A MINIMUM VARIANCE APPROACH TO SYSTEM IDENTIFICATION AND ITS APPLICATIONS

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CERTIFICATE

I am satisfied that the thesis presented by Rajendra K.P. Bhatt is worthy of consideration for the award of the degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under my guidance and supervision and that the results contained in it have not been submitted in part or full to any other University or Institute for award of any degree/diploma.

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ABSTRACT

The main conclusion to be drawn from this thesis is that in using Kalman filter for identification of linear systems, there is no need to linearize an augmented (state and parameters) nonlinear system as is done in the extended and linearized Kalman filter methods. After developing the proposed minimum variance method for estimation of parameters of both discrete and continuous linear systems, it is used in construction of adaptive observer, adaptive state estimator, controllers for systems with unknown parameters and digital filters of specified response characteristics.

The proposed minimum variance (MV) method of parameter estimation is first developed for identifying a simple non-recursive deterministic system. Then, a linear, single input/output, discrete time, stochastic system in observable canonical form is identified. In this (MV) method, the parameters are modelled as time invariant states and the output is expressed as sum of two terms. The first is a product of a row vector consisting of previous measurements and the state (parameter) vector. The other term is a correlated noise, whose mean,

variance and correlation are not known because they depend upon the unknown parameters. This correlated noise is whitened by considering output samples which are (n+1) intervals apart where n is the order of the system. The statistics of this whitened noise are estimated and a Kalman filter is used which yields minimum variance estimates of unknown system parameters. This MV method is then extended for identification of slowly time varying parameters, input noise coefficient vector, multi input and multi output/input systems. The convergence of parameter estimates to their true values is shown and the method is analysed for the presence of bias. A method for bias estimation is given and it is observed in the simulation that the bias is present only during the transient response of the estimator.

The performance of the proposed MV method is compared with the least squares (LS) method. Several examples are solved. It is observed that for low noise variances, the MV method performs better than LS but for larger noise variances both have approximately the same performance. This is shown by using average estimates (based on 50 runs). The reason for such a performance is, also given.

The MV method is then developed for analog identification of continuous time systems. It begins with identification of a first order linear stochastic system with two unknowns

and then the method is generalized for n^{th} order systems. It is done so to elaborate the problem of increasing dimensionality of the Kalman-Bucy filter used for parameter estimation. Two methods are given. The first requires a filter of dimension $\frac{n(n+1)}{2} + 3n$ and in the second the filter dimension is reduced to 6n. A method to further reduce this dimension is also suggested. Only single input/output systems are considered.

The proposed MV method is then used in the construction of adaptive observer and adaptive state estimator for single input/output systems (analog and discrete). To construct these, the state is expressed as product of a matrix (containing unknown parameters) and a column vector (containing previous measurements). The estimated parameter values are used to yield state estimates. The MV method is then used in design of controllers for systems with unknown parameters. Two types of controllers are constructed. The first minimizes the accumulated state and input energies while the second yields minimum variance of the output. Simulation results are given only for the second controller. Finally, it is shown that any identification method can be used for design of recursive digital filters. It depends on the ability to convert the filter specifications into an input/output record. Both time and frequency domain specifications are considered. The simulation results are given only for time domain and the MV

method is used to evaluate the filter coefficients. The thesis concludes with few suggestions for further work.

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