Simulink Design Optimization 1

Estimate and optimize Simulink model parameters

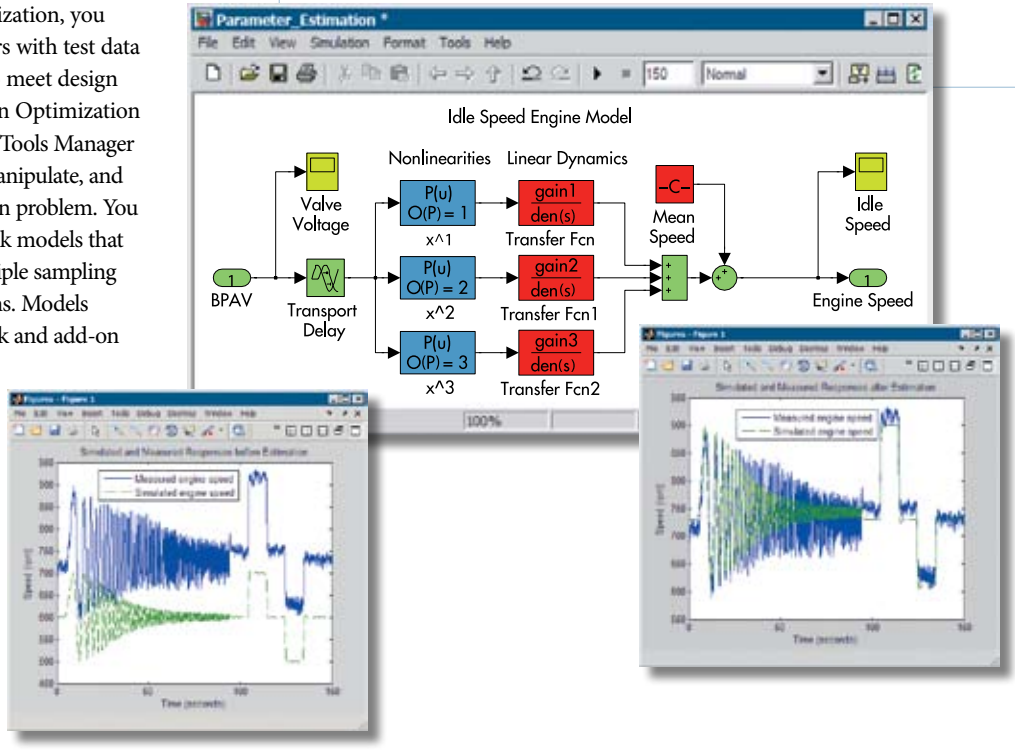
Simulink Design Optimization™ lets you improve designs by estimating and tuning model parameters using numerical optimization. You can increase model accuracy by using test data to calibrate physical parameters, such as mass or resistance. You can then improve system performance, reduce system cost, and meet other objectives by automatically tuning design parameters in your Simulink® model. For example, you can optimize controller gains to meet rise-time and overshoot constraints, or jointly optimize physical and algorithmic parameters to maximize overall system performance.

Working with Simulink Design Optimization

With Simulink Design Optimization, you can calibrate model parameters with test data and tune model parameters to meet design requirements. Simulink Design Optimization uses a Control and Estimation Tools Manager GUI to help you configure, manipulate, and run your Simulink optimization problem. You can work directly with Simulink models that include nonlinear effects, multiple sampling rates, or fixed-point calculations. Models using any blocks from Simulink and add-on products are supported.

KEY FEATURES

- Estimation of physical parameters from test data
- Preprocessing of test data, including data selection, offset removal, detrending, noise filtering, and missing data reconstruction
- Optimization of time-domain responses of nonlinear Simulink models
- Optimization of time- and frequency-domain responses of linear control systems (with Control System Toolbox™)
- Ability to graphically specify response requirements and then visually monitor the optimization progress
- Ability to factor in parameter variation or uncertainty for robust design optimization



Using Simulink Design Optimization with measured data to calibrate parameters for the blocks highlighted in red. The lower left and lower right images show measured versus simulated data before and after the calibration, respectively.

You can optimize multiple model parameters at the same time. The parameters can be scalars, vectors, matrices, or fields of structured variables defined in the MATLAB® or model workspace.

