System Identification Toolbox™ Release Notes
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Bug Fixes

R2011a

Bug Fixes
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No New Features or Changes

R2010a

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R14SP3

No New Features or Changes

R14SP2

No New Features or Changes
R2015b

Version: 9.3

New Features

Bug Fixes

Compatibility Considerations
Online Parameter Estimation Commands: Implement and deploy recursive estimators with MATLAB Compiler or MATLAB Coder

You can now estimate models online at the command-line using new online estimation commands: `recursiveAR`, `recursiveARMA`, `recursiveARX`, `recursiveARMAX`, `recursiveOE`, `recursiveBJ`, and `recursiveLS`. For more information, see “Perform Online Parameter Estimation at the Command Line”.

You can then deploy the generated code or standalone application in your target hardware using MATLAB® Compiler™ or MATLAB Coder™.

Compatibility Considerations

The old recursive estimators, `rarx`, `rarmax`, `roe`, and `rbj`, are not compatible with MATLAB Compiler or MATLAB Coder, and may be removed in a future release. Use the new online estimation commands instead.

Bayesian and Akaike Information Criteria (BIC and AIC) Metrics: Compare identified models and select orders

Bayesian Information Criteria (BIC) and Akaike Information Criteria (AIC) are now computed during model estimation. These metrics provide a measure of model quality that you can use to compare different models and pick the best one. The most accurate model has the smallest AIC and BIC values.

The software computes and stores the following new values in the `Report.Fit` property of the estimated model:

- Raw AIC (AIC)
- Small sample-size corrected AIC (AICc)
- Normalized AIC (nAIC)
- Bayesian Information Criteria (BIC)

For more information on these metrics, see “Loss Function and Model Quality Metrics”.

Alternatively, you can use the `value = aic(___,measure)` syntax to return the various AIC values. For more information, see the `aic` reference page.
**procest command returns estimated input offsets**

You can now use the following syntax for returning the estimated value of the offset in input signal:

\[
\text{[sys,offset]} = \text{procest}(\_\_) 
\]

`procest` automatically estimates the input offset when the model contains an integrator, or when you set the `InputOffset` estimation option to `'estimate'` using `procestOptions`.

**Unified `sim` command for simulating linear and nonlinear identified models**

The syntaxes for simulating linear and nonlinear identified models have been unified into a single `sim` command. Starting in R2015b, use a `simOptions` option set to configure your simulation. The previous syntax for nonlinear model simulation will continue to work in future releases.

**Compatibility Considerations**

- If your code uses any of the following functionality when simulating nonlinear models, consider updating the code.

<table>
<thead>
<tr>
<th>Nonlinear Model</th>
<th>Functionality</th>
<th>Use This Instead</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>idnlarx, idnlhw</code> or <code>idnlgrey</code></td>
<td>Simulate model with additive noise using ( y = \text{sim(model,u,'Noise')} )</td>
<td>opt = <code>simOptions('AddNoise',true); y = sim(model,y,opt);</code></td>
</tr>
<tr>
<td><code>idnlarx, idnlhw</code> or <code>idnlgrey</code></td>
<td>Simulate models with initial states specified using ( y = \text{sim(model,u,'InitialState')} )</td>
<td>opt = <code>simOptions('InitialCondition',i); y = sim(model,y,opt);</code></td>
</tr>
<tr>
<td><code>idnlgrey</code></td>
<td>Return simulation final states using ( [y,y_{sd},x] = \text{sim(model,u)}; XFINAL = x(end,:); )</td>
<td><code>[y,y_{sd},XFINAL] = \text{sim(model,u)}; XFINAL = x(end,:);</code></td>
</tr>
</tbody>
</table>
**Option for setting orientation of input-output data plots**

You can now specify the orientation of input-output data plots created using `plot`. Display options for input-output data include:

- All in one row
- All in one column
- All outputs in a column, and all inputs in a second column
- All outputs in a row, and all inputs in a second row

To do so in the plot window, right-click the plot, and choose **Orientation** option from the context menu.

At the command line, use the **Orientation** option of the `iddataPlotOptions` option set.

**Updates to compare command plot interface**

The plot generated using `compare` has the following changes:

- **Fit%**, the normalized root mean square measure of the goodness of the fit, now displays in the legend of the plot instead of in a separate panel to the right of the plot.
- The context menu now has the following new options:
  - **I/O Grouping** — Use this option to plot data I/O channels in their own separate axes (**None**), or group them together (**All**).
  - **Characteristics > Mean Value** — Use this option to view the mean value of the data.
  - **Data Experiment** — For multi-experiment data only. Use this option to toggle between data from different experiments. This option replaces the separate tabs that displayed multi-experiment data in the plot.

To access the context menu, right-click the plot.

**Modified normalized gradient algorithm for online estimation**

To prevent jumps in estimated parameters, the normalized gradient algorithm now includes a bias term in the scaling factor of the adaptation gain. For details about the algorithm, see “Recursive Algorithms for Online Parameter Estimation”. The
default value of the bias is \( \text{eps} \). Increase the bias when you see jumps in the estimated parameters.

- To change the bias in Simulink\(^\circledast\), in the Block Parameters dialog box of Recursive Polynomial Model Estimator and Recursive Least Squares Estimator blocks, in the Algorithm and Block options tab, use the Normalization Bias field.
- To change the bias at the command line, use the NormalizationBias property of the online estimation commands.

### Change in output and initial estimate specification of Recursive Polynomial Model Estimator block

The dimensions of Recursive Polynomial Model Estimator block output and initial estimate specification have changed.

- The Parameters outport of the block now outputs the estimated parameters \( A, B, C, D, \) and \( F \) as row vectors. For MISO polynomial models, \( B \) is a matrix where the \( i \)-th row parameters correspond to the \( i \)-th input. Previously, the estimated parameters were output as column vectors.
- In the block dialog box Model Parameters tab, if Initial Estimate is set to Internal, specify the initial parameter guess (Initial \( A(q) \), Initial \( B(q) \), Initial \( C(q) \), Initial \( D(q) \), or Initial \( F(q) \)) as a row vector only. Previously, initial guesses could also be specified as column vectors. For MISO polynomial models, specify Initial \( B(q) \) as a matrix where \( i \)-th row parameters correspond to the \( i \)-th input.

### Compatibility Considerations

- If your Simulink model requires the estimated parameters output from the block outport to be a column vector, transpose the block output as follows:
  - Split the Parameters outport bus signal into its individual parameter components \( A, B, C, D, \) and/or \( F \); depending on the model choice) by using the Bus Selector block from Simulink Signal Routing library.
  - Use the Permute Dimensions block from Simulink Math Operations library to convert each signal into a column vector.
  - Combine the parameters back into a bus signal, if necessary, using the Bus Creator block from Simulink Signal Routing library.
• If you specified the initial guess for any of the parameter values (Initial A(q), Initial B(q), Initial C(q), Initial D(q), or Initial F(q)) as column vectors, an error occurs during simulation. Specify them as row vectors. For MISO polynomial models, transpose the Initial B(q) matrix so that the i-th row parameters correspond to the i-th input.

Change in input specification of Model Type Converter block

The Model Type Converter block inport now only accepts bus signal elements specified as row vectors. Previously, you specified the bus elements as column vectors. For MISO data, specify B polynomial coefficients as a matrix where the i-th row parameters correspond to the i-th input.

Compatibility Considerations

If you specified the inport bus signal elements as column vectors, an error occurs during simulation. Specify them as row vectors. For MISO polynomial models, transpose the B matrix so that the i-th row parameters correspond to the i-th input.

Functionality Being Removed or Changed

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Result</th>
<th>Use This Instead</th>
<th>Compatibility Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>rarx</td>
<td>Warns</td>
<td>recursiveAR or recursiveARX</td>
<td>See “Online Parameter Estimation Commands: Implement and deploy recursive estimators with MATLAB Compiler or MATLAB Coder” on page 1-2 for more information.</td>
</tr>
<tr>
<td>rarmax</td>
<td>Warns</td>
<td>recursiveARMA or recursiveARMAX</td>
<td>See “Online Parameter Estimation Commands: Implement and deploy recursive estimators with MATLAB Compiler or MATLAB Coder” on page 1-2 for more information.</td>
</tr>
<tr>
<td>roe</td>
<td>Warns</td>
<td>recursiveOE</td>
<td>See “Online Parameter Estimation Commands: Implement and deploy recursive estimators with MATLAB Compiler or MATLAB Coder” on page 1-2 for more information.</td>
</tr>
<tr>
<td>Functionality</td>
<td>Result</td>
<td>Use This Instead</td>
<td>Compatibility Considerations</td>
</tr>
<tr>
<td>---------------</td>
<td>--------</td>
<td>-----------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Implement and deploy recursive estimators with MATLAB Compiler or MATLAB Coder” on page 1-2 for more information.</td>
</tr>
<tr>
<td>rbj</td>
<td>Warns</td>
<td>recursiveBJ</td>
<td>See “Online Parameter Estimation Commands: Implement and deploy recursive estimators with MATLAB Compiler or MATLAB Coder” on page 1-2 for more information.</td>
</tr>
<tr>
<td>y = sim(model,u,'Noise')returns for idnlarx, idnlhw, or idnlgrey models</td>
<td>Still works</td>
<td></td>
<td>See “Unified sim command for simulating linear and nonlinear identified models” on page 1-3 for more information.</td>
</tr>
<tr>
<td>y = sim(model,u,'Initial')works for idnlarx, idnlhw, or idnlgrey models</td>
<td>Still works</td>
<td></td>
<td>See “Unified sim command for simulating linear and nonlinear identified models” on page 1-3 for more information.</td>
</tr>
<tr>
<td>[y,y_sd,XFINAL] = sim(model,u) for idnlgrey models</td>
<td>Still works</td>
<td></td>
<td>See “Unified sim command for simulating linear and nonlinear identified models” on page 1-3 for more information.</td>
</tr>
<tr>
<td>Simulink model requiring output from Parameters output port of Recursive Polynomial Model Estimator block to be a column vector.</td>
<td>Error</td>
<td></td>
<td>See “Change in output and initial estimate specification of Recursive Polynomial Model Estimator block” on page 1-5 for more information.</td>
</tr>
<tr>
<td>Functionality</td>
<td>Result</td>
<td>Use This Instead</td>
<td>Compatibility Considerations</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>--------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Initial parameter guess specified as column vector in Recursive Polynomial Model Estimator block.</td>
<td>Error</td>
<td>Specify as row vector. For MISO polynomial models, transpose the original <strong>Initial B(q)</strong> matrix.</td>
<td>See “Change in output and initial estimate specification of Recursive Polynomial Model Estimator block” on page 1-5 for more information.</td>
</tr>
<tr>
<td>Inport bus signal elements specified as column vectors in Model Type Converter block.</td>
<td>Error</td>
<td>Specify the bus elements as row vectors. For MISO polynomial models, transpose the original <strong>B</strong> matrix.</td>
<td>See, “Change in input specification of Model Type Converter block” on page 1-6 for more information.</td>
</tr>
</tbody>
</table>
R2015a

Version: 9.2

New Features

Bug Fixes

Compatibility Considerations
**nlgreyest command for nonlinear grey-box model estimation**

You can use the nlgreyest estimator to estimate nonlinear grey-box models. Use the nlgreyestOptions option set to configure the model estimation objective and search method used by the estimator. For more information, see the corresponding reference pages.

**Estimation options for nonlinear ARX, Hammerstein-Wiener, and nonlinear grey-box model estimators**

You can use option sets for the nonlinear ARX, Hammerstein-Wiener and nonlinear grey-box model estimators to configure the model estimation objective and search method. Instead of using name-value pair input arguments in nlarx and nlhw, or the Algorithm property of the model, use the following commands:

- nlarxOptions — Option set for nlarx
- nlhwOptions — Option set for nlhw
- nlgreyestOptions — Option set for nlgreyest

To learn more about the estimation options, see the corresponding reference pages.

