System Identification Toolbox

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

System Identification Toolbox™ constructs mathematical models of dynamic systems from measured input-output data. It provides MATLAB® functions, Simulink® blocks, and an interactive tool for creating and using models of dynamic systems not easily modeled from first principles or specifications. You can use time-domain and frequency-domain input-output data to identify continuous-time and discrete-time transfer functions, process models, and state-space models.

The toolbox provides maximum likelihood, prediction-error minimization (PEM), subspace system identification, and other identification techniques. For nonlinear system dynamics, you can estimate Hammerstein-Weiner models and nonlinear ARX models with wavelet network, tree-partition, and sigmoid network nonlinearities. The toolbox performs grey-box system identification for estimating parameters of a user-defined model. You can use the identified model for prediction of system response and for simulation in Simulink. The toolbox also lets you model time-series data and perform time-series forecasting.

Key Features

- Transfer function, process model, and state-space model identification using time-domain and frequency-domain response data
- Autoregressive (ARX, ARMAX), Box-Jenkins, and Output-Error model estimation using maximum likelihood, prediction-error minimization (PEM), and subspace system identification techniques
- Time-series modeling (AR, ARMA, ARIMA) and forecasting
- Identification of nonlinear ARX models and Hammerstein-Weiner models with input-output nonlinearities such as saturation and dead zone
- Linear and nonlinear grey-box system identification for estimation of user-defined models
- Delay estimation, detrending, filtering, resampling, and reconstruction of missing data
- Blocks for using identified models in Simulink

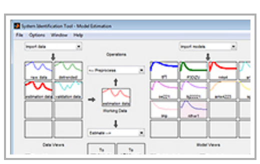
The principal architect of the toolbox is Professor Lennart Ljung, a recognized leader in the field of system identification.

Using System Identification Toolbox (top) to import, analyze, and preprocess data (left), estimate linear and nonlinear models (bottom), and validate estimated models (right).

Identifying Models from Data

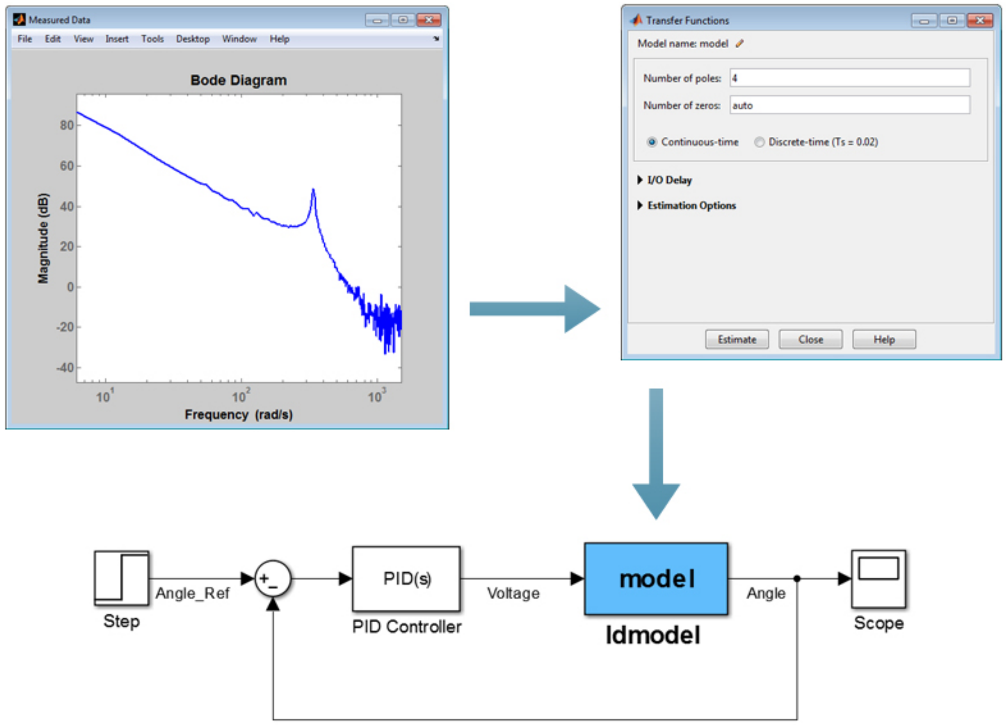
System Identification Toolbox lets you create models from measured input-output data. You can:

- Analyze and process data
- Determine suitable model structure and order, and estimate model parameters
- Validate model accuracy



Introduction to System Identification Toolbox 2:28
Get started with System Identification Toolbox.

