

# Robust Identification of Time-Varying Stochastic Systems

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**Abstract** - This is a second part for robust parameters estimation. Here we shall consider the case of time-varying parameters. First is considered parameters as deterministic which are modeled as random walk. As an estimator the robust Kalman filter is used. As an input signal is considered 1/f signal with corresponding autocovariance function. This signal is suitable for system identification, especially for the case of robust experiment design. In this part the some modifications for robust Kalman filter, as in part 1, are used. The simulations show good behavior of robust real-time identification algorithms.

**Key words:** Robust Kalman filter, deterministic parameter variation, random walk, signal with prescribed autocovariance

## I. INTRODUCTION

The standard approach to control system design is to develop a linear model for the process for some operating condition and to design a controller having constant parameters. While linear, time invariant models no doubt form the most common way of a describing a dynamical system, it is also quite, often useful or necessary to employ other descriptions.

A specific, but common, case is when the systems properties vary with time. In this case, the task of the identification algorithm is to adapt itself so that it can approximately track the system dynamics, and it leads to the recursive identification. This is widely studied subject, and among the main references in this area of system identification we find the books [1-4].

One of the problems that appears in the area of identification of industrial processes is the identification in the presence of stochastic disturbance. Practical studies show that disturbance, in general, has non-Gaussian distribution. It is an especially important case when appears inconsistent, in relation to the main part of population, observations (outliers). Probability distributions for this case are approximately normal ( $\mathcal{E}$ -contaminated) and they are the subject of intense research in mathematical statistics. For such a case, we consider the robust procedures for parameters estimation.

We used output error (OE) type predictor for parametric identification of the dynamic system with time-varying parameters. Output error predictors can provide good performance when the plant output measurement is disturbed by noise. This can be explained by the fact that the output of this predictor does not directly depend upon the measured variables disturbed by noise, as the case with prediction error type predictor. The output of this predictor de-

pends indirectly upon the measurements through the adaptation algorithm but this dependence can decrease in time by using a decreasing adaptation gain [4-5].

In this paper, we will apply the robust filter theory for solving problem of the robust parameter estimation of time-varying system. The Kalman filter works well, but it assumes that the system model and noise statistics are known. If any of these assumptions are violated then the filter estimates can degrade, [6-7].

Although the Kalman filter is the optimal linear filter, it is not the optimal filter in general for non-Gaussian noise. Noise in nature is often approximately Gaussian but with heavier tails, and the Kalman filter can be modified to accommodate these types of density functions [8-10].

Because of some disadvantages which are associated with the robust Masreliez-Martin's filter, we have decided to make some modification of the robust filter proposed by Masreliez and Martin, [11].

Since modified Masreliez-Martin's robust filter showed satisfactory properties in the case of constant parameters, we will use this robust Kalman filter as parameter estimator in the case of time-varying system.

The generation of input signal is inspired by recent work on experiment design where it was shown that a bandlimited '1/f' noise has good properties in robust identification, [12]. As in [11], the theory of experiment design is used in order to reduce the time needed for identification. Recall that the aim was to create the input signal for identification (excited signal) through a recursive relation for autocovariance function. Synthesis of autocovariance function is based on the ideas of predictive control, [13].

## II. PARAMETER ESTIMATION OF RANDOM WALK PROCESS

If the system parameters vary according to the random walk model, then it can met next assumption, which yields unbounded parameter trajectories.

There exists a constant  $0 < c < \infty$  such that

$$E\left(\|\theta(k)\|^2\right) < c \quad (1)$$

Assumption (1) implies boundedness of the parameter trajectory in the mean square sense.