**Compatibility Considerations**

- The option sets replace the Algorithm property of nonlinear ARX (idnlarx), Hammerstein-Wiener (idnlhw), and nonlinear grey-box (idnlgrey) models.

The following table shows the mapping of the fields of Algorithm to those of the estimation options set.

<table>
<thead>
<tr>
<th>Algorithm Property Field</th>
<th>Option Set Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>LimitError</td>
<td>Advanced.ErrorThreshold</td>
</tr>
<tr>
<td>Criterion/Weighting</td>
<td>OutputWeight</td>
</tr>
<tr>
<td></td>
<td>• If Algorithm.Criterion was 'det', use OutputWeight = 'noise'.</td>
</tr>
<tr>
<td></td>
<td>• If Algorithm.Criterion was 'trace', set OutputWeight to the values in Algorithm.Weighting.</td>
</tr>
</tbody>
</table>
Algorithm Property Field | Option Set Field
---|---
MaxIter | SearchOption.MaxIter
Tolerance | SearchOption.Tolerance
MaxSize | Advanced.MaxSize
Advanced.Search | SearchMethod and SearchOptions

- For nonlinear ARX models, the Focus property has been replaced by the Focus option in the nlarxOptions option set. See the reference page for more information.

**Reorganization of nonlinear model estimation reports**

A new property of nonlinear models, Report, provides information on the estimation. This read-only property replaces the EstimationInfo property and provides additional information regarding:

- Estimated parameters. For nonlinear grey-box models, it also contains the values of initial states, and parameter and initial state covariance matrices.
- The option set used for estimation.
- Information on data used for estimation, such as percentage fit to estimation data and the mean square error.

The Report fields are mostly uniform for the identified nonlinear models. However, certain fields of Report are model dependent.

To learn more about the estimation report, see Estimation Report, and the model and estimator reference pages.

**Compatibility Considerations**


The following table shows the mapping of the fields of EstimationInfo to those of Report.

<table>
<thead>
<tr>
<th>EstimationInfo Field</th>
<th>Report Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>LossFcn</td>
<td>Fit.LossFcn</td>
</tr>
<tr>
<td>EstimationInfo Field</td>
<td>Report Field</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>FPE</td>
<td>Fit.FPE</td>
</tr>
<tr>
<td>DataName</td>
<td>DataUsed.Name</td>
</tr>
<tr>
<td>DataLength</td>
<td>DataUsed.Length</td>
</tr>
<tr>
<td>DataTs</td>
<td>DataUsed.Ts</td>
</tr>
<tr>
<td>DataDomain</td>
<td>DataUsed.Type</td>
</tr>
<tr>
<td>DataInterSample</td>
<td>DataUsed.InterSample</td>
</tr>
<tr>
<td>WhyStop</td>
<td>Termination.WhyStop</td>
</tr>
<tr>
<td>UpdateNorm</td>
<td>Termination.UpdateNorm</td>
</tr>
<tr>
<td>LastImprovement</td>
<td>Termination.LastImprovement</td>
</tr>
<tr>
<td>Iterations</td>
<td>Termination.Iterations</td>
</tr>
<tr>
<td>InitialState</td>
<td>No replacement</td>
</tr>
<tr>
<td>Warning</td>
<td>No replacement</td>
</tr>
</tbody>
</table>

- For nonlinear grey-box models, the `SimulationOptions` algorithm property is now a property of the `idnlgrey` model itself. See the model reference page for more information.

**findopOptions command to create option set for operating point computation of nonlinear ARX or Hammerstein-Wiener models**

You can use `findopOptions` to create an option set for computing the operating point of a nonlinear ARX (`idnlarx`) or Hammerstein-Wiener (`idnlhw`) model. Use the option set with `idnlarx/findop` and `idnlhw/findop` to specify the optimization search options.

**Unified findstates command for nonlinear models**

The `findstates` methods of nonlinear ARX, Hammerstein-Wiener, and nonlinear grey-box models have been replaced with a single `findstates` command which provides a more unified syntax. You can also use `findstatesOptions` to create an option set for estimating initial states of the nonlinear models.
## Functionality being removed or changed

<table>
<thead>
<tr>
<th>Functionality</th>
<th>What Happens When You Use This Functionality?</th>
<th>Use This Instead</th>
<th>Compatibility Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithm property</td>
<td>Still works</td>
<td>nlarxOptions n1hwOptions</td>
<td>See “Estimation options for nonlinear ARX, Hammerstein-Wiener, and nonlinear grey-box model estimators” on page 2-2</td>
</tr>
<tr>
<td>Focus property of idnlarx models</td>
<td>Still works</td>
<td>Focus option in the nlarxOptions option set</td>
<td>See “Estimation options for nonlinear ARX, Hammerstein-Wiener, and nonlinear grey-box model estimators” on page 2-2</td>
</tr>
<tr>
<td>EstimationInfo property</td>
<td>Still works</td>
<td>Report property</td>
<td>See “Reorganization of nonlinear model estimation reports” on page 2-3</td>
</tr>
</tbody>
</table>
R2014b

Version: 9.1

New Features

Bug Fixes

Compatibility Considerations
AR, ARMA, Output-Error, and Box-Jenkins online model estimation with Recursive Polynomial Model Estimator block

The Recursive Polynomial Model Estimator block has been enhanced to estimate the coefficients of linear time-invariant and linear time-varying AR, ARMA, Output-Error (OE) or Box-Jenkins (BJ) models. The parameters are estimated as new data becomes available during the operation of the system. For more information, see Online Estimation.

You can also estimate a state-space model online from these models by using the Recursive Polynomial Model Estimator and Model Type Converter blocks together. Connect the output of the Recursive Polynomial Model Estimator block to the input of the Model Type Converter block to obtain online values of the state-space matrices. The conversion ignores the noise component of the models. In other words, the state-space matrices only capture the $y[k]/u[k]$ relationship, which is $B(q)/F(q)$ for OE and BJ models.

Kalman Filter block for estimating states of linear time-invariant and linear time-varying systems

Use the Kalman Filter block to estimate the states of linear time-invariant and linear time-varying systems online. The states are estimated as new data becomes available during the operation of the system. The system can be continuous-time or discrete-time. You can generate code for this block using code generation products such as Simulink Coder.

You can access this block from the Estimators sublibrary of System Identification Toolbox library. For an example of using this block, see State Estimation Using Time-Varying Kalman Filter.

Initial guesses for A(q) and C(q) polynomials in Recursive Polynomial Model Estimator block

The first element of the initial guesses for the $A(q)$ and $C(q)$ polynomials in the Recursive Polynomial Model Estimator block must be specified as 1. When the Initial Estimate option is Internal, you specify these values in the Initial $A(q)$ and Initial $C(q)$ parameters in the Block Parameters dialog box. When the Initial Estimate option is External, you specify these values using the Initial Parameters input of the block.
In previous releases, the software auto-scaled these values to 1.

**Compatibility Considerations**

If you specified the **Initial Estimate** parameter as **Internal**, an error occurs during simulation. If you specified this parameter as **External**, a warning occurs. Before you simulate the model, scale the initial guesses for the $A(q)$ and $C(q)$ polynomials by dividing both these vectors by their first elements.

**ident command renamed to systemIdentification**

The `ident` command to open the System Identification app has been renamed to `systemIdentification`.

**Functionality being removed or changed**

<table>
<thead>
<tr>
<th>Functionality</th>
<th>What Happens When You Use This Functionality?</th>
<th>Use This Instead</th>
<th>Compatibility Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR Estimator, ARMAX Estimator, ARX Estimator, BJ Estimator, and OE Estimator blocks</td>
<td>Still works</td>
<td>Recursive Polynomial Model Estimator</td>
<td>Consider replacing these blocks with the Recursive Polynomial Model Estimator block to perform recursive estimation.</td>
</tr>
<tr>
<td>PEM Estimator block</td>
<td>Still works</td>
<td>No replacement</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
R2014a

Version: 9.0

New Features

Bug Fixes

Compatibility Considerations
Recursive Least Squares Estimator and Recursive Polynomial Model Estimator blocks for online model parameter estimation

Use the Recursive Least Squares Estimator and Recursive Polynomial Model Estimator blocks to perform online model parameter estimation in Simulink. Online parameter estimation, also known as *online estimation* or *online tuning*, refers to estimating model parameters as new data becomes available during the operation of the model. You can generate code for these blocks using code generation products such as Simulink Coder. For example, you can estimate the coefficients of a time-varying plant from measured input-output data and feed them to an adaptive controller. After validating the online estimation in simulation, you can generate code for your Simulink model and deploy the same to an embedded target.

These blocks are in the Estimators library.

For examples of how to use these blocks, see Preprocess Online Estimation Data and Validate Online Estimation Results.

**Compatibility Considerations**

The following blocks will be removed in a future release: AR Estimator, ARMAX Estimator, ARX Estimator, BJ Estimator, OE Estimator, and PEM Estimator.

**Interactive identification of single-input/single-output plants from measured data in PID Tuner app**

As a part of the control design workflow, you can interactively identify a plant using measured data in the PID Tuner app in Control System Toolbox™. For example, to design a PID controller for a manufacturing process, you can start with response data from a bump test on your system. You can import this data instead of a plant model in the tuner. You can then interactively identify a linear plant model whose response fits the response data.

The PID Tuner automatically tunes a PID controller for the identified model. You can then interactively adjust the PID controller gains, and save the identified plant and tuned controller. For more information, see System Identification for PID Control.

To access the PID Tuner, enter pidtool at the MATLAB command line. For an example, see Interactively Estimate Plant Parameters from Response Data.
Interactive identification of single-input/single-output plants from simulation data when tuning PID Controller blocks using Simulink Control Design

You can obtain a linear representation of a Simulink model and tune the gains of a PID Controller block for the plant in the PID Tuner app. The identification-based approach serves as an alternative to the linearization-based approach and is useful where linearization fails to yield a good plant model. This functionality requires Simulink Control Design™ software.

The identification works by simulating the Simulink model and then using the simulated input-output data to obtain a plant model. You identify the plant using interactive graphical tools in the PID Tuner app. Next, you use the identified model to tune your PID Controller block. For example, suppose you want to tune the PID Controller block in a model that contains a Triggered Subsystem block. The analytical block-by-block linearization algorithm does not support event-based subsystems, and therefore the model linearizes to zero. Now, you can simulate the Simulink model for a chosen input and use the simulated data to identify a plant model. The PID Tuner automatically tunes the PID controller for the identified model. You can then interactively adjust the performance of the tuned control system, and save the identified plant and tuned controller. For more information, see System Identification for PID Control.

To access the PID Tuner, in the PID Controller block dialog box, click **Tune**. For an example, see “Design a PID Controller Using Simulated I/O Data” in the Simulink Control Design documentation.

**ssregest**, a regularization-based state-space model estimator, for improved accuracy on short, noisy data sets

You can use ssregest to estimate state-space models. This estimator is known to perform better than n4sid for short, noisy data sets. For some problems, the quality of fit using n4sid is sensitive to options, such as N4Horizon, whose values can be difficult to determine. In comparison, the quality of fit with ssregest is less sensitive to its options, which makes ssregest simpler to use.

ssregest estimates a regularized ARX model and converts the ARX model to a state-space model. The software then uses balanced model reduction techniques to reduce the state-space model to the specified order. You can specify estimation options for ssregest using ssregestOptions.
You can also select this estimator in the System Identification Tool. In the State Space Models dialog box, expand **Estimation Options** and select **Regularized Reduction** from the **Estimation Method** drop-down list.

