BOOK REVIEWS

Robust Estimation and Failure Detection

A Concise Treatment

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The book belongs to the *"Advances in Industrial Control"* series, a series destined to report and encourage technology transfer to control engineering. It brings together two of the most exciting areas of advanced signal processing and control: development of optimal estimators for uncertain signal and noise models and failure detection and isolation.

The book provides a gradual build-up of ideas moving from traditional Wiener and Kalman filtering to risk sensitive control and estimation problems. It is well- known that the solution of a robust estimation problem is crucial to solving the fault monitoring and detection problem effectively, this making one of the main difficulties in deciding whether an estimated fault condition is really due to a fault, or simply to poor system models.

The book provides a novel solution of a class of robust estimation problems and includes convincing application studies. It represents an amplification of the author's doctoral thesis, and is a concise treatment of recursive estimation and failure detection in dynamic plants.

This book is characterized by two unique features. First , it treats both optimal or Kalman filter, as well as the relatively new subject of robust filtering, or filtering for plants with uncertain dynamics and disturbance models. Second, it combines two subjects, namely state estimation and failure detection for dynamic systems, into one entity.

In the last fifteen years real progress has been made in the theory and implementation of control systems with robustness to both disturbance and plant model uncertainties. As a result, compensators that achieve both robust stability and performance objectives are no longer uncommon, at least for linear plants. These advances in control can benefit filtering theory and design.

The book includes **six Chapters** and **four Appendices**.

Chapter 1, *Introduction,* sets the background of the book, circumscribes its audience, and overviews the contents.

Chapter 2, *Estimation and failure detection: An overview*, presents an overview of estimation and failure detection for linear systems. First, a brief description of the Wiener and Kalman filters, the most commonly used filters for dynamic systems is given, and problems that are more general than linear least squares estimation, including robust filtering, are discussed. The need for robust filters is motivated, and the way the small gain theorem applies in robust estimation, is demonstrated. The robust filtering problem and the risk sensitive estimation problem, the stochastic version of robust filtering are also presented. The last Section of the Chapter offers a similar discussion on the problem of failure detection and isolation (FDI) with emphasis on the role of the Kalman filter. The generalized likelihood ratio test for the two different classes of failures is introduced, the sensitivity of this test to modelling uncertainties is demonstrated, and the subject of robust detection is motivated.

Chapter 3, *Discrete-time robust estimation,* derives estimators for discrete-time linear systems that are robust to plant and noise model uncertainties, using an approach based on a game theoretic formulation. An estimator for time-varying finite-horizon discrete-time linear systems, where the plant model dynamics is assumed to be accurate, but with models of the disturbances unknown, is then derivate. In the next Sections there are discussed estimators for finite-horizon discrete-time linear systems with both the plant dynamics and the disturbance models uncertain, the solution for the steady-state infinite-horizon problem in stable time-

invariant systems, the problem of fixed-interval smoothing, and finally there are given two numerical examples of a simple two-state system and of an application of robust filters to model based attitude determination.

Chapter 4, *Stochastic interpretation of robust estimation: Risk sensitivity*, is meant to demonstrate the relationship between risk sensitive and game theoretic estimation. It also presents the extension of the stochastic interpretation to systems with uncertain plant dynamics and finally a numerical example is discussed. The stochastic risk sensitive estimation problem is shown to be similar in nature to determinisic filtering problems dealt with in previous Chapters.

In **Chapter 5,** *Robust failure detection and isolation,* a methodology for the detection and isolation of failures in the presence of model uncertainties, is proposed. Its purpose is to be able to design an algorithm which, while being insensitive to failure mode, noise and plant model uncertainties, proves sensitive to the occurence of a failure. After stating the robust detection and isolation problem, a likelihood ratio test based on a Gauss-Markov failure model is initiated, assuming an accurate plant model, and the effect of plant model uncertainties on the algorithm is considered. Finally an algorithm showing robustness to failure mode, noise and plant model uncertainties, is described.

Chapter 6, *Two applications*, discusses which the two applications consist in: the first one is concerned with failure detection in an underwater vehicle, and the second, which is both a detection and an estimation problem, refers the monitoring and attitude control system of re-entry vehicles during the flight transition phase from space back into the atmosphere.

The **four Appendices** of the book present a derivation of the Kalman filter (Appendix A), some methods for computing the probability density functions of outputs in linear systems and their quadratic form (Appendix B), derive some estimators for continuous-time linear systems that are robust to a general class of model uncertainties (Appendix C) and include relevant numerical data for the applications discussed.

At the end of each Chapter, the reader is presented a short summary of the Chapter contents. References are given at the end of the book, mainly in the form which essential books and journals propose for the subject under study. A **Subject Index** constitutes the last Part of the book.

Concerning the readership of the book, they may include students, researchers, and practicing engineers who work with, or are interested in recursive estimation for dynamic systems. It is worth mentioning the author's preoccupation with developing a robust filtering methodology, which a reader with no background in control theory can highly appreciate. Also engineers and researchers interested in the problem of plant health monitoring and failure diagnosis will find the book helpful for their activity.

The material presented in the book is accessible to the novice in both filtering and detection theory. The reader is assumed to have some familiarity with linear systems and probability. This is generally assumed for advanced undergraduate and graduate level students.

The Chapters of the book are very well- structured, presented with clarity, and the reader's understanding is helped with some examples. It is to note the fluency of the style, the absence of typographical errors and the accuracy of the graphical material, which all makes the book quite agreeable for reading. From a pedagogical point of view the merit of the book is even greater.

Finally, I should say that this is a unique book in terms of the topics selected and the approach made, and I strongly recommend it to researchers and practitioners in the field of estimation and failure detection, who will certainly find this book an important reference. The series editors must be congratulated for their inspiration in inviting the author's contribution to the "*Advances in Industrial Control*" series.

Theodor- Dan Popescu