Editorial

Special Issue "Control theory for digitally networked dynamical systems"

Control theory for digitally networked systems has been a very active research topic during the last two decades. The widespread availability of fast and reliable digital communication infrastructure, particularly in the form of wireless connections, has created the possibility that in a complex system virtually every component can exchange information with any other component. In a control system, these components are typically *actuators* – which interact physically with the system to be controlled, *controllers* – i.e., formulas or algorithms which compute the control signals to be implemented by the actuators, and *sensors* – which measure the physical quantities needed as an input for the controllers. The efficient use of communication channels promises a more efficient interplay between these components yielding higher performance, lower energy consumption and lower production costs.

Since 2007, the Priority Program 1305 "Control Theory for Digitally Networked Dynamic Systems" of the German Science Foundation (DFG) has shaped research in this area. Within this program 13 research groups situated in control engineering, mathematics or communication departments all over Germany have jointly worked on various topics in networked control systems and the monograph [1] gives an comprehensive overview of the research efforts within this program. The papers in this special issue also originate from this program. Here the aim is to provide an in-depth and mathematically rigorous treatment of particular subproblems in the field of networked control. Thus the present issue concentrates on topics in which Applied Mathematics plays an important role. The interdisciplinary character of this research field becomes apparent by the fact that mathematical as well as engineering groups have contributed.

From an application point of view, there are two main questions which arise when incorporating digital networks into a control system:

- How to deal with the limitations and uncertainties introduced by a digital communications channel?
- How to design controllers which make efficient use of the newly available communication links?

Both questions lead to fundamental qualitative and quantitative problems as well as the need for practical design methods to construct efficient controllers and communication schemes.

For example, entropy concepts allow one to estimate the minimal amount of information which needs to be communicated in order to achieve a certain control objective, e.g., to keep the state of a system inside a desired set. On the other hand, event based controller design is a control methodology in which sensor and controller or controller and actuator only communicate when needed, thus trying to reduce the amount of information to be communicated. Newly available communication links also make it necessary to analyze classical control theoretic concepts like controllability and stabilizability under structural assumptions reflecting the network structure of the overall system. Finally, model predictive control (MPC) is an optimization based control method which is well suited to take advantage of the information available in a networked environment.

In all these areas mathematical concepts play a fundamental role. Many practical design methods rely on ideas from mathematical optimization and optimal control; in this issue optimization techniques are used in the papers by Molin and Hirche, Pannek and Worthmann, Koltai and Junge, and Groß and Stursberg. Similarly, stability properties and their mathematical characterization, e.g., via Lyapunov functions or via spectral methods are ubiquitous in this issue. Controllability, a dynamical property more specifically related to control systems, is investigated under suitable assumptions on the network structure in the paper by Rüppel and Helmke. Structural properties, here in the form of weak coupling, are also investigated in the paper by Koltai and Junge in the context of optimal value functions. Entropy concepts are used by Colonius and Helmke, and design methods for event based feedback control are developed by Molin and Hirche and by Stöcker and Lunze. All in all, the papers in this issue give insight into various different approaches and methods in the area of digitally networked control systems.

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References

[1] J. Lunze, ed., Distributed and Networked Model Predictive Control, Springer Verlag, 2014.