**plot command for iddata object enhanced**

The plot command for input-output data iddata has the following enhancements:

- Multiexperiment data or datasets with more than one input or output channels are plotted on a single plot
- Input and output channels can be grouped together

You can customize the plot, such as group and ungroup channels, and explore data characteristics, such as peak and mean value, using the right-click menu.

You can also customize the plot, such as specify axes labels, using iddataPlotOptions.
Options set and specification of input delay and noise source integrator for *arxRegul* command

You can now use *arxRegulOptions* to specify regularization options for *arxRegul*. Regularization options include the regularization kernel to use, such as 'TC' and 'SE', and search method for estimating regularization constants.

You can also specify input delay and presence of a noise source integrator as Name-Value pair arguments in *arxRegul*.

Compatibility Considerations

Replace `[lambda,R] = arxRegul(data,orders,kernel)` and `[lambda,R] = arxRegul(data,orders,kernel,max_size)` syntaxes with `[lambda,R] = arxRegul(data,orders,options)` syntax. Specify `kernel` and `max_size` in the options set created using *arxRegulOptions*. 
R2013b

Version: 8.3

New Features

Bug Fixes
Regularized estimation of linear and nonlinear models for obtaining parameter values with less variance

You can now obtain regularized estimates of parameters for linear and nonlinear models. Previously, you could specify this option for correlation model estimation only, using impulseestOptions.

Regularization reduces variance of estimated model parameters by trading variance for bias. Regularization is useful for:

- Identifying overparameterized models, such as nonlinear ARX models
- Imposing apriori knowledge of model parameters in structured models, such as grey-box models
- Incorporating knowledge of system behavior in ARX and FIR models

Using regularization adds a penalty proportional to the parameter dimension and values in the cost function that is minimized for estimation. Without regularization, the parameter estimates are obtained by minimizing a weighted quadratic norm of the prediction errors $\varepsilon(t,\theta)$:

$$V_N(\theta) = \frac{1}{N} \sum_{t=1}^{N} \varepsilon^2(t,\theta)$$

where $t$ is the time variable, $N$ is the number of data samples and $\varepsilon(t,\theta)$ is the predicted error computed as the difference between the observed output and the predicted output of the model.

A regularized estimation minimizes:

$$\hat{V}_N(\theta) = \frac{1}{N} \sum_{t=1}^{N} \varepsilon^2(t,\theta) + \frac{1}{N} \lambda \theta^T R \theta ,$$

where $\lambda$ is a constant that trades off variance for bias in the estimated values of parameters $\theta$. $R$ is an associated weighting matrix.

For more information on regularization, see Regularized Estimates of Model Parameters.

You can specify the regularization constants Lambda, R, and Nominal at the command line or in the System Identification Tool:
At the command line, use the `Regularization` option available in the estimation options set (tfestOptions, ssestOptions,...) for linear models.

For nonlinear models, the option is available in the `Algorithm` property of idnlarx, idnlhw, and idnlgrey models.

For ARX models, you can generate `Lambda` and `R` values automatically from a given regularization kernel using the `arxRegul` command.

See the estimator reference pages and Regularized Identification of Dynamic Systems for examples.

In the System Identification Tool, click `Regularization` in the linear model estimation dialog box or click `Estimation Options` in the Nonlinear Models dialog box.

For an example, see Estimate Regularized ARX Model Using System Identification Tool.

**ssarx subspace identification method for robust estimation of state-space models using closed-loop data**

`N4Weight`, which represents the weighting scheme used for singular-value decomposition by the N4SID algorithm, now includes a `ssarx` option. This option is an ARX estimation-based algorithm to compute the weighting. Specifying this option allows the N4SID algorithm to compute unbiased estimates of the model parameters when using data that is collected in a closed-loop operation. For more information about the algorithm, see Jansson, M., "Subspace identification and ARX modeling", *13th IFAC Symposium on System Identification*, Rotterdam, The Netherlands, 2003.

To specify this option:

- At the command line, set the `N4Weight` option in n4sidOptions or ssestOptions to `ssarx`.
- In the System Identification Tool, in the State Space Models dialog box, expand `Estimation Options` and select SSARX from the `N4Weight` drop-down list.

For an example of using the subspace algorithm for closed-loop data, see the n4sid reference page.
Redesigned state-space model and initial model refinement dialog boxes

The State Space Models and Linear Model Refinement dialog boxes have been redesigned to improve state-space model estimation and initial model refinement workflows.

To open the State Space Models dialog box, select Estimate > State Space Models in the System Identification Tool.

To access the redesigned Linear Model Refinement dialog box, in the System Identification Tool, select Estimate > Refine Existing Models.
The initial model must be in the Model Board of the System Identification Tool or a variable in the MATLAB workspace. This model can be a state-space, polynomial, process, or transfer function model.

For more information, click Help in the dialog boxes.

**getpar and setpar commands to obtain and set parameter attributes of identified linear models**

You can now use getpar with identified linear models to obtain parameter values, free or fixed status, minimum/maximum bounds, and labels. Identified linear models include process, input-output polynomial, state-space, transfer function, and grey-box models.

Similarly, use setpar to set these parameter attributes.

**Unstable models option added to System Identification Tool**

You can now estimate unstable models in the System Identification Tool. You can use this option to:
• Estimate transfer function models using frequency-domain data.
• Estimate state-space models using time- or frequency-domain data.
• Refine linear models using time- and frequency-domain data.

This functionality is the same as setting the estimation option Focus to 'prediction' at the command line.

The option allows the estimation process to use parameter values that might lead to unstable models. An unstable model is delivered only if it produces a better fit to the data than other stable models computed during the estimation process. Such an unstable model might be useful, if, for example, you plan to design a controller for the model.

To set this option in the Transfer Function dialog box, expand Estimation Options and select the Allow unstable models check box. In the State Space Models and Linear Model Refinement dialog boxes, this option is selected by default.

**SamplingGrid property for tracking dependence of array of sampled models on variable values**

For arrays of identified linear (IDLTI) models that are derived by sampling one or more independent variables, the new SamplingGrid property keeps track of the variable values associated with each model in the array. This information is shown when displaying or plotting the model array. The information is useful to trace results back to the independent variables.

Set this property to a structure whose fields are named after the sampling variables and contain the sample values associated with each model. All sampling variables should be numeric and scalar valued, and all arrays of sample values should be commensurate with the model array.

For example, if you collect data at various operating points of a system, you can identify a model for each operating point separately and then stack the results together into a single system array. You can tag the individual models in the array with information regarding the operating point:

```
nominal_engine_rpm = [1000 5000 10000];
sys.SamplingGrid = struct('rpm',nominal_engine_rpm)
```

where `sys` is an array containing three identified models obtained at rpms 1000, 5000, and 10000, respectively.
R2013a
Version: 8.2
Bug Fixes
R2012b

Version: 8.1

New Features

Bug Fixes

Compatibility Considerations
Regularized estimates of impulse response, specification of transport delays and estimation options using `impulseest`

You can obtain regularized estimates of impulse response using the regularization kernel (`RegulKernel`) estimation option. Regularization reduces variance of estimated model coefficients and produces a smoother response by trading variance for bias. You can also configure estimation options such as prefilter order and data offsets. You use `impulseestOptions` to specify the estimation options and pass them as an input to `impulseest`.

You can also specify filter orders and transport delays as inputs to `impulseest`.

Compatibility Considerations

- Using a time vector as an input to `impulseest` or specifying the `'noncausal'` flag warns and will be removed in a future version. Specify the order of the impulse response model instead.
- To compute the acausal part of the response up to a negative lag \( L \), set the input delay input argument to \( -L \).

`translatecov` command for translating model covariance across transformations

You can use `translatecov` to translate model covariance across model transformations such as continuous- and discrete-time conversions, concatenation and conversions to different model types. Previously, model covariance was lost when you performed such operations on a model directly. `translatecov` lets you perform these operations while also translating the covariance data. For example, transform an estimated continuous-time model \( mc \) to discrete-time:

```matlab
md = c2d(mc,Ts);
md2 = translatecov(@(x)c2d(x,Ts),mc)
```

The first operation produces a discrete-time model, \( md \), which does not contain parameter covariance data. The second operation produces the model, \( md2 \), which has the same structure and parameter values as \( md \) but contains parameter covariance data.
ssform command for quick configuration of state-space model structure

You can use ssform to configure model parameterization, feedthrough and disturbance dynamics. This command lets you quickly configure these properties when estimating state-space models in a structured way. You can use this command as a simpler alternative to explicitly modifying the Structure property of the idss model for some commonly applied changes. For example, typing

```matlab
ssform(model,'Form','canonical','DisturbanceModel','estimate')
```

configures the model structure such that:

- Its A, B, and C matrices are in observability canonical form
- The K matrix entries are all treated as free parameters

Feedthrough specification for discrete-time transfer function model estimation

When estimating a discrete-time transfer function model, you can specify whether the model has feedthrough. Use the Feedthrough name-value pair in tfest or click Feedthrough in the graphical interface. For MIMO systems, you can specify feedthrough for individual channels or a common value across all channels.
R2012a

Version: 8.0

New Features

Bug Fixes

Compatibility Considerations
Summary

Important new features and changes in the System Identification Toolbox™ software for this release include:

• New functions that perform continuous-time estimation for state-space and transfer function models.
• Support for multi-output estimation for polynomial models (such as ARMAX, OE, and BJ) and process models.
• A new, uniform design for linear, parametric models. You can specify whether a coefficient should be estimated and now impose minimum/maximum bounds on estimated coefficients in a standardized manner.
• Consolidation of the functions dealing with linear time-invariant systems in the Control System Toolbox software. This unification of code allows for a streamlined workflow in estimating models and analyzing them and improves numerical accuracy and consistency.
• Many commands now have a more unified syntax, but, with few exceptions, old syntax continues to work in this release for backward compatibility. Incompatibilities introduced this release mainly involve configuration of estimation options, translation of parameter covariance, reordering of output arguments for some functions and the treatment of certain model properties.

Note: Instances where the changes will break existing code or yield different results have been marked as "Backward incompatibility".

New Features in This Version

New features this release include:

• “Continuous-Time Transfer Function Identification for Time- and Frequency-Domain Data” on page 8-3
• “Time-Series Modeling and Forecasting, Including Generating ARIMA Models” on page 8-3
• “Estimation of Multi-Output Polynomial and Process Models” on page 8-4
• “Interactive Response Plots with Better Look and Feel” on page 8-4
• “Models Created with System Identification Toolbox Can Be Used Directly with Control System Toolbox Functions” on page 8-5
Continuous-Time Transfer Function Identification for Time- and Frequency-Domain Data

A new function, `tfest`, lets you estimate a linear transfer function based on a system’s response. `tfest` can be used for time- and frequency-domain data.

The output of `tfest` is an `idtf` model, which is a new identified linear model. An `idtf` model stores the identified numerator, denominator, and any transport delays using its `num`, `den`, and `ioDelay` properties, respectively.

For information regarding estimating a continuous-time transfer function using time-domain data, see How to Estimate Transfer Function Models by Specifying Number of Poles.

For information regarding estimating a continuous-time transfer function using frequency-domain data, see How to Estimate Transfer Function Models with Transport Delay to Fit Given Frequency Response Data.

Time-Series Modeling and Forecasting, Including Generating ARIMA Models

Forecasting

A new function, `forecast`, lets you forecast the response of an identified linear model for a specified future time interval. You may also specify the future inputs for models that are not time-series models.

`forecast` complements the functionality of `predict`, which evaluates fixed-step ahead predictions on historic data.

Use `forecastOptions` to create an option set to specify forecasting options.

For more information, see `forecast` and `forecastOptions`.

