the links are quantized. Starting from the well-known linear diffusion algorithm, the authors propose an adaptation that is able to preserve the average of states and to drive the system near to the consensus value. This is achieved in the presence of uniform quantized communication between agents. The article investigates the properties of this algorithm using worst-case analysis as well as probabilistic analysis. Similar to other contributions in the topic, the properties found depend on the spectral properties of the evolution matrix. Finally, special attention is devoted to the issue of the dependence of the performance on the number of agents. The validity of the results is demonstrated by several examples.

The third article is titled 'Subband Coding for Networked Control Systems' and is co-authored by Quevedo, Silva, and Goodwin, who study a source coding method for Networked Control Systems (NCS's) for SISO LTI plant models. The authors propose a non-uniformly sampled subband coding NCS architecture to minimize the tracking error variance caused by the quantization effects. This scheme improves the efficiency of the limited communication resources between the controller and the plant actuator. Although the topic has been studied in previous works, the main contribution is the addition of pre- and post-filters to each subband. The optimal filters characterization and the subband bit-allocation problem is solved by considering a signal-to-noise ratio model for the quantization and by explicitly taking into account the closed-loop nature of signals. The validity of the results is demonstrated by the simulation of non-idealized situations.

The fourth article is titled 'Optimal tracking control across erasure communication links, in the presence of preview' by Gupta and Martins. This article addresses the problem of designing a networked control scheme for a follower system, which guarantees that the state of the follower system tracks the state of the lead system optimally, according to a mean-squared cost. The two systems, the follower and the lead are two identical discrete-time, finite-dimensional, linear and time-invariant systems. The authors adopt a networked control scheme featuring two erasure links and three design blocks: a controller acting on the follower system and two encoders. The controller has remote access to noisy measurements of the outputs of both the systems, via two erasure links used to connect each encoder to the controller. The main contribution of this article is a methodology for jointly designing optimal controller and encoders with respect to optimal tracking of the lead system by the follower system and to provide necessary and sufficient conditions for the existence of a scheme that guarantees that the tracking error has a finite second moment.

The fifth and last article of this first issue is 'Energy-aware and entropy coding for Networked Controlled Linear Systems' by C. Canudas-de-Wit and J. Jaglin. This article addresses coding design in the context of control of systems equipped with low-energy sensors networks. The main focus of the article is on minimum bit and energy-aware coding. The article presents a coding strategy to quantify and to differentiate stand-still signal events from changes in the source. The authors also study energy savings under two different scenarios: (1) in the word-by-word transmission case and (2) in the package-based transmission case. Finally, the article studies the stability properties needed for entropy coding to operate properly, and quantifies the energy savings for each of the considered scenarios.

A common thread throughout the five articles is to achieve desirable closed-loop behavior by analyzing and designing around the limitations imposed by the communication channels that exist in a feedback control loop.

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