
Preface

Stability theory has allowed us to study both qualitative and quantitative properties of dynamical systems, and control theory has played a key role in designing numerous systems. Contemporary sensing and communication networks enable collection and subscription of geographically-distributed information and such information can be used to enhance significantly the performance of many of existing systems. Through a shared sensing/communication network, heterogeneous systems can now be controlled to operate robustly and autonomously; cooperative control is to make the systems act as one group and exhibit certain cooperative behavior, and it must be pliable to physical and environmental constraints as well as be robust to intermittency, latency and changing patterns of the information flow in the network. This book attempts to provide a detailed coverage on the tools of and the results on analyzing and synthesizing cooperative systems. Dynamical systems under consideration can be either continuous-time or discrete-time, either linear or non-linear, and either unconstrained or constrained.

Technical contents of the book are divided into three parts. The first part consists of Chapters 1, 2, and 4. Chapter 1 provides an overview of cooperative behaviors, kinematical and dynamical modeling approaches, and typical vehicle models. Chapter 2 contains a review of standard analysis and design tools in both linear control theory and non-linear control theory. Chapter 4 is a focused treatment of non-negative matrices and their properties, multiplicative sequence convergence of non-negative and row-stochastic matrices, and the presence of these matrices and sequences in linear cooperative systems.

The second part of the book deals with cooperative control designs that synthesize cooperative behaviors for dynamical systems. In Chapter 5, linear dynamical systems are considered, the matrix-theoretical approach developed in Chapter 4 is used to conclude cooperative stability in the presence of local, intermittent, and unpredictable changes in their sensing and communication network, and a class of linear cooperative controls is designed based only on relative measurements of neighbors' outputs. In Chapter 6, cooperative stability of heterogeneous non-linear systems is considered, a comparative

and topology-based Lyapunov argument and the corresponding comparison theorem on cooperative stability are introduced, and cooperative controls are designed for several classes of non-linear networked systems.

As the third part, the aforementioned results are applied to a team of unmanned ground and aerial vehicles. It is revealed in Chapter 1 that these vehicles belong to the class of so-called non-holonomic systems. Accordingly, in Chapter 3, properties of non-holonomic systems are investigated, their canonical form is derived, and path planning and control designs for an individual non-holonomic system are carried out. Application of cooperative control to vehicle systems can be found in Sections 5.3, 6.5 and 6.6.

During the last 18 years at University of Central Florida, I have developed and taught several new courses, including “EEL4664 Autonomous Robotic Systems,” “EEL6667 Planning and Control for Mobile Robotic Systems,” and “EEL6683 Cooperative Control of Networked and Autonomous Systems.” In recent years I also taught summer short courses and seminars on these topics at several universities abroad. This book is the outgrowth of my course notes, and it incorporates many research results in the most recent literature. When teaching senior undergraduate students, I have chosen to cover mainly all the matrix results in Chapters 2 and 4, to focus upon linear cooperative systems in Chapter 5, and to apply cooperative control to simple vehicle models (with the aid of dynamic feedback linearization in Chapter 3). At the graduate level, many of our students have already taken our courses on linear system theory and on non-linear systems, and hence they are able to go through most of the materials in the book. In analyzing and designing cooperative systems, autonomous vehicles are used as examples. Most students appear to find this a happy pedagogical practice, since they become familiar with both theory and application(s).

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Zhihua Qu

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Qu, Z.

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