Generating ARIMA Models

A new property for `idpoly` models, `IntegrateNoise`, designates if a model output contains an integrator in its noise source. Use the `IntegrateNoise` property to create, for example, ARI, ARIMA, ARIX, and ARIMAX models.
The `IntegrateNoise` property takes a logical vector of length \( Ny \), where \( Ny \) is the number of outputs.

For more information, see Estimating ARIMA Models.

**Estimation of Multi-Output Polynomial and Process Models**

**Multi-Output Polynomial Models**

`idpoly` models can now represent multi-output polynomial models. Use `idpoly` to create a multi-output polynomial model. You can also use the various estimator functions (ar, arx, bj, oe, and armax) to estimate a multi-output `idpoly` model.

A new function, `polyest`, may also be used to estimate a multi-output polynomial model of arbitrary structure. For more information, see `polyest` and `polyestOptions`.

**Compatibility Consideration: Backward incompatibility.** See “idarx Models No Longer Returned in Multi-Output Model Estimation” on page 8-20.

**Multi-Output Process Models**

`idproc` models can now represent multi-output process models. Use `idproc` to create a multi-output process model. You can also use the new process model estimator function, `procest`, to estimate a multi-output `idproc` model.

For more information, see `procest` and `procestOptions`.

**Interactive Response Plots with Better Look and Feel**

Enhanced response plots for identified linear models allow you to interactively:

- Choose the system characteristics that are displayed. To view a system characteristic, right-click on the plot, select Characteristics, and then select the system characteristic of interest.

- Modify plot properties, such as whether the grid is on or off, axes labels and units, advanced plot options, etc. To modify the plot properties, right-click on the plot, and select Properties. The Property Editor dialog box opens. Modify the plot property of interest.

You can plot the confidence intervals associated with identified linear models. You can now plot the confidence interval interactively, by right-clicking on the plot and selecting Characteristics > Confidence Region. You can also use the new function, `showConfidence`, to display the confidence region on a plot via the command line.
Models Created with System Identification Toolbox Can Be Used Directly with Control System Toolbox Functions

Identified linear models that you create using System Identification Toolbox software can now be used directly with Control System Toolbox analysis and compensator design commands. In previous releases, doing so required conversion to Control System Toolbox model types.

Identified linear models include idfrd, idss, idproc, idtf, idgrey, and idpoly models.

Identified linear models can be used directly with:

- Any Control System Toolbox or Robust Control Toolbox™ functions that operate on dynamic systems, including:
  - Response plots — nichols, margin, and rlocus.
  - Model simplification — pade, balred, and minreal.
  - System interconnections — series, parallel, feedback, and connect

For a complete list of these functions, type:

```matlab
methods('DynamicSystem')
```

- Analysis and design tools such as ltiview, sisotool, and pidtool.
- The LTI System block in Simulink models.

Improved Reliability of Numerical Computations

Algorithm sharing between the System Identification Toolbox and the Control System Toolbox products increase the accuracy and consistency of results for various operations. Operations affected include frequency-response and pole-zero computation, model conversion, settling-time deduction, and model discretization (c2d and d2c).

The handling of parameter covariance for over-parameterized systems has also improved. You can now fetch parameter covariance data in a factored form for over-parameterized systems, where the raw covariance matrix is ill-defined.

Estimating Functions and Estimation Option Sets

You can use the new estimating functions `tfest`, `ssest`, `procest`, `greyest`, `polyest`, and `impulseest` to estimate various model types. The new functions are based on the prediction error method, PEM.
Also, you can now configure model estimation objective functions and search schemes using dedicated option sets. To create and configure the option set for a model estimating function, use the corresponding option set function:

<table>
<thead>
<tr>
<th>Model Estimating Function</th>
<th>Options Set Function</th>
<th>Estimated Linear Model Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ar</td>
<td>arOptions</td>
<td>idpoly (AR structure polynomial)</td>
</tr>
<tr>
<td>armax</td>
<td>armaxOptions</td>
<td>idpoly (ARMAX structure polynomial)</td>
</tr>
<tr>
<td>arx</td>
<td>arxOptions</td>
<td>idpoly (ARX structure polynomial)</td>
</tr>
<tr>
<td>bj</td>
<td>bjOptions</td>
<td>idpoly (Box-Jenkins polynomial)</td>
</tr>
<tr>
<td>greyest</td>
<td>greyestOptions</td>
<td>idgrey</td>
</tr>
<tr>
<td>iv4</td>
<td>iv4Options</td>
<td>idpoly</td>
</tr>
<tr>
<td>n4sid</td>
<td>n4sidOptions</td>
<td>idss</td>
</tr>
<tr>
<td>oe</td>
<td>oeOptions</td>
<td>idpoly (Output-error polynomial)</td>
</tr>
<tr>
<td>polyest</td>
<td>polyestOptions</td>
<td>idpoly</td>
</tr>
<tr>
<td>procest</td>
<td>procestOptions</td>
<td>idproc</td>
</tr>
<tr>
<td>ssest</td>
<td>ssestOptions</td>
<td>idss</td>
</tr>
<tr>
<td>tfest</td>
<td>tfestOptions</td>
<td>idtf</td>
</tr>
</tbody>
</table>

For more information regarding these functions, enter `doc function_name` at the MATLAB command prompt.

**Compatibility Considerations**

The option sets replace the `Algorithm` model property.

The `Algorithm` property is no longer supported. The fields of `Algorithm` map to estimation options as follows:

<table>
<thead>
<tr>
<th>Algorithm Property Field</th>
<th>Options Set Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>LimitError</td>
<td>Advanced.ErrorThreshold</td>
</tr>
</tbody>
</table>
Algorithm Property Field | Options Set Field
--- | ---
Advanced.Threshold.Sstability | Advanced.StabilityThreshold.s
Advanced.Threshold.AutoInitThreshold | Advanced.AutoInitThreshold

Criterion/Weighting | OutputWeight
- If Algorithm.Criterion was 'det', use OutputWeight = 'noise'.
- If Algorithm.Criterion was 'trace', use OutputWeight = Algorithm.Weighting.

FixedParameter | No replacement. Use the Structure property of the identified linear model to designate its fixed parameters.

MaxIter | SearchOption.MaxIter
Tolerance | SearchOption.Tolerance
MaxSize | Advanced.MaxSize
Advanced.Search | SearchMethod and SearchOptions. These fields are available for only iterative estimation methods, such as tfestOptions.

Model Analysis and Validation Option Sets

You can now use option sets to configure the various attributes of model simulation and prediction commands. The option sets configure, among other things, how the initial conditions and data offsets are handled. They replace the property-value pairs used by the analysis commands as input arguments. To create and configure the option set for an analysis or validation function, use the corresponding option set creating function:

<table>
<thead>
<tr>
<th>Analysis/Validation Function</th>
<th>Options Set Function</th>
</tr>
</thead>
</table>
predict | predictOptions |
compare | compareOptions |
sim | simOptions |
simsd | simsdOptions |
### Analysis/Validation Function

<table>
<thead>
<tr>
<th>Analysis/Validation Function</th>
<th>Options Set Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>forecast</td>
<td>forecastOptions</td>
</tr>
<tr>
<td>findstates</td>
<td>findstatesOptions</td>
</tr>
<tr>
<td>pe</td>
<td>peOptions</td>
</tr>
</tbody>
</table>

For more information regarding these functions, enter `doc function_name` at the MATLAB command prompt.

### Compatibility Considerations

**Specifying Initial Conditions and Noise Data**

To specify the initial conditions and noise specifications for `sim` or `simsd`, use the corresponding option set with the `InitialCondition`, `AddNoise`, and `NoiseData` options set appropriately. In previous releases, you could use name and value pair input arguments to specify these options.

**Identified Linear Models**

**Support for Constraining and Fixing Parameters in All Identified Linear Models**

You can now specify minimum/maximum bounds for, and fix or free for estimation, any parameter of an identified linear model. You use the new model property, `Structure`, to access a parameter and configure it.

**Support for Model Arrays**

You can now create arrays of identified linear models to analyze multiple models simultaneously. You can create an array using array subassignment. For example, `sys(:,:,k) = new sys;`.

You can also use the `stack` function to create an identified linear model array. For more information, see `stack`.

You can also use the new function, `rsample`, to create an array of models that sample an identified linear model within the uncertainty limits of its parameters. For more information see `rsample`.

**Estimation Report**

You can use the new `Report` property of identified linear models for information regarding the estimation performed to obtain the model.

For more information, see “Reorganization of Estimation Reports” on page 8-18.
Convert Time-Series Model to Input-Output Model for Analysis

Use the new function, `noise2meas`, to convert a time-series model, which has no measured inputs, to an input-output model for linear analysis. `noise2meas` complements the functionality of `noisecnv`, which converts an identified model with noise channels to a model with only measured inputs.

For more information, see `noise2meas`.

Specify Input/Output Pairs Using Subsystems

You can now specify subsystems as input/output models for all identified linear models, except `idgrey` models.

For example, `sys(i,j) = sys0;`

Group Inputs and Outputs

You can now group inputs and outputs for identified linear models using the `InputGroup` and `OutputGroup` properties, respectively.

For more information regarding specifying input groups, enter `help idlti.InputGroup` at the MATLAB command prompt.

For more information regarding specifying output groups, enter `help idlti.OutputGroup` at the MATLAB command prompt.

Model Parameter Interaction

New commands for interacting with the parameters of identified linear models include:

- `getpvec` — Fetch the model parameters.
- `setpvec` — Set the model parameters.
- `getcov` — Fetch the parameter covariance matrix.
- `setcov` — Set the parameter covariance matrix.
- `nparams` — Fetch number of model parameters.

For more information regarding these functions, enter `doc function_name` at the MATLAB command prompt.

Random Sampling

The new `rsample` function creates a set of perturbed systems corresponding to an identified linear model. Use this random sampling of an identified linear model for Monte-Carlo analysis.
For more information see rsample.

**Compatibility Considerations**

The recommended usage and workflow has changed for some model parameters. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflows may not be supported in the future.

