Preface

The past decades have witnessed various applications of systems engineering methodologies to urban planning, economic models, power systems, industrial processes, transportation networks, and others. Due to economic factors and sociopolitical constraints, a fundamental constituent of these applications is frequently described by the following attributes: *multidimensional*, *highly interacting*, *and complex models*. Several approaches have been developed [2–4, 6, 11, 14] to deal with these models with the intention of reducing some measure of complexity in the course of analysis and design. Concepts and key ideas from economics, management science, and operation research have been exploited successfully and generalized in a dynamic framework. These continuous efforts systematically establish a body of theories pertaining to interconnected systems (ICS). The voluminous literature on theories and applications of large-scale systems (LSS), interconnected systems (ICS) or complex dynamical systems (CDS) includes survey articles and textbooks and monographs [1, 3, 5] and [7–13].

Throughout this book and in view of our technical experience, we will adopt *decentralized systems* (DS) as the most convenient designation for LSS, ICS or CDS since the common denominator in these systems is to deploy decentralization in the analysis, control, filtering and processing tasks. Equivalently stated, the effort of any task is essentially *distributed* among various units who are cooperating to achieve the desired objective.

It is often true that a book is developed through a long tour that consists of many tiny steps and interactions with many people. While the major idea of writing a book on decentralized systems has been in the back of my mind for quite long time, the thrust behind this volume started in July 2009 when I met with Oliver Jackson during the Systems and Control Conference in Saint Petersburg, Russia. It has been a good opportunity to start a fruitful communication channel that ended with writing the present book.

Over the past decades it was highly interesting and extensive activity to watch and interact with the global scientific/engineering development of decentralized systems leading to thousands of papers published and/or talks presented in journals and conferences about various related aspects. This book is basically an outgrowth of my

academic research work and postgraduate teaching activities. It provides an in-depth treatment to problems of interconnected systems which some requirements are imposed in the course of analysis and/or design.

In engineering and economic organizations, one can easily recognize the presence of several decision makers (DMs) that

1. generate decisions and control variables by acting on the same system,
2. have access to different information coming from the controlled system and
3. pursue different goals.

Such organizations are addressed in the wide research area called "game theory."

For the purpose of uniformity, we will adopt the following definition of an interconnected system throughout this book: *a dynamical system which contains a number of interdependent constituents which serve particular functions*, *share resources*, *and are governed by a set of interrelated goals and constraints*.

It is manifested that "complexity" is an essential and dominating problem in systems theory and practice. It leads to severe difficulties that are encountered in the tasks of analyzing, designing, and implementing appropriate control strategies and algorithms. With focus on the control design goal, these difficulties arise mainly from the underlying multi-modes of operation and gain perturbations, which from now onwards we term them as *design constraints*. Given the advanced development in robust control and time-delay theories, we treat uncertain time-delay systems as basic module in our subsequent analysis.

From this perspective, the notion of DS introduced in the context of control engineering problems arose when it became clear that there are real world control problems that cannot be solved by using conventional approaches. Such typical problems arise in the control of interconnected power systems with strong interactions, water systems which are widely distributed in space, traffic systems with many external signal, or large-space flexible structures. These problems recall for new ideas for dividing the analysis and synthesis of the overall system into independent or almost independent subproblems, for dealing with the incomplete information about the system, for coping with the uncertainties and for dealing with time-delays.

This book is written about recent advances in decentralized systems theories and methods with design constraints. It aims at providing a rigorous framework for studying analysis, stability and control problems of DS while addressing the dominating sources of design constraints. The primary objective is to focus on robust decentralized methods based on linear matrix inequalities framework while tacking into consideration possible design considerations and/or constraints. Such constraints include the presence of quantizers, nonlinear/overflow elements, encoder/decoder and networks.

The main features of the book are:

(I) It provides key concepts of decentralized systems with their proofs followed by efficient computational method;
(II) It establishes decentralized control techniques under design constraints; and
(III) It gives some representative applications.

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