System Identification Toolbox 7

Create linear and nonlinear dynamic models from measured input-output data

System Identification Toolbox lets you construct mathematical models of dynamic systems from measured input-output data. This data-driven approach helps you describe systems that are not easily modeled from first principles or specifications, such as chemical processes and engine dynamics. It also helps you simplify detailed first-principle models, such as finite-element models of structures and flight dynamics models, by fitting simpler models to their simulated responses.

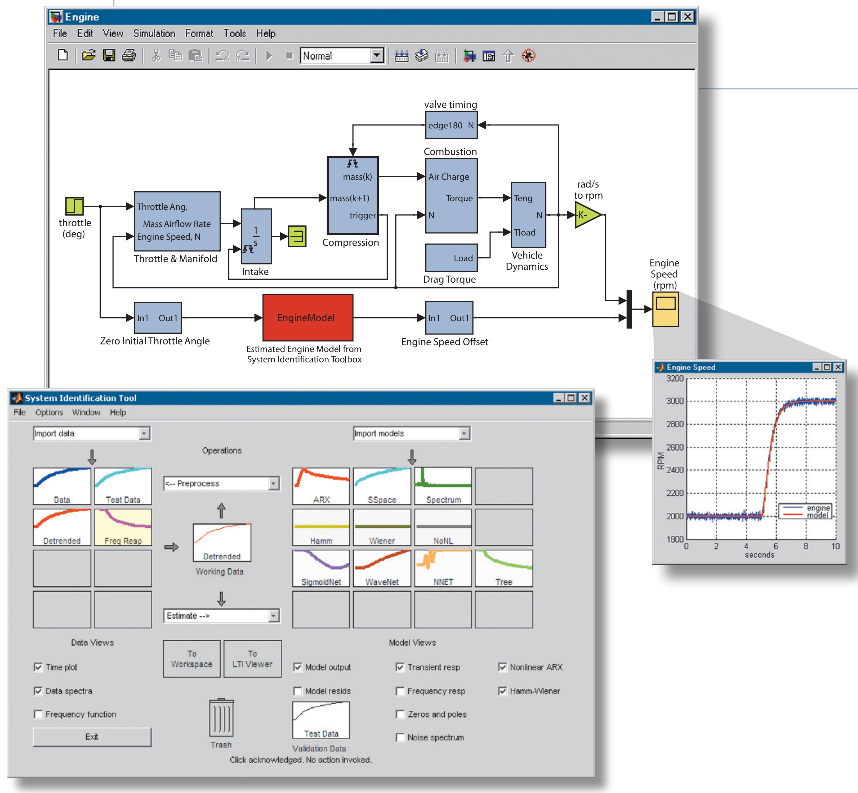
Models obtained with System Identification Toolbox are well suited for simulation, prediction, and control system design using products such as Simulink®, Control System Toolbox, and Model Predictive Control Toolbox (all available separately).

System Identification Toolbox lets you fit linear and nonlinear models to data, a process known as black-box modeling. Available model structures include low-order process models, transfer functions, state-space models, linear models with static nonlinearities at the inputs or outputs, and nonlinear autoregressive models. If you have a mathematical model of the system dynamics, you can tune its parameters to better match experimental data, a process known as grey-box modeling.

The principal architect of the toolbox is Professor Lennart Ljung, a recognized leader in the field of system identification.

KEY FEATURES

- Identifies linear and nonlinear models from time- and frequency-domain data
- Simplifies identification of first-, second-, and third-order continuous-time models
- Analyzes measured data and advises on data quality, required preprocessing, and presence of feedback or nonlinearities
- Provides data processing tools for detrending, filtering, and reconstructing missing data
- Provides Simulink blocks for simulating identified models and transferring data to and from the MATLAB® workspace
- Provides an interface for using linear models in Control System Toolbox (available separately)



Using System Identification Toolbox with Simulink. The toolbox provides blocks that let you bring identified models into Simulink.

Working with System Identification Toolbox

System Identification Toolbox facilitates the multistep process of identifying models from data. The toolbox enables you to:

- Analyze and process data
- Determine suitable model structure and order
- Estimate model parameters and validate model accuracy
- View the model responses and their uncertainties

You can perform these tasks by using either command-line functions or a graphical user interface (GUI).

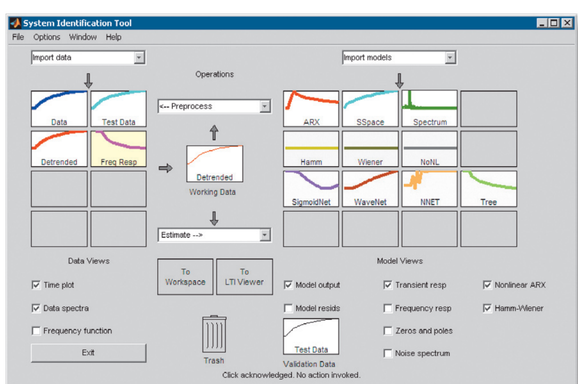
You can convert the models into linear time-invariant (LTI) objects for use with Control System Toolbox. You can incorporate most identified models into Simulink models using blocks provided by the toolbox.