The following table lists affected model properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Model Types Affected</th>
<th>What Happens in R2012a</th>
<th>Use This Instead</th>
</tr>
</thead>
<tbody>
<tr>
<td>ParameterVector</td>
<td>idss, idpoly, idgrey, and idproc</td>
<td>Still available.</td>
<td>Use the new function <code>getpvec</code> to access model parameters.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The list of parameters obtained from <code>ParameterVector</code> may differ from the list of parameters returned by <code>getpvec</code>.</td>
</tr>
<tr>
<td>PName</td>
<td>idss, idpoly, idgrey, and idproc</td>
<td>Still available.</td>
<td>Each identified linear model now has a <code>Structure</code> property, which consists of the parameters relevant to the model. Each of the parameters has an <code>Info</code> field, which may be used to store information regarding the parameter. To store the parameter name, use <code>Info.Label</code>.</td>
</tr>
<tr>
<td>Property</td>
<td>Model Types Affected</td>
<td>What Happens in R2012a</td>
<td>Use This Instead</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------</td>
<td>------------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Algorithm</td>
<td>idss, idpoly, idgrey, and idproc</td>
<td>Still available.</td>
<td>See “Estimating Functions and Estimation Option Sets” on page 8-5.</td>
</tr>
<tr>
<td>CovarianceMatrix</td>
<td>idss, idpoly, idgrey, and idproc</td>
<td>Still available.</td>
<td>Use the new functions, getcov and setcov, to interact with the covariance matrix of the model. Also, after a model, sys, is estimated, you may access the estimated covariance matrix using sys.Report.Parameters.</td>
</tr>
</tbody>
</table>
| All identified linear models. | **Backward incompatibility.** Parameter covariance is no longer translated for the following operations with identified linear models:  
  1. Model discretization  
  2. Model conversion  
  3. Model concatenation | N/A |
<table>
<thead>
<tr>
<th>Property</th>
<th>Model Types Affected</th>
<th>What Happens in R2012a</th>
<th>Use This Instead</th>
</tr>
</thead>
<tbody>
<tr>
<td>EstimationInfo</td>
<td>idss, idpoly, idgrey, and idproc</td>
<td>Still available.</td>
<td>Replaced by the new model property, Report.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For more information, see “Reorganization of Estimation Reports” on page 8-18.</td>
</tr>
<tr>
<td>InputName,OutputName</td>
<td>All identified linear models.</td>
<td>Backward incompatibility. By default, the input/output channel names are set to ''. In previous releases, the default channel names were set to {'u1','...'} and {'y1','...'} for input and output channels, respectively. When an identified linear model is estimated using an iddata object, it will inherit the input/output channels names from the iddata object.</td>
<td>N/A</td>
</tr>
</tbody>
</table>
### Property | Model Types Affected | What Happens in R2012a | Use This Instead |
--- | --- | --- | --- |
**TimeUnit** | All identified models. | You can now specify the TimeUnit as only one of the supported units. Supported units include: 'nanoseconds', 'microseconds', 'milliseconds', 'seconds', 'minutes', 'hours', 'days', 'weeks', 'months', and 'years'. | N/A |

**Ts** | idss and idpoly | **Backward incompatibility.** For discrete-time models, default is $Ts = -1$, which indicates an unspecified sample time. In previous releases, the default value of $Ts$ was 1. | N/A |

---

**Noise Channel Treatment When Converting Identified Linear Model to Numeric LTI Model**

**Backward incompatibility.** You can convert an identified linear model to a numeric LTI model for use in Control System Toolbox. When you do so, the model returned contains only the measured components of the original model. In previous releases, the noise channels of the original model were also returned as extra inputs of the resulting model.

For example, consider the following polynomial model:

```matlab
sys = idpoly([1 1],[1 2 3],[1 2])
```
In previous releases, executing `sys_tf = tf(sys)` returned a transfer function model with two inputs. The first input corresponded to the measured component, \( \frac{B}{A} \). The second input corresponded to the noise component, \( \frac{C}{A} \). \( \text{size}(\text{sys}, 2) \) is 1 but \( \text{size}(\text{sys}_\text{tf}, 2) \) is 2. Thus, \( \text{sys} \) had one input, while \( \text{sys}_\text{tf} \) had two inputs.

In this release, `sys_tf = tf(sys)` returns a SISO transfer function with one input. This input corresponds to the measured component, \( \frac{B}{A} \). \( \text{sys} \) and \( \text{sys}_\text{tf} \) both have the same number of inputs.

To obtain the noise input channels in addition to the measured inputs, as in previous releases, use the string `augmented` as an additional input.

\[
\text{sys}_\text{tf} = \text{tf}(\text{sys}, '\text{augmented}')
\]

The inputs of \( \text{sys}_\text{tf} \) are grouped in the `InputGroup` property. The inputs from the measured dynamics belong to the `Measured` input group, and the noise-related inputs belong to the `Noise` input group.

To obtain a model containing just the noise component of the original model, use the string `noise` as an additional input:

\[
\text{sys}_\text{tf} = \text{tf}(\text{sys}, '\text{noise}')
\]

### Conversion to Identified Linear Model of Numeric LTI Models Ignores Input Groups

**Backward incompatibility.** In previous releases, when you converted a numeric LTI model that had an input group named `noise` into an identified linear model, the corresponding inputs were converted to noise channels in the resulting model. This behavior is no longer supported. You can use the `split` input argument when you convert a numeric LTI model to an identified model. Using the `split` input argument results in the last \( Ny \) inputs being treated as noise channels in the identified model. Here, \( Ny \) is the number of outputs.

For example, in previous releases:

\[
\text{sys} = \text{rss}(2, 2, 5);
\text{sys}.\text{InputGroup} = \text{struct}('\text{noise}', 4:5);
\text{sys}_\text{idss} = \text{idss}(\text{sys});
\]

resulted in \( \text{sys}_\text{idss} \) having the fourth and fifth inputs of \( \text{sys} \) being treated as noise channels.

In this release, use:
sys_idss = idss(sys,'split');

As sys has two outputs and five inputs, its last two input channels are converted to noise channels in sys_idss. sys_idss has three measured input channels.

**Input Channel Referencing for Measured Components**

You can configure an estimated model to be free of the influence of noise by setting the NoiseVariance property value to 0. In previous releases, you achieved this result by subreferencing the inputs of the model using the 'measured' string, as in `sys(:, 'measured')`. This type of subreferencing is provided in this release for backward compatibility only and may not be supported in the future.

**Input Channel Referencing for Noise Components**

You can now extract only the noise components of an identified linear model using the syntax:

```
sys_noise_only = sys(:, []);
```

Here, the `:` indexes all the outputs and `[]` specifies that none of the measured inputs are extracted. `sys_noise_only` has zero measured inputs and is consequently a noise model.

In previous releases, you achieved this result by subreferencing the inputs of the model using the 'noise' string, as in `sys(:, 'noise')`. This type of subreferencing is provided in this release for backward compatibility only and may not be supported in the future.

**Model Precedence Rules**

The precedence order among identified linear models is `idfrd > idss > idpoly > idtf > idproc` and `idss > idgrey`.

When you combine a numeric LTI model with an identified model, the resulting model is a numeric LTI model. Interconnecting and combining identified linear models using functions such as `series`, `parallel`, and `feedback`, and performing model addition results in a numeric LTI model. Input-output concatenation and model stacking of identified models returns an identified model object.

**Simultaneous Model-Type Conversion and Property Value Setting**

Model conversion functions will not support setting model property values in the future.
Replace calls such as:

\[
\text{sys}\_\text{idfrd} = \text{idfrd}(\text{sys},w,'\text{InputName}','u1','\text{InputDelay'},3);
\]

With:

\[
\text{sys}\_\text{idfrd} = \text{idfrd}(\text{sys},w);
\text{set(}\text{sys}\_\text{idfrd},'\text{InputName}','u1','\text{InputDelay'},3);
\]

**Replace inpd2nk with absorbDelay**

The `inpd2nk` function is now obsolete. Use `absorbDelay` instead to absorb all time delays of a dynamic system model into the system dynamics or the frequency response data. In this release, calling `inpd2nk` results in the toolbox making an internal call to `absorbDelay`.

For more information, see `absorbDelay`.

**System Identification Tool GUI**

**Transfer Function Models**

You can now estimate transfer functions using the System Identification Tool GUI.

To open the Transfer Function dialog box:

1. Import a data set into the System Identification Tool GUI.
2. In the Estimate list, select Transfer Function Models.

For more information regarding transfer function estimation, open the Transfer Function dialog box, and click Help.

**Process Models**

You can now estimate multi-output process models using the System Identification Tool GUI.

To open the Process Models dialog box:

1. Import a data set into the System Identification Tool GUI.
2. In the Estimate list, select Process Models.

For more information regarding process model estimation, open the Process Model dialog box and click Help.

**State-Space Models**

You can now use the System Identification Tool GUI for these operations:
• Estimate continuous-time state-space models.
• Specify the parameterization form, such as canonical or modal.
• Specify feedthrough, which determines whether the D matrix of the state-space model is treated as free estimation parameter or fixed to zero.
• Specify input delay.

To open the Polynomial and State Space Models dialog box:

1 Import a data set into the System Identification Tool GUI.
2 In the Estimate list, select State Space Models.

For more information regarding state-space estimation, open the Polynomial and State Space Models dialog box and click Help.

**Polynomial Models**

You can now specify noise integration and input delays when estimating polynomial models using the System Identification Tool GUI.

You can also estimate multi-output polynomial models by specifying the appropriate model order.

To open the Polynomial and State Space Models dialog box:

1 Import a data set into the System Identification Tool GUI.
2 In the Estimate list, select Polynomial Models.

For more information regarding polynomial estimation, open the Polynomial and State Space Models dialog box and click Help.

**Compatibility Consideration:** You no longer select Linear parameteric models to open the Polynomial and State Space Models dialog box.

**Changes Introduced in This Version**

Changes introduced in this version:

• “Reorganization of Estimation Reports” on page 8-18
• “Polynomial Models” on page 8-19
• “State-Space Models” on page 8-24
“Process Models” on page 8-29
“Linear Grey-Box Models” on page 8-34
“Identified Frequency-Response Data Models” on page 8-37
“Identification Data Objects” on page 8-38
“Analysis Commands” on page 8-39
“Other Functionality Being Removed or Changed” on page 8-50

Reorganization of Estimation Reports

A new property of identified linear models, Report, provides information regarding the performed estimation. This property replaces the EstimationInfo property and provides additional information regarding:

- All estimated quantities — Parameter values and covariance, initiate state values for state-space models and values of input levels for process models.
- The option set used for estimation.
- Additional fit criteria — Percentage fit to estimation data and the mean square error.

The Report field is mostly uniform for the various identified linear models. However, certain fields of Report are model dependent.

To access the Report property of an identified linear model, sys, use sys.Report.

Compatibility Considerations

Report replaces the EstimationInfo property. The fields of EstimationInfo map to those of Report as:

<table>
<thead>
<tr>
<th>EstimationInfo Field</th>
<th>Report Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>LossFcn</td>
<td>Fit.LossFcn</td>
</tr>
<tr>
<td>FPE</td>
<td>Fit.FPE</td>
</tr>
<tr>
<td>DataName</td>
<td>DataUsed.Name</td>
</tr>
<tr>
<td>DataLength</td>
<td>DataUsed.Length</td>
</tr>
<tr>
<td>DataTs</td>
<td>DataUsed.Ts</td>
</tr>
<tr>
<td>DataDomain</td>
<td>DataUsed.Type</td>
</tr>
<tr>
<td>DataInterSample</td>
<td>DataUsed.InterSample</td>
</tr>
</tbody>
</table>
### EstimationInfo Field | Report Field
--- | ---
**WhyStop** | Termination.WhyStop
Termination information is not provided for models estimated using a noniterative estimation function, such as `arx` or `n4sid`.

**UpdateNorm** | Termination.UpdateNorm
Termination information is not provided for models estimated using a noniterative estimation function, such as `arx` or `n4sid`.

**LastImprovement** | Termination.LastImprovement
Termination information is not provided for models estimated using a noniterative estimation function, such as `arx` or `n4sid`.

**Iterations** | Termination.Iterations
Termination information is not provided for models estimated using a non-iterative estimation function, such as `arx` or `n4sid`.

**InitialState** | Either:
- InitialState (state-space models)
- InitialCondition (other identified linear models)

**Warning** | No replacement.

---

**Polynomial Models**

**Polynomial Model Estimators**

Use the new function, `polyest`, to estimate a polynomial model containing an arbitrary subset of A, B, C, D, and F polynomials.

For more information, see `polyest` and `polyestOptions`.

Also, the functions `ar`, `arx`, `bj`, `oe`, and `armax` now support multi-output polynomial estimation.
Integration on Noise Models (ARIMA models)

You can now introduce integrators in the dynamics of the disturbances added to the output of the model.

For more information, see “Generating ARIMA Models” on page 8-3.

idarx Models No Longer Returned in Multi-Output Model Estimation

idarx models are no longer returned when you use estimating functions for multi-output ARX models. Support for idarx models may not be provided in the future. Use idpoly models to estimate and represent multi-output ARX models instead.

Compatibility Consideration: Backward incompatibility. arx, iv4, and ivx now return idpoly models for multi-output estimation. In previous releases, they returned idarx models.

