Design of Guaranteed Extended Kalman Filter Using Set Inversion Techniques

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Abstract: We study the problem of design of extended Kalman filter (EKF) that is a widely used model-based estimator in the industrial and academic practice. To design an effective EKF, one needs to decide upon a set of tuning parameters. Those are mainly represented by selection of the expectation of magnitude and correlation of the process and measurement noises. For non-linear systems in general, it is not straightforward how to select such tuning parameters appropriately to achieve desired performance of the filter. Practical experiences of the researchers and practitioners underpin this statement especially when dealing with strongly non-linear and uncertain systems.

The problem of design of guaranteed EKF is generally formulated as finding (or inner-approximating) the set of all design parameters that guarantee the fulfillment of the required performance of the estimator under bounded measurement and process noise. We consider the performance to be specified in terms of mean and covariance of the estimation error under given expectation for the range of measurement noise and parametric uncertainty of the employed model.

We resolve the problem of the design of guaranteed EKF by using the set inversion techniques that are based on exhaustive search over the design space of the EKF. The employed method successively branches the design space and evaluates its partitions in the terms of the specified estimator performance. The continuous formulation of EKF is considered in this work. The numerical implementation exploits rigorous bounding techniques of the solutions of nonlinear parametric differential equations based on Taylor models and ellipsoidal calculus. These techniques are exploited to provide a bounding of the dynamics of the estimator in order to infer its performance on the selected partition of the design space.

Several examples of different complexity are studied. It is shown that the proposed method can successfully incorporate various design requirements and yields validated set of design parameters guaranteed to achieve desired performance for the design of EKF of nonlinear and uncertain systems.

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