Foreword

The attraction of achieving higher efficiency and reliability for industrial plants and networked systems has created new research opportunities in the control and optimisation field. Among different design methods, the model predictive control (MPC) strategies, first developed for the petroleum refining industry, have proved to be effective in many applications. Originally found widespread used in the stand-alone sites, the non-centralised adaption such as distributed and decentralised MPCs have been progressing towards more heterogeneous architectures that are able to cope with system complexities and variations in application domains.

This book presents a stabilising method for the control of interconnected systems having mixed connection configurations with distributed and decentralised model predictive control schemes. The novel notions of asymptotically positive realness constraint (APRC) and quadratic dissipativity constraint (QDC) are introduced as a fundamentally constituent part of this book. In both constraints, the function of inputs and outputs in the form of a supply rate, or a 'supply power', are quadratic. From the communication and information perspective, the quadratic constraint packs two pieces of information, the control and state vectors, into one variable, before carrying to different locations, then unpacks them for use with the local control algorithm. The employment of quadratic constraints in two distinct approaches, segregation from and integration into the control algorithms, for the constrained stabilisation of interconnected systems is another contribution of this book.

Solutions for linear systems are given in distributed and decentralised strategies whereby the communication between subsystems is either fully connected, partially connected, or totally disconnected. The interconnected systems and their distributed computerised-control platforms are considered within the realm of a cyber-physical system consisting of the physical connections between subsystems and the communication links between local computing processors. Within the auspice of the integrated construction method, the distributed and decentralised MPC strategies deal with the communication links from the cyber-connection side – The subsystems are wholly or partially connected in a distributed MPC scheme while being totally disconnected in a decentralised MPC.

By having the control inputs entirely or partially decoupled between subsystems, and no additional constraints imposed on the interactive variables, rather than the coupling constraint itself, the proposed approaches outreach various types of networked systems and applications. The effects of coupling delays and device networks are also resolved in a part of the development. For parallelised connections that emulate parallel redundant structures and have unknown splitting ratios, a fully decentralised control strategy is developed as an alternative to the hybrid system approach. For the semi-automatic control systems, which is involved with both closed-loop and human-in-the-loop regulatory controls, the stability-guaranteed method of decentralised stabilising agents that are inter-operable with different control algorithms is germinated and implemented for each single subsystem.

For nonlinear input-affine systems, the extended output vector that includes the vector field are introduced such that the dissipativity criterion can be rendered in linear matrix inequalities. The compound vector can be viewed as manifest variables in the beviourial framework for dynamical systems. From the perspective of the dissipative system theory, both storage function and supply rate with the extended output vectors are parameterised to avoid any conservativeness that may incur to the stabilisation of nonlinear systems.

In this book, the MPC is formulated with state space models having a standardised cost function. The stability constraint here is a constraint imposed on the current-time control vector, independently to the MPC objective function. For interconnected systems, the terminal constraint computations are formidable when dealing with subsystems having dissimilar dynamics whose settling times are heterogeneous. The quadratic constraint approach resolves this difficulty by having a constraint on the current-time control vector. As a result, the physical control constraint is naturally dealt with by the employed method. The state constraint and recursive feasibility are, nevertheless, not included in this book, but presented elsewhere.

A broad range of applications in the process and manufacturing industries, networked robotics, networked control systems and network centric systems such as power systems, telecommunication networks, and chemical process systems will benefit from the approaches in this book. Illustrative examples of networked interconnected systems are provided with numerical simulations in Matlab environment. Specifically, a power system having four control areas, a dependable control of cyber-physical systems, and some other numerical examples are implemented with the distributed and decentralised MPC strategies employing the quadratic constraint approach to demonstrate their theoretical appraisals.

An extension of the method to new applications with the Internet of Things (IoT) is presented with a dependable control system scheme in which multiple controllers and sensors are cross-connected via the IoT communication network to ensure the duty-standby architecture for achieving quantitatively higher reliability of cyber-physical systems.

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