To convert an existing idarx model, sys_idarx, to an idpoly model, use idpoly(sys_idarx).

Similarly, to convert an existing idpoly model, sys_idpoly, to an idarx model, use idarx(sys_idpoly).

Specify Transport Delays

Use the new idpoly property, ioDelay to specify the transport delays for individual input/output pairs.

You can use ioDelay as an alternative to the nk order when estimating polynomial models. Using ioDelay reduces the complexity of the model by factoring out the leading zeros of the B polynomials, controlled by nk.

For example:

```matlab
load iddata1 z1
load iddata2 z2
data = [z1 z2(1:300)];
a = [2 3; 1 2];
b = [1 2; 2 2];
n = [2 1; 7 0];
sys1 = arx(data,[a b n]);
sys2 = arx(data,[a b zeros(2)],'ioDelay',n);
```

In this case, sys1 and sys2 are equivalent, but sys2.b shows fewer terms in each B polynomial than sys1.b.
For more information, see idpoly.

**Specify Display Variable**

You can now specify the variable used to display model equations for idpoly models. Use the new model property, `Variable`. For continuous-time models, specify either 's' or 'p' as the variable. For discrete-time models, use either 'z^-1' or 'q^-1' as the lag variable.

For more information, see idpoly.

**Multi-Output Weighting Using arx**

For estimating multi-output ARX models, use the `OutputWeight` estimation option to specify the output weighting. You create the option set for ARX model estimation using `arxOptions`. In previous releases, to do so you specified a `NoiseVariance` name-value pair input for `arx`.

`arx` uses the following syntaxes for assigning output weight:

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Output Weight Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>arx(data,[na,bk,nk])</code></td>
<td><code>eye(Ny)</code>, where Ny is the number of outputs</td>
</tr>
<tr>
<td><code>arx(data,[na nb nk],opt)</code>, where opt is an option set created using <code>arxOptions</code></td>
<td><code>opt.OutputWeight</code></td>
</tr>
<tr>
<td></td>
<td>If <code>opt.OutputWeight = []</code>, then <code>eye(Ny)</code>.</td>
</tr>
<tr>
<td><code>arx(data,init_model)</code>, where <code>init_model</code> is an estimation initialization model</td>
<td><code>init_model.NoiseVariance</code></td>
</tr>
<tr>
<td><code>arx(data,init_model,opt)</code></td>
<td><code>opt.OutputWeight</code></td>
</tr>
<tr>
<td></td>
<td>If <code>opt.OutputWeight = []</code>, then <code>init_model.NoiseVariance</code></td>
</tr>
</tbody>
</table>

**Polynomial Structure**

The new `Structure` property of idpoly models stores the adjustable parameters, which include:

- The active polynomials

For example, consider the ARX model:
A = [1 2 1];
B = [0 3 4];
sys = idpoly(A,B);

sys.Structure lists the polynomials A and B as parameters. You can specify nominal values and constraints for these parameters.

sys.Structure does not list the C, D, and F polynomials.

- The transport delays and integrate noise flag

You can set these delays and the flag for models of any polynomial configuration.

You interact with the Structure property to specify constraints (such as maximum/minimum bounds) for the various parameters. To change only the values of the polynomials or the transport delays, use the relevant idpoly model property, viz a, b, c, d, f, ioDelay, and IntegrateNoise.

For more information, see idpoly.

Compatibility Considerations

The recommended usage and workflow has changed for some model parameters and functionality. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflow may not be supported in the future.

The following table lists affected functionality:

<table>
<thead>
<tr>
<th>Functionality</th>
<th>What Happens in R2012a</th>
<th>Use This Instead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model properties that store the polynomial order — na, nb, nc, nd, nf, and nk</td>
<td>You may still modify the value of these properties as long as their sizes are compatibility with the input/output sizes. The estimation commands for polynomial models will continue to support the specification of “in-model” delays using nk.</td>
<td>Use idpoly to create a new model of desired orders. Use ioDelay and InputDelay to specify delays separate from the B polynomial.</td>
</tr>
<tr>
<td>Functionality</td>
<td>What Happens in R2012a</td>
<td>Use This Instead</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Model properties that store standard deviation information — da, db, dc, dd, and df</td>
<td>You may still access these model properties using dot notation. For example, <code>sys.da</code>.</td>
<td>Use the functions getpvec and polydata to access parameters and their standard deviations.</td>
</tr>
</tbody>
</table>
| Treatment of the leading zeros of the B polynomials                           | If you have a discrete-time `idpoly` model that has nk leading zeros, then nk-1 of them are treated as delays. When you convert such a model into another linear model, these delays are set to the appropriate delay related property. For example,  
  ```matlab
  sys = idpoly([1 2],[0 0 0 4]);
  % nk = 3
  sys2 = tf(sys);
  ```  
  The `ioDelay` property of `sys2` is 2, and the numerator is `[[0 4]]`. | N/A                                                                                                                                                                                                               |
| Model property — InitialState                                                | Still works.                                                                                                                                                                                                       | Use the option, `InitialCondition`, when creating the relevant option set for estimation, prediction, simulation, and comparison.                                                                             |
| Storage of the B and F polynomials                                           | For multi-input models, the b and f properties are no longer saved as a matrix of doubles. These properties will now be saved using cell arrays. 
  To continue storing these properties as a matrix of doubles, use `setPolyFormat` | N/A                                                                                                                                                                                                               |
### Functionality

| Treatment of the trailing zeros of the B and F polynomials | Trailing zeros in the $B$ and $F$ polynomials of a discrete-time `idpoly` model are not discarded. For example, in previous releases: `sys = idpoly([1 2], [2 4 0 0 0]);` resulted in `[2 4]` as the $B$ polynomial for `sys`. Now, the same code gives `[2 4 0 0 0]` as the $B$ polynomial for `sys`. Similar considerations apply to leading zeros of $B, F$ polynomials of a continuous-time model. | N/A |

### State-Space Models

#### State-Space Model Estimator

The new function, `ssest`, can be used to estimate a discrete-time or continuous-time identified state-space model. You can use time-domain or frequency-domain data with `ssest` and perform both structured and unstructured model estimation. You can also choose a canonical form of the identified state-space model.

To configure the handling of initial conditions and other initialization choices, data offsets and search algorithm, use the associated option command, `ssestOptions`.

For more information, see `ssest` and `ssestOptions`.

For a structured state-space model, which is an `idss` model with finite parameters, you can use either `pem` or `ssest` to update the values of those parameters for measured input-output data.
**n4sid Supports Canonical Forms**

The subspace estimator function, n4sid, now supports new parameterization options, such as modal and companion canonical forms and the presence of feedthrough.

To configure the handling of initial conditions and other initialization choices and data offsets, use the associated option command, n4sidOptions.

For more information, see n4sid and n4sidOptions.

**State-Space Structure**

The new Structure property of idss models stores the adjustable parameters, which include the a, b, c, d and k matrices.

You interact with the Structure property to specify constraints (such as maximum/minimum bounds) for the various parameters. To only change the values of the matrices, use the relevant idss model property, viz a, b, c, d, and k.

For more information, see idss.

**Compatibility Considerations**

The recommended usage and workflow has changed for some model parameters. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflow may not be supported in the future.

The following table lists affected model properties:

<table>
<thead>
<tr>
<th>Model Property</th>
<th>What Happens in R2012a</th>
<th>Use This Instead</th>
</tr>
</thead>
<tbody>
<tr>
<td>X0, InitialState</td>
<td>Still available.</td>
<td>Use the InitialState option for estimation and the InitialCondition option for prediction, simulation, and comparison.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For example, replace: sys = n4sid(data,2,... 'InitialState','estimate'); with:</td>
</tr>
<tr>
<td>Model Property</td>
<td>What Happens in R2012a</td>
<td>Use This Instead</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Opt = n4sidOptions(...)</td>
<td></td>
<td>Use the <strong>Structure</strong> property to specify constraints (such as maximum/minimum bounds) for A, B, C, D, and K. Use the <strong>InitialState</strong> estimation option to specify constraints on the initial state vector. For example, instead of: sys = idss(A,B,C,D,K); sys.X0s = [nan;1] syse = pem(data,sys); Use: opt = ssestOptions; X0 = idpar([nan;1]); X0.Free(2) = false; opt.InitialState = X0; sys = idss(A,B,C,D,K); syse = ssest(data,sys,opt);</td>
</tr>
<tr>
<td>As, Bs, Cs, Ds, Ks, and X0s</td>
<td>Still available.</td>
<td></td>
</tr>
<tr>
<td>da, db, dc, dd, and dk</td>
<td>Still available.</td>
<td>Use the new function <strong>idssdata</strong> to obtain the state-space matrix standard deviations.</td>
</tr>
<tr>
<td>Model Property</td>
<td>What Happens in R2012a</td>
<td>Use This Instead</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------------</td>
<td>-------------------</td>
</tr>
</tbody>
</table>
| nk             | Still available but **may cause a backward incompatibility**. If you previously specified both nk and InputDelay, you could see different results in this release. For example, load iddata1 z1; sys = pem(z1,4,... 'nk',5,'InputDelay,2); In this release, sys.nk is 3, whereas sys.nk was 5 in earlier releases. | For estimation, use the InputDelay and Feedthrough estimation properties instead. When creating an idss model, specify the InputDelay and Structure.d properties. nk, InputDelay, and Feedthrough are related:  
• nk(j) = 0 means that the model has no delay for the jth input. Therefore, InputDelay is 0, and Structure.d.Free(:,j) is true.  
• nk(j) = 1 means that the model has zero delay for the jth input. Therefore, InputDelay is 0, and there is no feedthrough. Structure.d.Free(:,j) is false, and Structure.d.Value(:,j) is zero.  
• nk(j) = N, N>1 means that the model has nonzero delay for the jth input. Therefore, InputDelay is N-1, and there is no feedthrough. Structure.d.Free(:,j) is false, and Structure.d.Value(:,j) is 0. |
<table>
<thead>
<tr>
<th>Model Property</th>
<th>What Happens in R2012a</th>
<th>Use This Instead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>nk &gt; 1</strong> can only be used for a discrete-time model.</td>
</tr>
<tr>
<td>SSPParameterization</td>
<td>Still available.</td>
<td>• Use the 'form'/value name-value pair when estimating using either <code>n4sid</code> or <code>ssest</code> to specify the form of the estimated model.</td>
</tr>
<tr>
<td></td>
<td>However, when you use <code>get</code> to obtain the value of <code>SSParameterization</code>, the software may report a canonical form as the structured form.</td>
<td>• To change the structure of an existing model, use one of these methods:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Change each matrix individually using the <code>Structure</code> property.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use <code>canon</code> to specify a canonical form.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use <code>ss2ss</code> and specify a transformation matrix.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Note:</strong> Parameter covariance is not translated in these operations.</td>
</tr>
<tr>
<td>Model Property</td>
<td>What Happens in R2012a</td>
<td>Use This Instead</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------------------------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>DisturbanceModel</td>
<td>Still available.</td>
<td>For estimation, specify DisturbanceModel as an option for estimation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For changing the model structure, for its disturbance component, use Structure.k.Value and Structure.k.Free instead. For example, DisturbanceModel = 'none' corresponds to setting model.Structure.k.Value to zeros and model.Structure.k.Free to false.</td>
</tr>
<tr>
<td>CanonicalIndices</td>
<td>Still available if the model is in canonical form.</td>
<td>Use canon and ss2ss to change the state-space form.</td>
</tr>
</tbody>
</table>

**Process Models**

**Process Model Estimator**

The new function, procest, lets you estimate process models using time-domain or frequency-domain data. You can also specify the handling of input offsets and disturbances using an option set for this function using procestOptions.

For more information, see procest and procestOptions.

