Role of modelling on state and parameter estimation

Role of modelling on state and parameter estimation

Marcella Porru
Dept. of Electrical Engineering, CS
TU/Eindhoven, Netherlands
m.porru@tue.nl

Leyla Özkan
Dept. of Electrical Engineering, CS
TU/Eindhoven, Netherlands
l.ozkan@tue.nl

1 Introduction

In process industry, plants are generally operated at conditions that differ from the designed ones mainly due to disturbances. Disturbances can enter the system in form of fluctuations in feed flow, temperature and composition, or fluctuation of the utilities quality. These events cause a deterioration of the plant performance that cannot be quantified and online compensated by means of controllers unless online measurements of the quality targets (e.g. concentration, conversion, etc) are available. However the problem of online monitoring cannot be always solved in practice by means of hardware analysers because of unreliable and delayed measurements. An alternative approach is based on estimators that infer the variables of interests by means of secondary measurements and a often nonlinear model of the process. This type of realization of observers can include the online estimation of model parameters for a more accurate alignment of the model with the process behaviour.
This work addresses the role of the estimation model on estimation performance. Recent studies [1, 2] pointed out that for a defined set of plant measurements the choice of the estimation model and the innovated states play a key role on the performance of the estimator regardless the algorithm employed. Even if in the cited studies some features of the estimation model (such as level of detail, computational complexity) have been taken into account, the effect on the estimation performance of model manipulations such as variables and parameters scaling [3] and transformation have not been investigated yet. For this reason the role of different realizations of the same estimation model needs to be further investigated.

2 Informative content of the estimation model

For a given measurement processed by the estimator, the information retained by the nonlinear model to be used for state and parameter estimation are encrypted in the observability matrix (**O**). If **O** is full rank and well conditioned, robust estimation performance over disturbances and noisy measurements can be achieved. It turned out from our studies that for nonlinear systems the condition number of **O** can be altered by means of variable scaling, influencing estimation performance.
In this paper, this concept is explained by using the non isothermal CSTR with first order irreversible reaction and Arrhenius-like dependency of the reaction rate with the temperature [4]. The process can be rigorously modelled by means of material and energy balances. From a phenomenological description perspective, the solute dynamics can be equally expressed in terms of solute concentration C or conversion x, leading to two different modelling solutions: M1 and M2 respectively. The relation between the two variables is static, and the model in terms of x (M2) can be seen as the dimensionless counterpart of M1. By means of temperature measurements and a nonlinear state estimator we are interested in inferring the temperature of the system, the solute dynamics (C or x) and the feed concentration C_e. The latter is a parameter for the models M1 and M2 that, in the industrial practice, may not be a measurable source of disturbances for the process. Two well tuned and full order geometric estimators (GE) [1] have been built to solve the state and parameter estimation problem. The outcome is that the GE based on M2 has much faster convergence rates than the one based on M1. The performance difference is attributable to a better conditioning of the obsevability matrix derived from M2 over the one from M1, leading to a more efficient information transmission mechanism from the measurements to the innovated states.

3 Acknowledgments

This work has been done within the project Improved Process Operation via Rigorous Simulation Models (IMPROVISE) in the Institute for Sustainable Process Technology (ISPT).

References

[1] C. Fernandez, J. Alvarez, R. Baratti, and A. Frau (2012). Estimation structure design for staged systems. *J. Process Control*, 22(10), 2038-2056.

[2] M. Porru; J. Alvarez; R. Baratti (2013) A distillate composition estimator for an industrial multicomponent IC4-NC4 splitter with experimental temperature measurements. *IFAC Proceedings Volumes*, 10, 391-396

[3] R. Aris (2012) *Mathematical modelling techniques.* Courier Corporation.

[4] R. Aris, N.R. Amundson (1958). An analysis of chemical reactor stability and control I, II, III. *Chem. Eng. Sci.*, 7, pp. 121-147.