SERIES EDITORS' FOREWORD

The series *Advances in Industrial Control* aims to report and encourage technology transfer in control engineering. The rapid development of control technology has an impact on all areas of the control discipline. New theory, new controllers, actuators, sensors, new industrial processes, computer methods, new applications, new philosophies..., new challenges. Much of this development work resides in industrial reports, feasibility study papers and the reports of advanced collaborative projects. The series offers an opportunity for researchers to present an extended exposition of such new work in all aspects of industrial control for wider and rapid dissemination.

This new monograph by Alberto Isidori, Lorenzo Marconi and Andrea Serrani concerns nonlinear systems, robust control design and detailed applications studies. The opening chapter is a challenging development of a robust design theory, firstly performed with a linear system description and then followed by the nonlinear system control design extensions. The presentation is succinct, brisk and with depth. The mathematics here make precise some common industrial control design situations and the objective is a robust control design procedure which is analogous to "the classical way in which integral-control-based schemes cope with constant but unknown disturbances".

The applications for the newly devised robust controller design procedures are Low Earth Orbit (LEO) control, Vertical Take-Off and Landing Control (tracking and stabilizer) and helicopter control. Four very detailed chapters, one for each application, present review material, design insights, and finally simulation results. These are all difficult high-performance uncertain control system design exercises which make this an excellent and distinguished entry to the *Advances in Industrial Control* monograph series.

One of the objectives of the series is to introduce readers to techniques which might be appropriate for application in other areas of industrial control. The first chapter of this monograph prescribes a new robust control procedure which could easily be considered for application in other areas. As such both control systems academics and industrial control engineers will find this presentation and the subsequent applications intriguing, illuminating and inspiring.

M.J. Grimble and M.A. Johnson
Industrial Control Centre
Glasgow, Scotland, U.K.

PREFACE

The purpose of this book is to present a self-contained and coordinated description of a new design philosophy for nonlinear control systems, and its application to autonomous guidance in highly uncertain conditions. Specifically, the book describes a number of new design principles for robust asymptotic tracking and/or disturbance attenuation. The core of these methods is the design of robust and adaptive internal models of any exogenous perturbation and the use of this model to asymptotically offset their effect.

It has long been recognized that, in linear systems, a control philosophy in which the control device contains a model of certain classes of external disturbances and/or commands is able to handle simultaneously plant parameter uncertainties as well as uncertainties in the data which characterize the external stimuli. In fact, it has been proven that, if the trajectory which the regulated output of the plant is required to track (or the disturbance which is to be rejected) belongs to the set of all trajectories generated by some fixed finite-dimensional linear system, a controller which incorporates an internal model of such a system is able to secure asymptotic decay to zero of the tracking error for every possible trajectory in this set and does it robustly with respect to parameter uncertainties. Tracking via internal-model-based control is particularly effective in handling highly nonlinear uncertain dynamics. In fact, in contrast to the basic design philosophy underlying dynamic inversion and most methods for adaptive tracking of nonlinear systems, this design philosophy does not appeal to the idea of using control to offset the presence of specific nonlinear effects. Rather, the specific feature of the internal model is to shape the nonlinear dynamics of the closed-loop system in such a way as to induce a manifold which remains invariant in the presence of a given set of nonlinear uncertainties and on which the tracking error remains identically zero for a fixed set of required trajectories.

The purpose of this book is to describe in detail how the classical repertoire of internal model based design can be enhanced in two basically new directions: adaptation of the parameters of the internal model and stabilization in the large of the associated zero-error manifold. The former makes it possible to deal with tracking/rejection problems in which not just initial conditions, but also the "natural frequencies" of the model of the disturbance inputs are unknown, and breaks a long-standing barrier in feedback design.

The latter makes it possible, in dealing with highly nonlinear dynamics, to substantially depart from local analysis and from the need for an accurate model of the controlled plant.

As a demonstration of the effectiveness of these new design techniques, the book describes three relevant case studies in autonomous guidance: attitude control of a low-earth-orbit satellite, and autonomous landing of a vertical takeoff-and-landing aircraft and of a helicopter on the deck of a ship which oscillates in high seas. The study of these cases consists of two distinct phases. In the first one, the (possibly adaptive) internal model of the exogenous inputs is synthesized. In the second one, a feedback law securing convergence to the zero-error manifold for any arbitrarily large envelope of initial data as well as parameter uncertainties is designed. It is precisely the ambition of obtaining convergence for large initial deviations (or uncertainties) that make the design challenging. This is reflected in a number of elaborate rigorous convergence proofs that are dispersed throughout the book. In the course of the research project in which these case studies have been worked out, the authors had stimulating exchanges of ideas with the friends and colleagues Alessandro Astolfi, Claudio Bonivento, Chris Byrnes, Lorenzo Pollini. Their contribution in this way is deeply appreciated.

The book is intended as a graduate text as well as a reference to scientists and engineers interested in the design of feedback laws for nonlinear control systems.

TABLE OF CONTENTS

Springer

http://www.springer.com/978-1-85233-695-0

Robust Autonomous Guidance
An Internal Model Approach
Isidori, A.; Marconi, L.; Serrani, A.
2003, XVI, 229 p., Hardcover
ISBN: 978-1-85233-695-0