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# Constructive Nonlinear Control

With 41 Figures

Springer

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# Preface

In this book several streams of nonlinear control theory are merged and directed towards a constructive solution of the feedback stabilization problem. Analytic, geometric and asymptotic concepts are assembled as design tools for a wide variety of nonlinear phenomena and structures. Differential-geometric concepts reveal important structural properties of nonlinear systems, but allow no margin for modeling errors. To overcome this deficiency, we combine them with analytic concepts of passivity, optimality and Lyapunov stability. In this way geometry serves as a guide for construction of design procedures, while analysis provides robustness tools which geometry lacks.

Our main tool is passivity. As a common thread, it connects all the chapters of the book. Passivity properties are induced by *feedback passivation* designs. Until recently, these designs were restricted to weakly minimum phase systems with relative degree one. Our recursive designs remove these restrictions. They are applicable to wider classes of nonlinear systems characterized by feedback, feedforward, and interlaced structures.

After the introductory chapter, the presentation is organized in two major parts. The basic nonlinear system concepts - passivity, optimality, and stability margins - are presented in Chapters 2 and 3 in a novel way as design tools. Most of the new results appear in Chapters 4, 5, and 6. For cascade systems, and then, recursively, for larger classes of nonlinear systems, we construct design procedures which result in feedback systems with optimality properties and stability margins.

The book differs from other books on nonlinear control. It is more design-oriented than the differential-geometric texts by Isidori [43] and Nijmeijer and Van der Schaft [84]. It complements the books by Krstić, Kanellakopoulos and Kokotović [61] and Freeman and Kokotović [26], by broadening the class of systems and design tools. The book is written for an audience of graduate students, control engineers, and applied mathematicians interested in control theory. It is self-contained and accessible with a basic knowledge of control theory as in Anderson and Moore [1], and nonlinear systems as in Khalil [56].

For clarity, most of the concepts are introduced through and explained by examples. Design applications are illustrated on several physical models of practical interest.

The book can be used for a first level graduate course on nonlinear control, or as a collateral reading for a broader control theory course. Chapters 2, 3, and 4 are suitable for a first course on nonlinear control, while Chapters 5 and 6 can be incorporated in a more advanced course on nonlinear feedback design.

* * *

The book is a result of the postdoctoral research by the first two authors with the third author at the Center for Control Engineering and Computation, University of California, Santa Barbara. In the cooperative atmosphere of the Center, we have been inspired by, and received help from, many of our colleagues. The strongest influence on the content of the book came from Randy Freeman and his ideas on inverse optimality. We are also thankful to Dirk Aeyels, Mohammed Dahleh, Miroslav Krstić, Zigang Pan, Laurent Praly and Andrew Teel who helped us with criticism and advice on specific sections of the book. Gang Tao generously helped us with the final preparation of the manuscript. Equally generous were our graduate students Dan Fontaine with expert execution of figures, Srinivasa Salapaka and Michael Larsen with simulations, and Kenan Ezal with proofreading.

Our families contributed to this project by their support and endurance. Ivana, Edith, Simon and Filip often saw their fathers absent or absent-minded. Our wives, Natalie, Seka, and Anna unwaveringly carried the heaviest burden. We thank them for their infinite stability margins.

* * *

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