On the Solution of Forward and Inverse Problems in Possibilistic Uncertainty Quantification for Dynamical Systems

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Abstract

Stochastic approaches look back on a long tradition in the quantification of uncertainty in dynamical systems. However, most of the developed techniques share a common denominator; when considering the various forms of noise, they rely on a precise probability distributions for their description.

For instance, the standard Kalman-Filter, one of the most prominent filters, assumes Gaussian process and measurement noise for the correct estimation of states in a linear time-invariant system. These assumptions allow for a nice analytical solution, and its successful application in a wide variety of systems alone is proof enough for its usefulness. However, many engineers will assert that it is a tedious task of finding suitable covariance matrices for the process noise and the measurement error. Often, identifying those beforehand does not yield great benefit, or the matrices in industrial filters do not at all resemble a realistic error description.

This contribution demonstrates how possibilistic error descriptions allow for a more general description of measurement error and process noise, and presents intuitive techniques for the exact numerical solution of a selection of problems in linear time-invariant systems, following the paradigm "*Integrate First, Then Optimize*" of possibility theory. In particular, output prediction and state filtering tasks are considered and the respective optimization problems are formulated.

Special emphasis is put on the preservation of possibility-probability consistency in all calculations, which is enabled by recent results of Hose and Hanss (2019), and possibilistic approximations of Dempster's rule of combination, which are newly derived.

References

Hose, D. and Hanss, M. Possibilistic calculus as a conservative counterpart to probabilistic calculus. *Mechanical Systems and Signal Processing*, 133:106290, 2019.