Improving Models of Dynamic Systems by Combining Physical Insights with Measurements

Elias Palmkvist

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Improve Models of Dynamic Systems

Models of systems are used in the design phase of product development as well as for control design. By using accurate models, the cost of product development can be decreased by simulating the systems in a virtual environment. The model design is a very important procedure to get as accurate a model as possible. When modeling dynamic physical systems there are three main design topics: the equations, the constants and the parameters. The equations can be seen as the skeleton of the model and are derived from physical equations. Then the equations usually contain a set of constants and parameters. Constants are well known without any uncertainties. The parameters are instead quantities with some uncertainty. It can be hard to know the correct parameter values during the design of the model so there is a need of estimation of the parameters.

Grey-Box Identification

In grey-box identification, the uncertainties of nonlinear models are estimated. For model design and verification, grey-box identification is used to identify the uncertain parameters by using some measurement data. In grey-box identification the noise model is included in the optimization. Examples of two methods that are used for parameter estimation of nonlinear systems are Maximum Likelihood (ML) estimation and Output Error (OE) estimation.

JModelica.org

Modelica is a modeling language, mainly used for modeling dynamical system. Modelica is today used for example in the car industry and the power industry. JModelica.org is an open source platform for simulation and optimization of Modelica models. With the simulation and optimization tools available in JModelica.org there is a huge potential to support grey-box identification.

Implementation

In [1] it was investigated how far it is possible to implement grey-box identification in JModelica.org. The focus of the work is to identify uncertain model parameters from measurement data. An iterative method has been implemented to find the best identification from a given sequence of measurement data.

One can not expect that all uncertain parameters can be estimated from a given sequence of measurement data. More data generally contains more information about the system, sequences of measurements where the outputs are constant usually contain very little interesting information about the system behavior. An iterative method was implemented to find the best set of parameters to estimate out of the given sequence of measurements. In order to analyze the estimation a method to calculate the robustness of the estimation was also imlemented.

Implementation performance

The same signal with 300 different noise realizations was estimated with ML estimation. The estimation distribution can be seen in Fig. 1. The distribution given from multiple estimations are looking like the expected result given from the theory. And none of the estimates differs more than 2 % from the true value.

The implemented iterative method was used to identify parameters in a drum boiler model. Simulation of the initial drum boiler model, without

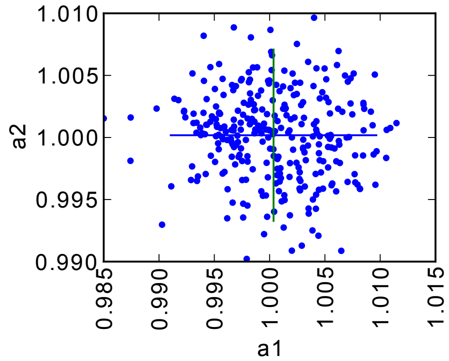

Figure 1: Estimation distribution for 300 different noise realization for a nonlinear system. True values for the parameters are 1.0 the intersection between the lines are showing the mean values.

any identification, can be seen in Fig. 2. From this the iterative method was used to identify uncertain parameters. The optimal trajectory given from the parameter estimation of a drum boiler model can be seen in Fig. 3. The optimal trajectory found from the estimation is, as one can see, close to the measured signal. The estimates are close to the true values which indicates that the estimation works as expected.

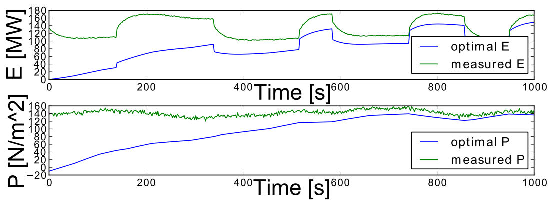

Figure 2: Simulation of the initial drum boiler model, without any identification, compared with the measured system output.

The Future of Grey-Box Identification

A user friendly interface and support for more noise models has to be implemented in order to make the implementation more useful for the public. When this is implemented the technique has a huge potential in model design. The models can be more accurate in parameters that is hard to measure with physical equipment. For large scale system the parameters can be defined faster by using the statistics that grey-box identification offers. Another use case, that has been briefly investigated in the thesis, is to use grey-box identification to simplify complex models. By using simplified complex models, the computation time during simulations can be decreased.

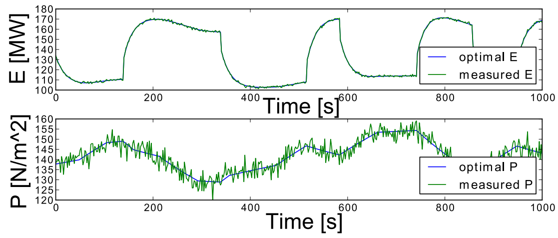

Figure 3: Simulation of the final estimated drum boiler model compared with the measured system output.

References

[1] Palmkvist E. (2014) "Implementation of Grey-Box Identification in JModelica.org". Master Thesis, TFRT-5941, Department of Automatic Control, Lund University