Recursive Algorithms for Set-Membership Estimation

Doctoral Dissertation
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Recursive Algorithms for Set-Membership Estimation

Abstract

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Abstract

System identification and control of linear time varying (LTV) systems are topics of great interest in the control community. This is motivated by the fact that most real-world problems involve systems which have, at least to some extent, a time-varying nature. These problems have been addressed thoroughly in the literature under the classical framework, where the measurements are assumed to be corrupted by noise that is described statistically, and the bounded-errors or set-membership (SM) framework, where uncertainties are assumed to belong to a given set. The contributions that have addressed this problem in the SM framework have considered the case known as equation error, where the sources of uncertainty are all taken into account by a single error term added to the difference equation. The case when both input and output measurements are affected by bounded noise, referred to as the errors-in-variables (EIV) structure, remains an open topic.

The objective of the PhD work is to develop new algorithms for identification and control of LTV systems in the SM framework, considering an EIV setting. The main difficulty of the addressed problem(s) is that, due to their structure, we need to solve nonconvex optimization problems whose global optimum can be approximated by means of semidefinite programming (SDP) relaxation techniques. However, due to the high computational burden for solving SDPs, they are not effective when the estimation needs to be performed in real-time (online). Starting from this last point, we propose novel algorithms for the addressed problem(s), that can compute the solution of the EIV problem(s) in a small amount of time, while assuring global optimality.

In the first part of thesis, a recursive identification approach to single-input single-output LTV systems when both the output and the input measurements are corrupted by bounded noise is considered. First, the problem is formulated in terms of errors-in-variables identification in presence of bounded noise. Then, two linear programming

based algorithms for online computation of tight bounds on the parameters of the LTV system are proposed.

Following that, considering the case of LTV systems with parameter jumps, we reformulate the problem to account for these abrupt behaviours. The method consists of two stages. First, we detect the jumps through an ℓ_1 based method and we characterize the dynamic profile in terms of variation bounds. Starting from these computed bounds, we evaluate the parameter uncertainty intervals.

Finally, we look at the problem controlling LTV systems through an adaptive data-driven scheme. We formulate the controller design problem through a model-matching scheme, i.e., designing a controller such that the closed-loop behaviour matches that of a given reference model. The problem is then reformulated as to derive a controller that corresponds to the minimum variation bounding its parameters, assuring fast convergence, and good tracking performance.