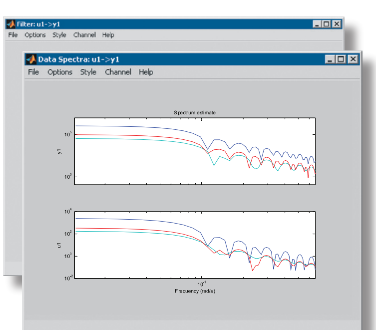
Working with Measured Data

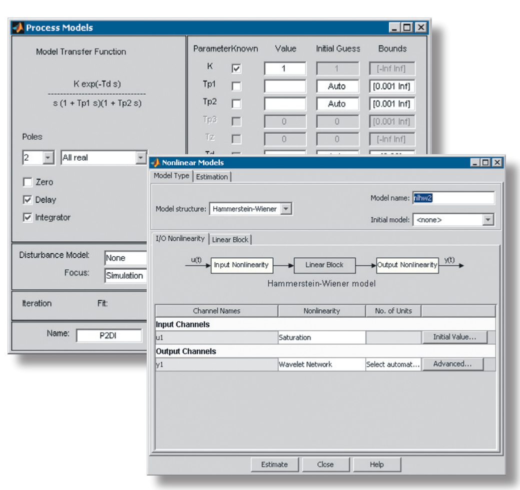
When preparing data for identification of models, you need to specify information such as input-output channel names, sampling interval, and intersample behavior. The toolbox lets you attach this information to the data using data objects. The data objects facilitate easy visualization of data, domain conversion, and various preprocessing tasks.

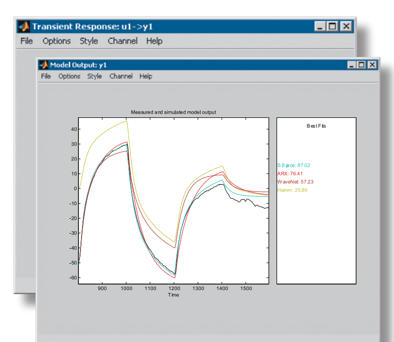
Measured data often has offsets, slow drifts, outliers, missing values, and other anomalies. The toolbox removes such anomalies by performing operations such as detrending, filtering, resampling, and reconstruction of missing data. The toolbox can analyze the suitability of data for identification and provide diagnostics regarding persistence of excitation, existence of feedback loops, intersample behavior, and presence of nonlinearities.

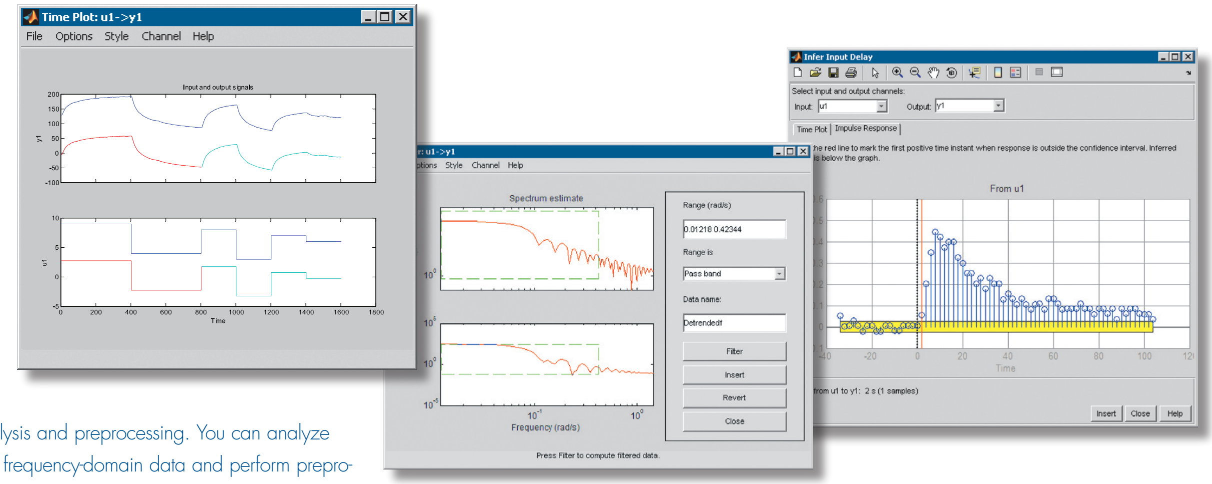
Deriving models from data. You can use the System Identification Toolbox GUI (right) to analyze and preprocess data (below, left), estimate linear and nonlinear models (below, middle), and validate estimated models (below, right).











Data analysis and preprocessing. You can analyze time- and frequency-domain data and perform preprocessing tasks, such as filtering and detrending.

The toolbox produces estimates of step and frequency responses of the system directly from measured data. Using these responses, you can analyze system characteristics, such as time constants, input delays, and resonant frequencies. You can use this information to configure the parametric models during estimation.