Simulink Design Optimization gives you access to a variety of optimization algorithms: gradient descent, nonlinear least squares, simplex search, and pattern search (with Genetic Algorithm and Direct Search Toolbox™). You can fine-tune optimization performance by adjusting optimization algorithm settings, such as convergence tolerances and number of iterations. You can use Simulink Design Optimization in conjunction with Parallel Computing Toolbox™ to accelerate the optimization process.

Calibrating Model Parameters with Test Data

Using Simulink Design Optimization to calibrate parameters with test data involves three steps:

- Importing and preprocessing data
- Estimating parameters
- Comparing and validating estimations

Importing and Preprocessing Data

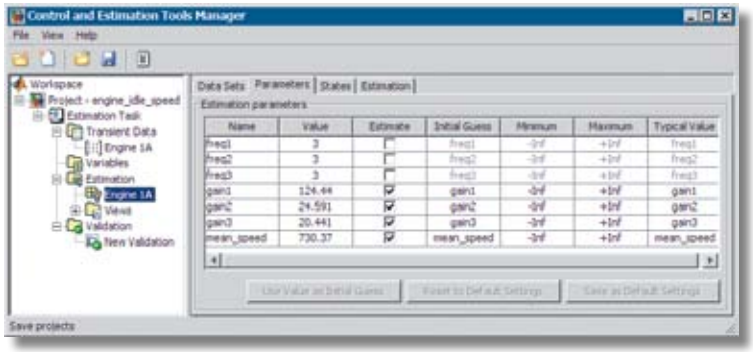
Simulink Design Optimization can use measured input-output data from actual hardware to estimate and validate the parameters of a Simulink model. Simulink Design Optimization lets you import measured data from MATLAB, Microsoft® Excel®, ASCII, and CSV files, as well as from the MATLAB workspace. Measured data often has offsets, outliers, periods of missing values, and other anomalies that can lead to inaccurate parameter estimation. Simulink Design Optimization lets you preprocess your measured data to remove these sources of error by:

- Detrending to remove data drift and offset
- Filtering to remove noise and band-limited disturbances
- Interpolating to fill in missing values
- Excluding to remove questionable sections of the data set

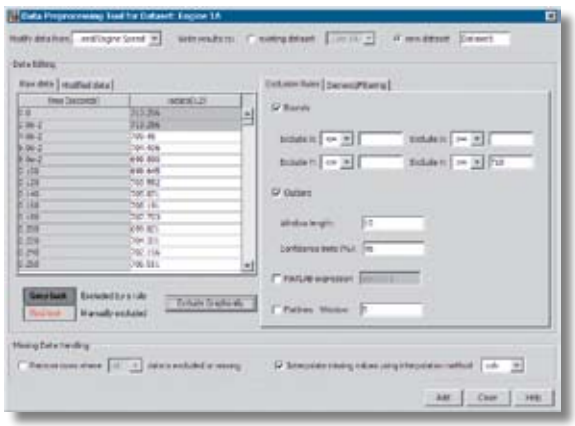
Estimating Parameters

Simulink Design Optimization lets you set up and maintain multiple estimation tasks. For each estimation task, you can specify which model parameters and initial conditions you want to estimate and which sets of input-output data you want to use. This approach lets you estimate parameters for one section of the model by using one combination of data sets and independently estimate parameters for other model sections by using different combinations of data sets. You can refine the parameter tuning process by using parameter values from previous estimation tasks as initial values for subsequent estimations or set ranges for estimated parameters.

In addition to estimating model parameters, Simulink Design Optimization provides functionality to estimate static lookup table values and a Simulink block for implementing adaptive lookup tables. You can connect your adaptive lookup table directly to an actual system by compiling your Simulink model and implementing the code using an appropriate host, such as xPC Target™.



Control and Estimation Tools Manager GUI for configuring, manipulating, and running optimization problems. In this example, the parameters with check marks have been selected for estimation.



Preprocessing data using Simulink Design Optimization to remove outliers and unwanted trends.

Comparing and Validating Estimations

Simulink Design Optimization can generate comparative plots of estimation results to help determine which model parameter values result in the best model and measured data fit. Plots include views of parameter sensitivity, measured versus simulated model outputs, and residual values.

