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ADAPTIVE WIENER FILTERS IN CONTROL AND SIGNAL PROCESSING

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1 Introduction

In this project, work has been carried out on problems spanning the fields of Signal processing, Communications, and Control. The idea is to develop general tools and methods useful for a large range of problems. A guiding principle is to formulate general problems, originating from relevant applications. Here *equalization of fading mobile radio channels* has been a main source of inspiration and also a useful application for testing of new ideas.

Very central in our work is the desire to obtain explicit solutions and to gain engineering insight. As a means to accomplish that, the Polynomial Systems framework has been used in conjunction with general IIR-filter structures, implicit adaptive schemes, probabilistic descriptions of model errors, and utilization of *a priori* information. Our long term goal is to provide a new and general concept for solving a variety of important problems in signal processing, communications and control. A step toward this goal is the the completion of the book chapters [1],[2].

Next, we will focus on some of the most important main activities within the project. For a more complete picture, see the reference list.

2 Multivariable estimation and control

The initial steps in this project were taken towards linear recursive and decison feedback equalization, [4],[6]. During that work, in particular when struggling with the decision feedback equalization problem in [6], we felt that no simple and systematic method was available for solving (multivariable) estimation and control problems, formulated in input–output form. In [8] and [11], such a metod is suggested. The method has proved its utility in solving a variety of estimation and control problems, see eg. [1],[2]. The approach has also been generalized to cope with robust estimation and control problems [12], [27], [28]. Relations between this method, the classical Wiener approach, and the inner–outer factorization approach has been clarified in [8] and [15].

3 Adaptive equalization

We advocate the use of *indirect* adaptive schemes. They offer considerable advantages as compared to direct schemes. For example, the number of parameters in a channel estimator is often smaller than the required number of equalizer parameters. This is particularly evident when large smoothing lags are used. In an indirect scheme, the equalizer parameters do not need to be updated at every sample. The updating can be tailored to the rate of change of the channel coefficients. For severe time variations, as in eg. a Rayleigh fading mobil radio environment, the channel parameters vary more smoothly than the corresponding equalizer parameters do. This makes tracking easier. Also, time variations of channel coefficients can be modelled explicitely, eg. by means of nonlinear functions. If feasible, this would be much harder to accomplish for the equalizer parameters directly. Furthermore, there might exist several local minima to loss functions used in direct schemes. For fading mobile radio channels, *deterministic modelling* of channel coefficients has proved to be very useful. In a Rayleigh fading environment, the time–variant channel coefficients resemble sinusoids with frequencies proportional to the speed of the mobile, on average. An adequate model would thus be a first order Fourier series expansion. Such *a priori* information can also be built into a Kalman filter.

Based on an estimated channel model, a Viterbi detector, or a DFE could be used to estimate the transmitted sequence. We have used the approaches described above for channel tracking. When tested on a channel model used in the specifications for the North American mobile radio standard, they performed better than both direct and indirect schemes based on ordinary RLS–tracking. See [3], and [29], presented at this conference.

4 Robust estimation and control

Irrespective of how models in signal processing, communications and control are obtained, they are imperfect. This is so, for example, in mobile radio applications where standards often impose constraints on the acheivable model quality. To obtain filters and controllers which are insensitive to uncertainties, we suggest a robust design philosophy based on probabilistic descriptions of model errors. For an ensemble of systems, it outperforms both nominal and minimax designs on average. The idea is that large but unlikely model uncertainties should be credited, but they are not allowed to dominate the design. In this way conservative filters are avoided.

As error models we use polynomial fractions, having stochastic numerators and fixed denominators. (How to obtain these error models from data is under current investigation.) This structure is flexible enough without sacrificing linearity. Results have been obtained for linear recursive equalizers, decision feedback equalizers, state estimation, and feedforward control. Somewhat surprisingly, the resulting design equations become almost as simple as in the nominal case. Work on robust feedback control is currently under way. For details see [12], [28], and [27], presented at this conference.

5 Time–variant systems

As a complement to adaptation and robust designs, one might think of a time–variant system as a means to describe measured data. Work has been initiated here and some introductory results obtained. It is our belief that nominal designs, adaptation, robust designs and designs based on time–variant systems are important *complements* to each other. Which approach to be preferred depends on the problem at hand. For example, in the European mobile radio standard, GSM, a robust equalizer, eg. along the lines of [27], might be preferred instead of an adaptive, for complexity and safety reasons.

We would like to conduct a more elaborate investigation of the different approaches, and their advantages, eg. for channel equalization. What can be gained by using an adaptive equalizer or a time–variant filter instead of a robust time–invariant equalizer? When can the performance improvement justify the increased complexity?

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