**Multi-Output Support**

You can now create and estimate multi-output process models.

For more information, see “Multi-Output Process Models” on page 8-4

**Noise Transfer Function**

Use the new property NoiseTF of idproc models to specify the value of the noise transfer function in numerical form. NoiseTF is a structure with the fields num (numerator) and den (denominator) representing the noise-transfer function. This property replaces the DisturbanceModel property.
**Input Delay**

The InputDelay property of idproc model represents input delays and is now independent of the Td property.

The Td property represents the transport delay, which is thus similar to the ioDelay property of idpoly and idtf models.

For more information, see idproc.

**Process Model Structure**

The Structure property of idproc models houses active parameters. These parameters are a subset of \( K_p, T_{p1}, T_{p2}, T_{p3}, T_w, Zeta, T_d, \) and \( T_z \), depending on the Type option used to create the model. Structure also contains the Integration property whose value determines if the model structure contains an integrator.

You use the Structure property to specify constraints (such as maximum/minimum bounds) for the various active parameters.

Structure is an \( Ny \)-by-\( Nu \) array, where \( Ny \) is the number of outputs and \( Nu \) is the number of inputs. The array specifies a transfer function for each input/output pair.

For example:

```matlab
sys = idproc({'p2u' 'p0' 'p3zi'; 'p1' 'p2d' 'p2uz'});
```

In this case, `sys.Structure` is a 2-by-3 array. `sys.Structure(1,1).Zeta` is a parameter, while `sys.Structure(1,2)` does not have a Zeta field, as this parameter is inactive for the (1,2) output-input pair.

To change the list of active parameters, you must create a new model. However, you may change the Integration property at any time.

**Lower Bound on Time Constants**

The minimum value permitted for the time constants of an idproc model, \( T_{p1}, T_{p2}, T_{p3}, T_w, \) and \( Zeta \) is now 0. In previous releases, you could not specify for these constraints a value smaller than 0.001. For well-conditioned estimations, it is still recommended that you specify reasonable upper and lower bounds around the time-constant values.
**Compatibility Considerations**

The recommended usage and workflow has changed for some model parameters. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflow may not be supported in the future.

The following table lists affected model properties:

<table>
<thead>
<tr>
<th>Model Property</th>
<th>What Happens in R2012a</th>
<th>Use This Instead</th>
</tr>
</thead>
<tbody>
<tr>
<td>InputLevel</td>
<td>Still available.</td>
<td>Use the InputOffset option for estimation using procestOptions. For advanced control, you can specify the InputOffset option as 'estimate' or a param.Continuous object.</td>
</tr>
</tbody>
</table>
| InitialState         | Still available.       | Use the InitialCondition option for estimation, prediction, simulation and comparison. For example, replace:  

\[
\text{sys} = \text{pem} (\text{data}, 'p1d', ..., 'InitialState', 'estimate');
\]

with:

\[
\text{opt} = \text{procestOptions} (..., 'InitialCondition', 'estimate');
\text{sys} = \text{procest} (\text{data}, ..., 'p1d', \text{opt});
\]
<p>| DisturbanceModel     | Still available.       | The DisturbanceModel property of idproc models in previous releases represented both the estimation flag and as the actual value of the noise transfer function. The DisturbanceModel property has now been replaced by: |</p>
<table>
<thead>
<tr>
<th>Model Property</th>
<th>What Happens in R2012a</th>
<th>Use This Instead</th>
</tr>
</thead>
</table>
|                | • The NoiseTF property, which represents the value of the noise transfer function.  
• The DisturbanceModel estimation option, which is contained in the procestOptions option set. This option stores the flag, which determines how the noise transfer function is estimated.  
For example, replace:  
load iddata1 z1;  
sys = pem(z1,'p1d',...  
'DisturbanceModel','arma1');  
NoiseTF = sys.DisturbaceModel{2};  
with:  
load iddata1 z1;  
opt = procestOptions(...  
'DisturbanceModel','arma1');  
sys = pem(z1,'p1d',opt);  
NoiseTF = sys.NoiseTF;  
For more information, see procestOptions. | Still available.  
There is no replacement for this model property as idproc is not a state-space model. Continuing to use X0 may produce bad results. |
### Model Property

<table>
<thead>
<tr>
<th>Kp, Tp1, Tp2, Tp3, Tw, Zeta, Td, and Tz</th>
</tr>
</thead>
</table>

### What Happens in R2012a

**Backward incompatibility.**

These properties are now saved as double matrices. In previous releases, they were stored as structures.

Assigning the value of these parameters to structures will continue to work:

```matlab
model = idproc('p1','Tp1',1,'
model.Tp1.value = 5;
```

In previous releases, you could obtain the value of a parameter as a structure and access its fields. Now, you will receive an error.

```matlab
model = idproc('p1','Tp1',1,'Kp',2)
Tp1 = model.Tp1;
Tp1.status % throws error
```

However, subreferencing for a field of the old parameter structure will continue to work:

```matlab
model = idproc('p1','Tp1',1,'Kp',2)
model.Tp1.status
% returns {'estimate'}
```

Use the `Structure` property to specify parameter constraints.

**Structure** replaces the specification of process model parameter bounds. See Call Replacements.

### Call Replacements

<table>
<thead>
<tr>
<th>Replace a Call Like...</th>
<th>With...</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>model.Tp1.min = value</code></td>
<td><code>model.Structure.Tp1.Minimum = value</code></td>
</tr>
</tbody>
</table>
Replace a Call Like...

<table>
<thead>
<tr>
<th>Replace</th>
<th>With...</th>
</tr>
</thead>
<tbody>
<tr>
<td>For multi-input models: <code>model.Tp1.status{2} = ‘estimate’</code></td>
<td><code>model.Structure(1,2).Tp1.Free = true;</code></td>
</tr>
<tr>
<td>For multi-input models: <code>model.Tp1.value(2) = value</code></td>
<td><code>model.Structure(1,2).Tp1.Value = value</code></td>
</tr>
</tbody>
</table>

Linear Grey-Box Models

Linear Grey-Box Model Estimator

The new function `greyest` lets you estimate the parameters of a linear grey-box model. You can specify an option set for the estimation by using the function, `greyestOptions`.

For more information, see `greyest` and `greyestOptions`.

Complex Parameters Support

You can now parameterize a real system using complex-conjugate pairs of parameters in an `idgrey` model.

When the parameters of such a system are estimated, they continue to be complex conjugates. Thus, symmetry is maintained across the real axis.

For more information, see the related example in the `greyest` reference page.

ODE file API

You can now specify an arbitrary number of parameters as independent input arguments to the ODE file. In previous releases, the parameters of the model had to be consolidated into a single vector that was then passed as the first input argument of the ODE file. Now, you can pass independent parameters as separate input arguments. The same holds true for the optional input arguments.

Old syntax:

`ODEFUN(ParameterVector, Ts, OptionalArg)`

New syntax:

`ODEFUN(Par1, Par2, …, ParN, Ts, OptArg1, OptArg2, …)`
If all the model parameters are scalars, you can still combine them into a single vector and pass them as a single input argument to the ODE file.

Also, specifying the value for the output arguments K and X0 is now optional. In earlier releases, you were required to set a value for K and X0 even if you did not want to parameterize them. Now, you can omit them entirely from the output argument list. For more information, see idgrey.

**Linear Grey-Box Model Structure**

The *Structure* property of the *idgrey* model stores information on the ODE function and its parameters. *Structure* contains the following properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Role</th>
</tr>
</thead>
</table>
| **FcnType**| The sample time handling behavior of the linear ODE model. *FcnType* specifies whether the ODE file returns state-space data that corresponds to one of the following:  
|            | • 'c' — A continuous-time model.  
|            | • 'd' — A discrete-time model.  
|            | • 'cd' — A continuous-time model if the sample time is 0 and a discrete-time model if the sample time greater than 0. |
| **Function** | Name or function handle to the MATLAB function that parameterizes the state-space structure. |
|            | **Compatibility Consideration:** Use instead of the CDmfile property. |
| **Parameters** | Vector of parameter objects, with an entry for each model parameter. Use the parameter object to specify initial values and minimum/maximum constraints. You can also indicate whether the parameter is a free- or fixed- estimation parameter. |

**Compatibility Consideration:** Use instead of the MfileName property.
Property | Role
---|---
ExtraArgs | Option input arguments used by the ODE file to compute the state-space data.

**Compatibility Consideration:** Use instead of the FileArgument property.

StateName | Model state names.
StateUnit | Model state units.

## Compatibility Considerations

The recommended usage and workflow has changed for some model parameters. Where possible, backward compatibility is maintained in this release. However, adoption of the recommended changes is strongly encouraged as obsoleted model properties and workflow may not be supported in the future.

The following table lists affected model properties:

<table>
<thead>
<tr>
<th>Model Property</th>
<th>What Happens in R2012a</th>
<th>Use This Instead</th>
</tr>
</thead>
<tbody>
<tr>
<td>MfileName</td>
<td>Still available.</td>
<td>Use the Structure.Function property to specify the ODE function name or function handle instead.</td>
</tr>
<tr>
<td>X0</td>
<td>Still available.</td>
<td>Use the InitialState option when you create an estimation option set using greyestOptions.</td>
</tr>
<tr>
<td>dA, dB, dC, dD, dK and dX0</td>
<td>Still available.</td>
<td>Use the functions getpvec and idssdata to access parameters and their standard deviations.</td>
</tr>
<tr>
<td>FileArgument</td>
<td>Still available.</td>
<td>Use the Structure.ExtraArgs property to specify the additional ODE function arguments.</td>
</tr>
</tbody>
</table>
Model Property | What Happens in R2012a | Use This Instead
---|---|---
CDmfile | Still available. | Use the Structure.FcnType property to specify sample time handling behavior.
InitialState | Still available. | Use the InitialState option for estimation and the InitialCondition option for prediction, simulation and comparison.
DisturbanceModel | Still available. | Use the DisturbanceModel estimation option in the option set created using greyestOptions.

**Identified Frequency-Response Data Models**

**Specify InterSample Behavior of Inputs**

You can use the new InterSample property of idfrd models to specify the behavior of the input signals between samples for model transformations between discrete-time and continuous-time. This property is relevant only for discrete-time idfrd models.

For more information, see the InterSample property information in idfrd.

**Frequency Unit**

Use the new property FrequencyUnit of idfrd models to specify the units for frequency-domain data.

For a list of the supported units for FrequencyUnit, see idfrd.

**Compatibility Consideration:** The FrequencyUnit property replaces the Unit property.

**Compatibility Considerations**

**Input Delay Treatment (Backward incompatibility.)** When you convert an identified model into an idfrd model, its InputDelay and ioDelay properties are translated into the corresponding properties of the idfrd model. In previous releases, the delays were absorbed into the ResponseData property as additional phase lag.
The `OutputDelay` property of an identified model is converted to the `ioDelay` property of an `idfrd` model.

**Identification Data Objects**

**Frequency-Domain Data Units**

Use the new property `FrequencyUnit` of `iddata` objects to specify the units for frequency-domain data.

For a list of the supported units for `FrequencyUnit`, see `iddata`.

**Compatibility Consideration:** The `FrequencyUnit` property replaces the `Unit` property.

**Impulse and Step Response Plots**

Plot the impulse or step response for `iddata` objects by estimating a discrete-time transfer function model using `impulseest`. Use the resulting model as the input argument for `impulse` or `step`.

In the previous release, you could plot the step response without first estimating a discrete-time transfer function model:

```matlab
load iddata1 z1;
step(z1);
```

where `z1` is an `iddata` object.

Now, you must use `impulseest` to estimate a discrete-time transfer function. Then, plot the appropriate response for the model. For example:

```matlab
load iddata1 z1;
sys = impulseest(z1);
step(sys);
```

For more information, see `impulseest`.