Estimating Parametric Models

Parametric models, such as transfer functions or state-space models, use a small number of parameters to capture system dynamics. The toolbox estimates model parameters and their uncertainties. You can analyze these models, or their linear equivalents, using time- and frequency-response plots such as step, impulse, bode plots, and pole-zero maps.

Estimating Linear Black-Box Models

You can identify polynomial and state-space models using various estimation routines offered by the toolbox. These routines include autoregressive models (ARX, ARMAX), Box-Jenkins (BJ) models, Output-Error (OE) models, and state-space parameterizations. Estimation techniques include maximum likelihood, prediction-error minimization schemes, and such subspace methods as CVA, MOESP, and N4SID. You can also estimate a model of the noise affecting the observed system.

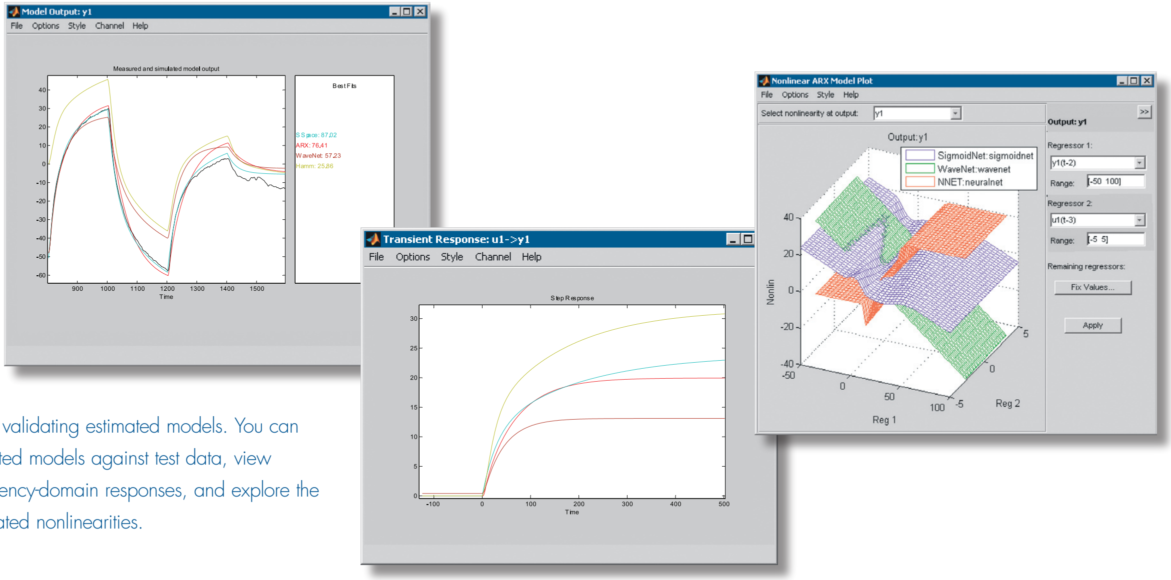
In cases where you only need a low-order continuous-time model, the toolbox provides special capabilities to simplify the estimation process and obtain results quickly. These models are expressed as simple transfer functions involving three or fewer poles, and optionally, a zero, a time-delay, or an integrator.

Estimating Nonlinear Black-Box Models

When linear models are not sufficient to capture system dynamics, you can estimate nonlinear models, such as nonlinear ARX and Hammerstein-Wiener models. Nonlinear ARX models enable you to model nonlinearities using wavelet networks, tree-partitioning, sigmoid networks, and neural networks (with Neural Network Toolbox, available separately). Using Hammerstein-Wiener models, you can estimate static nonlinear distortions present at the input and/or output of an otherwise linear system. For example, you can estimate the saturation levels affecting the input current into a DC motor, or capture a complex nonlinearity at the output using a piecewise linear nonlinearity.

Estimating Parameters in User-Defined Models

A user-defined (grey-box) model is a set of differential or difference equations with some unknown parameters. The toolbox lets you specify the model structure and estimate its parameters using nonlinear optimization techniques. For linear models, you can explicitly specify the structure of state-space matrices and impose constraints on identified parameters. For nonlinear models, you can specify differential equations as C, FORTRAN, or M-code.



Analyzing and validating estimated models. You can validate estimated models against test data, view time- and frequency-domain responses, and explore the shape of estimated nonlinearities.

Validating Results

System Identification Toolbox helps validate the accuracy of identified models using independent sets of measured data from a real system. For a given set of input data, you can compare simulated output of the identified model with the measured output from the real system. You can also view the prediction error and produce time- and frequency-response plots with confidence bounds to visualize the effect of parameter uncertainties on model responses.

Required Products

MATLAB

Related Products

Simulink. Simulation and Model-Based Design

Control System Toolbox. Design and analyze control systems

Neural Network Toolbox. Design and simulate neural networks

Signal Processing Toolbox. Perform signal processing, analysis, and algorithm development

Simulink® Parameter Estimation. Estimate model parameters using test data

For a complete list of related products, visit *www.mathworks.com/products/sysid*

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