Robust Experiment Design for Identification of Thermophysical Parameters – Part II: A Multi-objective Approach

Anna Kučerová, Adéla Pospíšilová, Matěj Lepš
Faculty of Civil Engineering, Czech Technical University in Prague
anicka@cml.fsv.cvut.cz, adela.pospisilova@fsv.cvut.cz, leps@cml.fsv.cvut.cz

Abstract

The goal of an experiment design is to maximise a sensitivity of measured quantities to input parameters like material properties of theoretical and/or numerical models. The sensitivities can be formulated either in a local way using local derivatives or in a global way, e.g. using the variance-based Sobol indices. The advantage of Sobol indices lies in the possibility of their analytical computation from a polynomial chaos approximation of the model response constructed over the domain of model inputs, see [2]. Sobol indices thus allow for quantification of sensitivity w.r.t. large intervals for model inputs.

For a set of material properties to be identified from a set of measured quantities, irrespective of formulation of sensitivity used, all relevant sensitivities form a sensitivity matrix. During the process of experiment design optimisation, some measure of the sensitivity matrix is typically applied to formulate a scalar-value objective function. Many widespread measures are used, let us mention the D-optimality maximising the determinant, the E-optimality maximising the smallest eigenvalue or A-optimality minimising the trace of the inverse, all applied to the information matrix. The choice among those criteria is, however, not straightforward, especially in case of the globally defined sensitivity matrix. Therefore, we focus on a detailed comparative study of particular criteria. We investigate their properties using a set of Pareto optimal solutions obtained by a direct multi-objective maximisation of individual sensitivities. In particular, we use a multi-objective genetic algorithm using a non-dominated sorting principle, which can handle a high number of objectives.

The comparison is performed for an illustrative example concerning a non-stationary heat transfer elaborated in [1]. The experiment is designed for identifying the volumetric thermal capacity and conductivities in two principal directions from the temperature values observed at three sensors in 60 equidistant time steps. The specimen is modelled by 2D squared domain with the prescribed constant heat flux on left and bottom edges and the goal of the given experiment design is to find optimal positions of three sensors.

References

1. E. Ruffio and D. Saury and D. Petit. Robust experiment design for the estimation of thermophysical parameters using stochastic algorithms. International Journal of Heat and Mass Transfer, 55(11-12):2901–2915, 2012.
2. G. Blatman and B. Sudret. Efficient computation of global sensitivity indices using sparse polynomial chaos expansions. Reliability Engineering and System Safety, 95(11):1216–1229, 2010.