Abstract

Milad Karimshoushtari

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The topic of this thesis is applications of set membership identification to Design of Experiments (DoE) and fault detection. DoE is a fundamental step in system identification. Regardless of the chosen model structure and identification method, the quality of the DoE determines an upper bound on the accuracy of the identified model. One of the greatest challenges in this context is to design an experiment which gives the maximum information about the dynamics of the system of interest.

The first main contribution of this thesis is a novel DoE algorithm for input-constrained MISO nonlinear systems. A key element to design a proper DoE algorithm is understanding which are the regions of the regressor space where the model is most uncertain. Set membership identification allows us to properly quantify the uncertainty of the identified model in a deterministic manner. Therefore, we formulated the DoE problem in a set membership framework and proposed a quasi-local nonlinear set membership approach that results in less conservative uncertainty bounds compared to the global approach. However, knowing where the model is most uncertain is not sufficient. Since the unknown system is dynamic, the DoE algorithm has to be able to generate an input sequence such that the system moves toward those uncertain regions of the regressor space, in order to take new measurements. For this reason, we propose a novel adaptive Set Membership Predictive Control (SMPC) algorithm to move the system toward the most uncertain regions of the regressor space and take new informative measurements. Finally, a Set Membership DoE (SM-DoE) algorithm for input-constrained MISO nonlinear dynamic systems is proposed which is aimed to minimize the so-called radius of information, a quantity giving the worst-case model error. The proposed SM-DoE algorithm is able to guarantee any desired worst-case error larger than the measurement error in a finite-time experiment. Applications of the proposed method are clearly most useful in areas where experiments are expensive and/or a very accurate model is desired. Two numerical examples and a case study in the automotive field are also presented, showing the effectiveness of the approach and its potential in view of real-world applications.

The second main contribution of this thesis is an innovative approach to fault detection for nonlinear dynamic systems, based on the introduced quasi-local set membership identification method, overcoming some relevant issues proper of the "classical" techniques. The approach is based on the direct identification from experimental data of a suitable filter and related uncertainty bounds. These bounds are used to detect when a change (e.g., a fault) has occurred in the dynamics of the system of interest. The main advantage of the approach compared to the existing methods is that it avoids the utilization of complex

modeling and filter design procedures since the filter/observer is directly designed from data. Other advantages are that the approach does not require to choose any threshold (as typically done in many "classical" techniques) and it is not affected by under-modeling problems.