Preface

Design of optimal and robust controllers has been one of the most active research areas in linear control systems engineering. Several methods have been developed that enable the controller to cope with parametric uncertainties (both structured and unstructured) in the plant dynamics. A common denominator of these methods is that they rely on the YJBK parameterization of all stabilizing controllers for a fixed linear time-invariant plant, which provides a free parameter over which an appropriate function of a closed-loop transfer function may be minimized. Using this framework, elegant techniques for minimizing different norms of the closed-loop transfer functions have been formulated. In addition, efficient numerical approaches have been developed. The majority of the foregoing formulations represents a remarkable direction of systems research reflecting robust stability and/or robust performance.
The underlying assumption of modern robust control design methods thus far is that the designed controller will be implemented exactly. On one hand, this is generally valid when the main focus is on the plant uncertainty and considering that the controller will be implemented using high-precision hardware. On the other hand, it is expected that any controller being a part of a closed-loop system must be able to tolerate some uncertainty in its coefficients. Sources of this uncertainties include finite word length, imprecision inherent in analog-digital and digital-analog conversions, finite resolution measuring equipments and round-off errors in numerical computations, to name a few. More importantly, controller redesign is a basic operation in fine-tuning of the developed controllers to be several practical considerations that might have been overlooked. This raises an important issue, that is a robust controller can be very sensitive, or fragile, with respect to errors or perturbations in the controller coefficients. In turn, that brings about a fundamental problem in robust control system design which has been recently termed the fragility problem and hence the design of non-fragile (resilient) controller is an important research topic.

This book provides a complete description of resilient control theory. In our viewpoint, this theory stands as robust redesign approach. Thus the book unifies the methods for developing resilient controllers and filters for a class of uncertain dynamical systems and reports on the recent advances in design methodologies. Seeking generality, this class possesses inherent time-delay model, parametric uncertainties and external disturbances. Indeed, this class reflects several important and practical system applications. Throughout the book, we follow a systematic modeling approach in that a convenient representation of the system state would be by observing a finite-dimensional vector at a particular instant of time and then examining the subsequent behavior. Looked at in this light, the primary objective of this book is to present an introductory, yet comprehensive, treatment of resilient controller design methods by jointly combining three fundamental attributes:

- the system dynamics possesses an inherent time-delay,
- the system parameters may undergo uncertainties and
- the controller gains are subject to perturbations.

To the best of our knowledge, the integration of these attributes is quite unique and deserves special consideration. A basic feature of the book is that it places great emphasis on the derivation of necessary and sufficient design conditions and on the use of linear matrix inequalities as a convenient computational tool.

The major thrust of this book is to focus on material related to the new developments in the design methods of resilient controllers including guaranteed cost control, $\mathcal{H}_\infty$ control for both state-feedback and output feedback. After an introductory chapter, it is intended to split the book into seven self-contained chapters with each chapter being equipped with illustrative examples, problems and questions. The book will be supplemented by an extended bibliography, appropriate appendices and indexes.

It is planned while organizing the material that this book would be appropriate for use either as graduate-level textbook in applied mathematics as well as different engineering disciplines (electrical, mechanical, civil, chemical, systems), a good volume for independent study or a reference for practicing engineers, interested readers, researchers and students.

Acknowledgment

Although the material contained in this volume is an outgrowth of my academic research activities over the past several years, the idea of writing the book arouse and developed only after joining UAE University in fall 2002. In this regard, the overall scientific environment at UAEU is gratefully recorded. Special thanks must go to my colleagues Dr Abdulla Ismail, Dr Habib-Ur Rehman, Dr Hazem Nounou and Dr Mohamed S. Laghari of the Electrical Engineering department for providing various sources of help.

I am deeply appreciated to the Scientific Research Council of UAE University for providing a support to this work through a research grant # 02 – 04 – 7 – 11/03.

In writing this monograph, I took the approach of referring within the text to papers and/or books which I believed taught us some ideas and methods. Then I further complement this by adding some notes and questions at the end of each chapter to shed some light on other related results. I therefore apologize in advance in case I committed injustice and assure our colleagues that any mistake was unintentional.

I am immensely pleased for many stimulating discussions with colleagues, students and friends throughout my technical career which have definitely enriched our knowledge and experience.

The great support and enthusiasm of Professor Manfred Thoma as well as Dr Thomas Ditzinger and Miss Heather King, Engineering Editorial of Springer, were instrumental to the success of this project. The expert assistance and invaluable advises of Frank Holzwarth are gratefully acknowledged.

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Al-Ain, UAE *Magdi S. Mahmoud*
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