Preface

This book presents new computational tools for the $\mathcal{H}_\infty$ control of distributed parameter systems. Transfer functions are considered as input-output descriptions for the plants to be controlled. Detailed examples are given from various applications ranging from computer/communication networks and mechanical systems to biological systems. The main emphasis is on the computation of the controller parameters and reliable implementation. Over the last 10 years new results have been obtained for the computation of the $\mathcal{H}_\infty$ controllers for a large class of distributed parameter systems. This book presents some of these results, taken from articles written by the authors. It is assumed that the plants to be controlled are described by their transfer functions and the weights defining the $\mathcal{H}_\infty$ optimality condition are low order rational functions. First, a special type of factorization is done on the plant transfer function. For this purpose new computational techniques are presented (the general case considers retarded and neutral time delay systems, but for other classes of distributed parameter systems the methods are demonstrated on specific examples). Second, the computation of the optimal controller is reduced to solving a set of finitely many linear equations. Finally, reliable implementation (in terms of series, parallel, and feedback connections of stable transfer functions) is demonstrated. Most of the book is devoted to single-input-single-output plants; in the last chapter, extensions to a certain class of multiple-input-multiple-output plants are demonstrated.

We believe that a first year graduate level control course can be taught from the material presented here. In fact, the first author taught courses at Bilkent University and at The Ohio State University, covering most of the topics included in the book.

Many people have helped us in the production of this book. Historically, we first got interested in the subject matter thanks to Allen Tannenbaum, Ciprian Foias, George Zames, Pramod Khargonekar, Malcom Smith, and Tryphon Georgiou. Some of the earlier results discussed in various parts of the book are based on their contributions. In fact, theoretical foundations of the present work were laid by these pioneers from the mid-1980s to the mid-1990s. One of the first books on this theory is by Foias, Özbay, and Tannenbaum [66].

Parts of the book on fractional order systems are based on discussions with Catherine Bonnet. On several occasions over the last 10 years, the first and last authors have visited INRIA-Saclay and L2S to collaborate with her and with Silviu Niculescu on related topics. We also thank them for providing us an early version of a software, YALTA, developed in their group, which has proven to be very useful in finding the right half plane roots of quasi-polynomials (a crucial step in factorizations used in the book). Likewise, we thank Tomas Vyhlidal for sending us his version of the quasi-polynomial root finding code, `QPmR`. We also had fruitful discussions with Jie Chen on the delay margin optimization problem (Section 5.1.2). The second author thanks Wim Michiels from K.U. Leuven for high quality research collaboration in his postdoctoral

study on numerical methods of $\mathcal{H}_\infty$ norm computation and fixed-order $\mathcal{H}_\infty$ controller design.

As one can easily identify, detailed controller designs in the book are in Chapters 6 and 7. The first section of Chapter 6 is expanded from an old joint work with Onur Toker. The newer part of Chapter 6 (mostly Section 6.2) is based on a joint paper with Mustafa Oğuz Yeğin (more detailed examples are in his MS thesis [265]). The new formula for the optimal Nevanlinna–Pick interpolant (Section 2.4.1) is from a recent work with Veysel Yücesoy. In their MS theses, Erdem Karagül and Ezgi Ateş have worked out examples for $\mathcal{H}_\infty$ control of fractional order systems, and $\mathcal{H}_\infty$-based estimation, respectively. These examples are reworked in the book (Sections 6.3.3 and 6.3.5). All other parts of the book are based on the authors' individual or joint publications.

We should mention that Kirsten Morris was an invisible force behind the conception of this project; she was one of the few vocal people to give us encouragement and suggestions before we considered writing such a book.

Our editor, Elizabeth Greenspan, has been very patient with us throughout the writing process, which was painfully slow due to the first author's involvement with various other activities he could not decline. Completion of the book was possible thanks to a sabbatical leave granted from Bilkent University, and thanks to The Ohio State University for hosting him during this leave.

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Özlem and Olsan E. Özbay
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