Validation involves comparing the model output with an independent set of test data to determine whether the calibrated model accurately represents the system dynamics. Simulink Design Optimization lets you compare multiple model outputs against the validation data set to select the best estimation and parameter sets.

Meeting Design Requirements

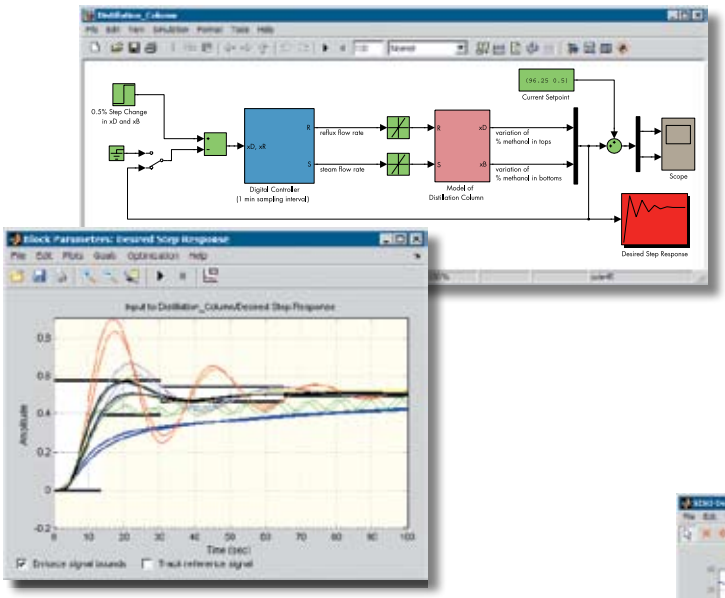
With Simulink Design Optimization, you can tune nonlinear Simulink model parameters to meet time-domain requirements and optimize compensators for linear systems to meet both time- and frequency-domain requirements.

Tuning Simulink Model Parameters to Meet Time-Domain Requirements

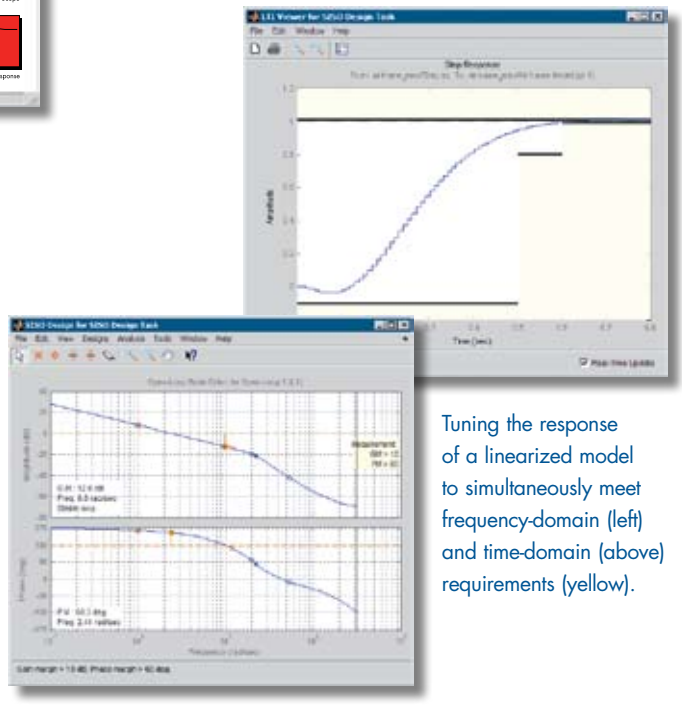
Simulink Design Optimization lets you automatically tune model parameters to meet time-domain requirements. You can optimize any design criterion by expressing it as a Simulink signal and connecting this signal to the Signal Constraint block provided by Simulink Design Optimization. The Signal Constraint block lets you constrain the signal by either graphically shaping the desired response or specifying a reference signal trajectory. It then adjusts values of chosen model parameters to satisfy the constraints. The Signal Constraint block GUI updates during optimization so that you can visually monitor the optimization progress. You can use several Signal Constraint blocks simultaneously to optimize multiple design criteria.