You can use identified linear models for analysis and control system design with Control System Toolbox™. You can incorporate most identified models into Simulink using blocks that the toolbox provides. You can also use identified models for forecasting.



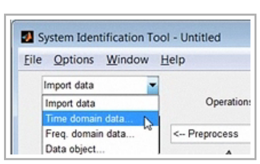
Identifying a transfer function model from frequency-domain test data and using the identified model in Simulink.

Analyzing and Processing Data

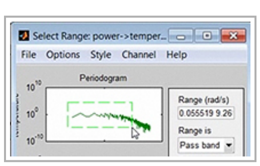
When preparing data for identifying models, you need to specify information such as input-output channel names, sampling time, and intersample behavior. The toolbox lets you attach this information to the data, which facilitates visualization of data, domain conversion, and various preprocessing tasks.

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 on the persistence of excitation, existence of feedback loops, and presence of nonlinearities.

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



Importing and Manipulating Data Sets 3:24
Import test data for estimating the model and validating results.



Preprocessing Data 1:42
View test data, filter out noise, and remove offsets.

Estimating Model Parameters

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

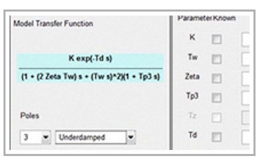
Estimating and Validating Models 1:21
Estimate multiple models and validate against the validation data set.

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, the toolbox computes the output of the identified model and lets you compare that output with the measured output from a real system. You can also view the prediction error and produce time-response and frequency-response plots with confidence bounds to visualize the effect of parameter uncertainties on model responses.

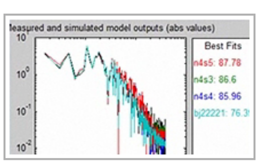
Identifying Linear Models

System Identification Toolbox lets you estimate multi-input multi-output continuous or discrete-time transfer functions with a specified number of poles. You can specify the transport delay and the number of zeros or let the toolbox determine those parameters automatically. In cases where you need a low-order continuous-time model in pole-zero form, the toolbox lets you estimate process models, which are simple transfer functions involving three or fewer poles, and optionally, a zero, a time-delay, and an integrator.



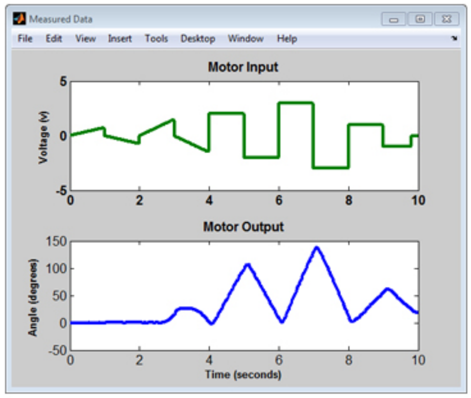
Estimating Transfer Functions and Process Models 2:27
Estimate continuous-time and discrete-time transfer functions and low-order process models. Use the estimate models for analysis and control design.

You can identify polynomial and state-space models using estimation routines provided in 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 subspace methods, such as CVA, MOESP, and N4SID. You can also estimate a model of the noise affecting the observed system. For all estimations, you can designate fixed model parameters and specify bounds for free parameters.

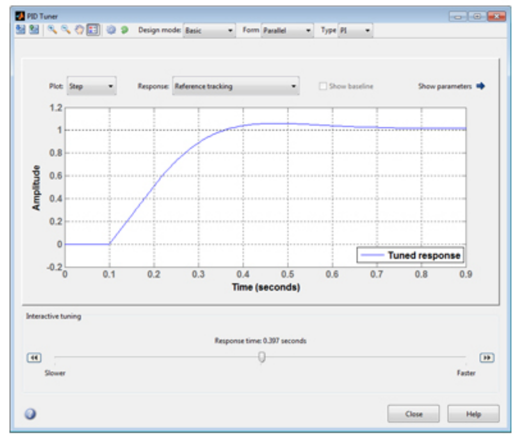


Estimating State-Space and Polynomial Models 2:20
Determine optimal model order and estimate state-space models. Estimate ARX, ARMAX, Box-Jenkins, and Output-Error polynomial models.

