Adaptive Filtering and Change Detection

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The book is mainly dedicated to the areas of adaptive filtering and change detection, fields quite active in research and applications. It has the aim to provide theory, algorithms and applications of adaptive filters with or without support from change detection algorithms. Industrial interest in adaptive filtering grows continously with the increase in computer performance that allows ever more complex algorithms to be run in real time. Change detection is a type of adaptive filtering for non-stationary signals and is also the basic tool in fault detection and diagnosis.

The book answers many problems that could be formulated by an applied engineer or researcher: from algorithms with complete derivations and their properties to implementation aspects. The specific applications can be divided into the following categories: surveillance and parameter tracking, state estimation, and fault detection.

The book has been originally developed during several courses, with major revisions in between held by the author at Nordic Matlab Conference (1997), SAAB (1998), ABB Corporate Research (1998) and graduate school Ecsel at Linkoping University (1998, 1999). It contains five main parts, with 13 chapters, two appendices, bibliography and an index.

Part I, with two chapters, should serve as an overview of the field, suitable for those who want to know *what* can be done rather *how* it is done. Chapter 1 "Extended summary" is a summary and overview of the book, while Chapter 2 "Applications" overviews possible applications and reviews the basic mathematical signal models. Both chapters are helpful for people from within industry who want an orientation in what adaptive filtering is, and what change detection can add to performance. An important goal is to understand what kind of practical problems can be solved.

Part II, on signal estimation, which includes two chapters, has many interesting signal processing applications, but it also serves as a primer on the change detection chapters in Part III and IV. Chapter 3 "On-line approaches" presents a review of averaging strategies, stopping rules, and change detection ideas. Most of the ideas to follow in subsequent chapters are introduced here. Chapter 4 "Off-line approaches" surveys off-line formulations of single and multiple change point estimation. This chapter is basically a projection of the more general results in Chapter 7 to the case of signal estimation. The chapter ends by some applications in the area of photon emissions, altitude sensor quality and rat EEG.

Part III, having as subject parameter estimation, contains three chapters. Chapter 5 "Adaptive filtering" starts with signal models and system identification and continues with some adaptive algorithms (LS, RLS and Kalman filter) and performance analysis of them. Other problems discussed in the chapter are: whiteness based change detection, adaptive filters in communications, noise cancelation, three applications (human EEG, DC motor and friction estimation) and speech coding in GSM; square root implementation and some algorithm properties derivations make the subject of two local appendices. Chapter 6 "Change detection based on sliding windows" presents basic elements on change detection problem, introduces some distance measures, likelihood based detection and isolation, design optimization and three applications on rat EEG, belching sheep and digital communications. Chapter 7 "Change detection based on filter banks" contains a basics section, statistical criteria, information based criteria, on-line local search and off-line search for optimum, three applications: EEG signals storing, speech segmentation and car's driven path segmentation and ends by two local appendices on two inequalities for likelihoods and main theorems on posterior probabilities of a jump sequence.

Part IV, dedicated to state estimation, includes four chapters. Chapter 8 "Kalman filtering" explains the fundamentals of Kalman filter theory by a few illustrative examples, and discusses other specific problems: state space modeling, the Kalman filter, time-invariant signal model, smoothing problem, computational aspects, square root implementation, sensor fusion, the extended Kalman filter, whiteness based change detection using Kalman filter, estimation of covariances in state space models. The chapter ends by three applications on DC motor, target tracking and GPS. Chapter 9 "Change detection based on likelihood ratios" is devoted to the problem of detecting additive abrupt changes in linear state space models. After some basic elements the likelihood approach, GLR and MLR tests are introduced.

Performance, robustness and sensitivity for GLR and three different MLR variants for a first order motion model are investigated in a simulation study. Derivation of the GLR test and LS-based derivation of the MLR test end the chapter. Chapter 10 "Change detection based on multiple models" addresses the most general problem formulation of detection in linear systems. First, some basic elements and examples of applications are presented, followed by on-line and off-line algorithms and local pruning in blind equalization; a local appendix on posterior distribution ends this chapter. Chapter 11 "Change detection based on algebraical consistency tests" presents parity space change detection problem, an observer approach, an input-output approach and three applications on simulated DC motor, DC motor and vertical aircraft dynamics.

Part V, with two chapters, is a somewhat abstract presentation of filter theory in general, without using explicit signal models. Chapter 12 "Evaluation theory" has as main topics filter evaluation. evaluation of change detectors and performance optimization. Chapter 13 "Linear estimation" gets a geometric understanding of linear estimation, presents conditional expectations, derives and interprets the Wiener filters.

Appendix A overviews the signal models used in the book, and presents the main notations, while Appendix B summarizes notation used in the literature on fault detection. References, in a great number, are given at the end of the book and include the most recent works on the topic. A useful Index constitutes the last part of the book.

We must mention, as a merit of the book, the inclusion of many examples illustrating the richness of its potential applications. The book includes more than 130 examples, of which at least 10 are case studies and other examples are "student approach". Many of the examples in the book come from academic and professional consulting, and are the results of a strong cooperation of the author with Volvo car, SAAB Aircraft, SAAB Dynamics, ABB Corporate Research, Ericsson Radio, Ericsson Components and Ericsson-SAAB Avionics.

The book is strong connection to MATLAB. The author develops a toolbox, where each algorithm in the book is implemented as one function, builts a demo for each example, whose algorithm design, tuning, testing and learning are done in the graphical user interface. The toolbox works under MATLAB, but to some extent also under the freeware clone *Octave*. It is also worth mentioning that this toolbox had been developed before the plans to write the book, and the outline and structure of the book follow many features of this toolbox.

The book bridges a gap in the literature with a unified treatment of adaptive filtering and change detection, emphasizing that change detection is a natural extension of adaptive filters, and adaptive filters are the basic building blocks in all change detectors.

The material of the book is well organized, presented with clarity, and the reader's understanding is helped by many examples, developed in sufficient detail. Also, all arguments are clear and logically correct. It is worth mentioning the fluency of the style, the absence of the typographical errors and the accuracy of graphical material that all make the book agreeable to read.

Concerning the audience of the book, it is addressed to applied engineers, researcher and postgraduate students studying digital signal processing. It is not a book for the unitiated; some mathematical maturity is essential to study the material. An understanding of the book requires from reader some prior knowlwdge on statistical theory, calculus, matrix algebra, signal modeling and classical filter theory.

To conclude, the book presents a comprehensive and complete treatment of adaptive filtering, and provides a unifying framework for the theory of change detection based on a filtering approach. It combines mathematical tools (algebra, calculus, statistics) and applications areas (airborne, automotive, communications systems, standard signal processing and automatic control applications).

In my opinion, this is a good book in terms of the topics selected and the approaches adopted and I am sure that the book will prove useful for all specialists interested of the digital signal processing, who will find the book an indispensable and enlightening read.

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