Optimizing Compensators to Meet Time- and Frequency-Domain Requirements

Linear compensator design often involves tradeoffs among requirements for stability, robustness, and performance. Simulink Design Optimization lets you account for these tradeoffs as you fine-tune compensators that have been designed with Control System Toolbox and Simulink Control Design™.



Tuning the response of a nonlinear model. The Signal Constraint block (top, red) adjusts the parameters of the Digital Controller block (top, blue) to produce the desired response (tuning progress shown lower left).



Tuning the response of a linearized model to simultaneously meet frequency-domain (left) and time-domain (above) requirements (yellow).

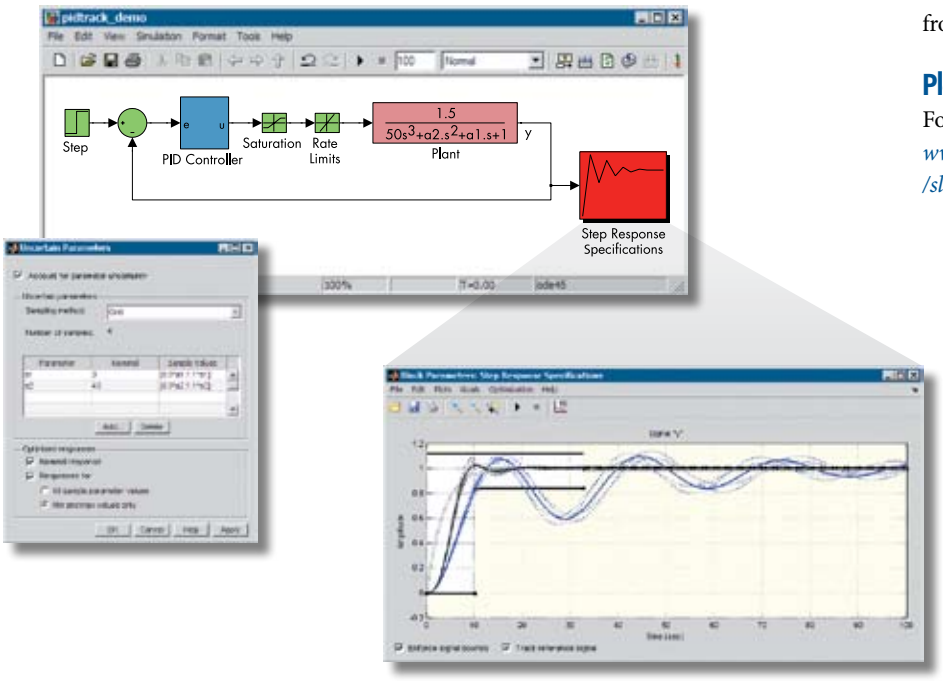
You can specify a variety of time- and frequency-domain requirements to optimize the controller performance. Typical requirements include gain and phase margins, damping ratio, minimum bandwidth, high-frequency rolloff, and constraints on the step or impulse responses. You can optimize the poles, zeros, and gains of your compensators, or directly tune the parameters of the corresponding blocks in Simulink. Plots comparing the current response with your design requirements help you monitor progress while the optimization runs.

Specifying Model Uncertainty

Simulink Design Optimization helps you test the robustness of your design against variations in model parameters. You can use either Monte Carlo or fixed-grid simulations to improve the robustness of designs involving uncertain parameters. Simulink Design Optimization also enables you to set nominal and bounding values for each uncertain parameter in the model.

Required Products

MATLAB®
Simulink®
Optimization Toolbox™



Tuning the parameters associated with the PID Controller block (top, blue) in the presence of parameter uncertainty (lower left) in the Plant block (top, pink). The step response specifications (lower right) include design constraints (yellow), reference signal (gray), initial response with uncertainty (solid and dotted blue lines), and final response with uncertainty (solid and dotted black lines).

Related Products

Control System Toolbox™
Design and analyze control systems

Genetic Algorithm and Direct Search Toolbox™
Solve optimization problems using genetic algorithms, simulated annealing, and direct search

Parallel Computing Toolbox™
Perform parallel computations on multicore computers and computer clusters

Simulink Control Design™
Design and analyze control systems in Simulink

System Identification Toolbox™
Create linear and nonlinear dynamic models from measured input-output data

Platform and System Requirements

For platform and system requirements, visit *www.mathworks.com/products/sl-design-optimization.* ■

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