You can use identified linear models directly with Control System Toolbox functions for analysis and compensator design without converting the models.




```
% estimate continuous-time transfer function
% with 1 pole and no zeros
% estimate delay
model=tfest(data,1,0,NaN);
% interactively design a pid controller
% using model as a plant
pidtool(model)
```

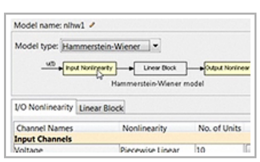


MATLAB code for identifying a transfer function model from time-domain test data in System Identification Toolbox (top) and using the identified model to tune a PID controller in Control System Toolbox (bottom).

Identifying Nonlinear Models

When linear models are not sufficient for capturing system dynamics, you can use System Identification Toolbox to estimate nonlinear models, such as nonlinear ARX and Hammerstein-Wiener.

Nonlinear ARX models enable you to model nonlinearities using wavelet networks, tree-partitioning, sigmoid networks, and neural networks (with Neural Network Toolbox™). Using Hammerstein-Wiener models, you can estimate static nonlinear distortions present at the input and output of an otherwise linear system. For example, you can estimate the saturation levels affecting the input current running a DC motor, or capture a complex nonlinearity at the output using a piecewise linear nonlinearity.



Estimating Nonlinear Black-Box Models 4:29
Estimate nonlinear ARX and Hammerstein-Wiener models.

Estimating Parameters in User-Defined Models

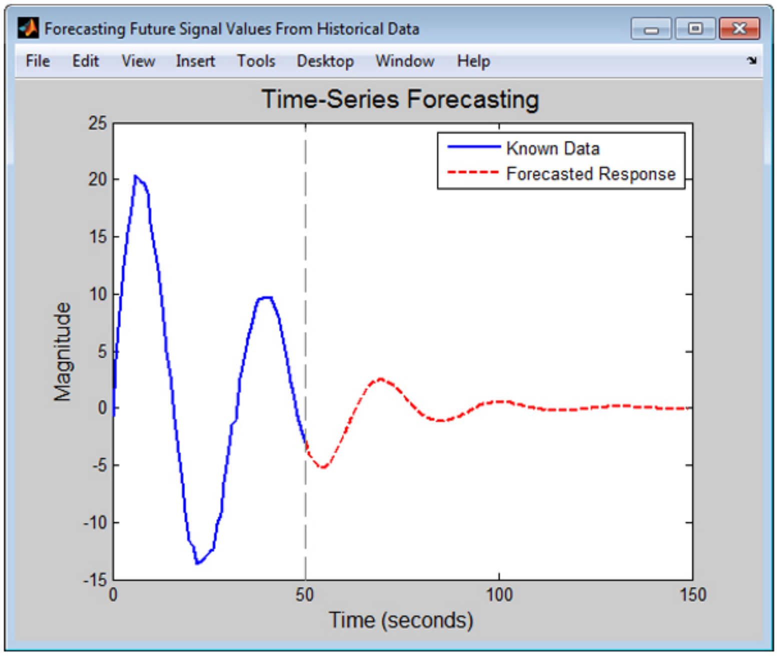
A user-defined (grey-box) model is a set of differential or difference equations with some unknown parameters. If you understand the physics of your system and can represent the system as a grey-box model, System Identification Toolbox lets you specify the model structure and estimate its parameters using nonlinear optimization techniques. For linear models you can explicitly specify the structure of state-space matrices and impose constraints on identified parameters. You can specify differential equations as MATLAB, C, or Fortran code.

Modeling Time-Series Data

A time series is one or more measured output channels with no measured input. System Identification Toolbox lets you create time-series data models to forecast future signal values based on previous ones. You can estimate time-series models using both time-domain and frequency-domain data.

You can estimate time-series spectra that describe time-series variations using cyclic components at different frequencies. You can also estimate parametric autoregressive (AR), autoregressive and moving average (ARMA), autoregressive integrated moving average (ARIMA), and state-space time-series models.

```
% Create autoregressive fourth-order model from data
model = ar(data,4);
% Forecast response from known data for 100 seconds
ForecastedResponse = forecast(model,KnownData,100);
```



MATLAB code for creating a time-series data model and using it to forecast future signal values.

Resources

Product Details, Examples, and System Requirements
www.mathworks.com/products/sysid

Trial Software
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