**Compatibility Consideration:** Backward incompatibility. To see the step or impulse response for negative time values, use the `noncausal` input argument with `impulseest`. In previous releases, you could call `impulse(data)` to do this.

**Compatibility Considerations**

**Supported Units for TimeUnit Property** You can now specify the `TimeUnit` property of an `iddata` object as only one of the supported units. Supported units include:
'nanoseconds', 'microseconds', 'milliseconds', 'seconds', 'minutes', 'hours', 'days', 'weeks', 'months', and 'years'.

**Analysis Commands**

<table>
<thead>
<tr>
<th>Function</th>
<th>What Has Changed in R2012a</th>
</tr>
</thead>
</table>
| predict  | • predict now returns a data object of the same type as the input data.  
           • You can now specify an infinite prediction horizon with time-series models. When you specify the prediction horizon as Inf, predict returns the initial condition response of the model.  
           • **Compatibility Consideration**: For a multi-output system, the predictor model is now returned as a dynamic system. In previous releases it was returned as a cell array. |
| compare  | • When using FRD validation data, compare plots the magnitude and phase response. The fit percentage shown corresponds to the closeness of the complex frequency response of the system to that of the data (using normalized root mean square, NRMSE).  
           • For complex-valued validation data or model, compare plots the real and imaginary parts on separate axes.  
           • You can now use compare to compare data sets. The data sets may be either iddata or frd objects.  
           • You can interactively change the prediction horizon for time-domain comparison plots. You can also interactively change the initial conditions. Right-click on the plot to select the appropriate option.  
           • You can now compare arrays of systems to a validation data set. |
<table>
<thead>
<tr>
<th>Function</th>
<th>What Has Changed in R2012a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• You can now specify the initial conditions and sample range for comparison using the option set created by the new function <code>compareOptions</code>. For more information, see <code>compareOptions</code>.</td>
</tr>
<tr>
<td></td>
<td>• <strong>Compatibility Consideration: Backward incompatibility.</strong> The format of the outputs has changed when you call <code>compare</code> using the syntax:</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
|          |     `[yh,fit,x0] = compare(data,...
|          |     sys1,...,sysn,m,options)` |
|          | For example, `fit` is a cell array rather than a 3-d numeric array when comparing responses of multiple systems or when using multi-experiment validation data.
<table>
<thead>
<tr>
<th>Function</th>
<th>What Has Changed in R2012a</th>
</tr>
</thead>
<tbody>
<tr>
<td>step</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• You can specify an option set for the generated plot using the function stepDataOptions.</td>
</tr>
<tr>
<td></td>
<td>• You can customize a step plot by creating a plot using stepplot. Then, to display confidence intervals on the plot programmatically, use showConfidence.</td>
</tr>
<tr>
<td></td>
<td>• <strong>Compatibility Considerations:</strong></td>
</tr>
<tr>
<td></td>
<td>• Specify the number of standard deviations for the confidence region using the new ConfidenceRegionNumberSD option in the corresponding option set. In previous releases, you used the 'sd'/N name-value pair to specify the number of standard deviations.</td>
</tr>
<tr>
<td></td>
<td>• <strong>Backward incompatibility.</strong> Using a 2-element double vector to indicate the plot time range is no longer supported. You can only specify a scalar, the final time, or a vector containing the time instants to be plotted.</td>
</tr>
<tr>
<td></td>
<td>• <strong>Backward incompatibility.</strong> The third output argument now returns the state trajectory. In previous releases, the third output argument was the response standard deviation, which is now returned as the fourth output argument.</td>
</tr>
</tbody>
</table>
### Function: impulse

**What Has Changed in R2012a**

- You can specify an option set for the generated plot using the function, `timeoptions`. For more information, see `timeoptions`.
- You can customize an impulse plot by creating a plot using `impulseplot`. Then, to display confidence intervals on the plot programmatically, use `showConfidence`.

**Compatibility Considerations:**

- Specify the number of standard deviations for the confidence region using the new `ConfidenceRegionNumberSD` option in the corresponding option set. In previous releases, you used the `'sd'/N` name-value pair to specify the number of standard deviations.

- **Backward incompatibility.** Using a 2-element double vector to indicate the plot time range is no longer supported. You can only specify a scalar, the final time, or a vector containing the time instants to be plotted.

- **Backward incompatibility.** The third output argument now returns the state trajectory. In previous releases, the third output argument was the response standard deviation, which is now returned as the fourth output argument.
### Function | What Has Changed in R2012a
---|---
**bode** | 
- To customize a bode plot, use `bodeplot`. You can specify an option set for the generated plot using the function `bodeoptions`. For more information, see `bodeplot` and `bodeoptions`.

To display confidence intervals on a bode plot programmatically, use `showConfidence`.

- **Compatibility Considerations:**
  - Specify the number of standard deviations for the confidence region using the new `ConfidenceRegionNumberSD` option in the corresponding option set. In previous releases, you used the `'sd'/N` name-value pair to specify the number of standard deviations.
  - The plot input arguments `'fill'`, `'mode'`, and `'AP'` are no longer supported. Use the plot options, `bodeoptions`, `getoptions` and `setoptions`, instead. Alternatively, you may interactively change these options by right-clicking on the plot and choosing the appropriate options.

- **Backward incompatibility.** You can no longer specify the frequency range using `w = {wmin, wmax, np}`. Instead, use `logspace(wmin, wmax, np)`.

- Do not use `bode` for plotting time-series models. Instead, use the new function `spectrum`. For more information, see `spectrum`. |
### pzmap

<table>
<thead>
<tr>
<th>Function</th>
<th>What Has Changed in R2012a</th>
</tr>
</thead>
<tbody>
<tr>
<td>pzmap</td>
<td><strong>Compatibility Considerations:</strong></td>
</tr>
<tr>
<td></td>
<td>• <strong>Backward incompatibility.</strong> For multi-input, multi-output systems, <code>pzmap</code> now shows the system poles and transmission zeros. In previous releases, <code>pzmap</code> showed the poles and zeros of individual input/output pairs.</td>
</tr>
<tr>
<td></td>
<td>To plot the poles and zeros for individual input/output pairs, use <code>iopzmap</code> and <code>iopzplot</code>. For more information, enter <code>help function_name</code> at the MATLAB command prompt.</td>
</tr>
<tr>
<td></td>
<td>• The 'sd/N' name-value input argument for displaying the pole-zero confidence regions is no longer supported. Instead, use <code>iopzmap</code> and its corresponding options set (<code>pzoptions</code>). Use the <code>ConfidenceRegionNumberSD</code> option to specify the standard deviations for the confidence regions. You can also use the <code>showConfidence</code> command to view the confidence regions programmatically.</td>
</tr>
<tr>
<td>Function</td>
<td>What Has Changed in R2012a</td>
</tr>
<tr>
<td>----------</td>
<td>----------------------------</td>
</tr>
</tbody>
</table>
| nyquist  | - You can customize a nyquist plot by creating the plot using `nyquistplot`. Then, to display confidence intervals on the plot programmatically, use `showConfidence`.  
  - **Compatibility Considerations:**  
    - The `'sd/N'` name-value input argument for displaying the confidence ellipses is no longer supported. Create an option set using `nyquistoptions`. Use the `ConfidenceRegionNumberSD` option to specify the standard deviations for the confidence ellipses. Use the `ConfidenceRegionDisplaySpacing` option to specify the spacing of the confidence ellipses. For more information, see `nyquistoptions`.  
    - **Backward incompatibility.** You can no longer obtain the complex frequency response and its uncertainty as the outputs of `nyquist`. Instead, use `freqresp` to obtain these values. `nyquist` now returns the real and imaginary parts of the frequency response and their individual uncertainties. For more information, see `nyquist`.  
    - **Backward incompatibility.** You can no longer specify the frequency range using `w = [wmin, wmax, np]`. Instead, use `logspace(wmin, wmax, np)`.  
    - The plot input name-value pair `'mode' / 'same'` is no longer supported. Use the plot options instead (see `nyquistoptions`, `getoptions` and `setoptions`). Alternatively, you may interactively change these options by |
<table>
<thead>
<tr>
<th>Function</th>
<th>What Has Changed in R2012a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>right-clicking on the plot and choosing the appropriate options.</td>
</tr>
<tr>
<td>c2d</td>
<td>• You can now use the conversion methods 'tustin', 'matched' and 'impulse' without requiring the Control System Toolbox software.</td>
</tr>
<tr>
<td></td>
<td>• You can specify the conversion method and associated option for c2d using c2dOptions. For more information, see c2dOptions.</td>
</tr>
<tr>
<td></td>
<td>• Compatibility Considerations:</td>
</tr>
<tr>
<td></td>
<td>• Parameter covariance translation is no longer supported by c2d. Therefore, the 'CovarianceMatrix' - 'none' name-value pair is no longer supported.</td>
</tr>
<tr>
<td></td>
<td>• <strong>Backward incompatibility.</strong> Grey-box models of FcnType 'c' cannot be discretized directly. Instead, convert such models to idss models before using c2d.</td>
</tr>
<tr>
<td></td>
<td>• <strong>Backward incompatibility.</strong> Process models cannot be discretized directly. You must first convert your process model to an idpoly model or an idtf model and then discretize the new model.</td>
</tr>
</tbody>
</table>
### d2c

- You can now use the conversion methods `'tustin'` and `'matched'` without requiring the Control System Toolbox software.
- You can specify the conversion method and associated option for `d2c` using `d2cOptions`. For more information, see `d2cOptions`.

**Compatibility Consideration:**

- Parameter covariance translation is no longer supported by `d2c`. Therefore, the `'CovarianceMatrix'-'none'` name-value pair is no longer supported.

**Backward incompatibility.**

Grey box models of `FcnType 'd'` cannot be converted into continuous-time models directly. Instead, convert such models to `idss` models before using `d2c`.

- The input name-value pair `'InputDelay' '/0` are no longer supported. Input delays are now handled uniformly, as described in Continuous-Discrete Conversion Methods.
### ssdata

- Use the new function `idssdata` to fetch state-space matrices for identified linear models. If `idssdata` is used for a model other than `idss` or `idgrey`, it returns empty matrices for uncertainty outputs.

  For more information, see `idssdata`.

- You can still call the `ssdata` command with six or more output arguments to fetch the state-space matrices and related uncertainty information. However, this syntax of `ssdata` may be removed in the future and it is recommended to use `idssdata` instead.

- **Compatibility Consideration: Backward incompatibility.** `ssdata` now returns the sampling time, $T_s$, as the fifth output when it is called with five outputs. In previous releases, `ssdata` returned the disturbance matrix, $K$, as the fifth output.

### tfdata

**Compatibility Consideration: Backward incompatibility.** `tfdata` now returns the sampling time, $T_s$, as the third output. In previous releases, `tfdata` returned the numerator standard deviation as the third output.

The new syntax is:

```matlab
[num, den, Ts, sdnum, sdden] = tfdata(sys);
```

$sdnum$ and $sdden$ are `[ ]` if `sys` does not contain uncertainty information or for multi-output polynomial models with a nondiagonal $A$ polynomial array.
<table>
<thead>
<tr>
<th>Function</th>
<th>What Has Changed in R2012a</th>
</tr>
</thead>
<tbody>
<tr>
<td>zpkdata</td>
<td><strong>Compatibility Consideration: Backward incompatibility.</strong> <code>zpkdata</code> now returns the sampling time, <code>Ts</code>, as its fourth output argument. In previous releases, <code>zpkdata</code> returned the standard deviations of the zeros. The new syntax is: <code>[z,p,k,z,Ts,covz,covp,covk] = zpkdata(sys)</code> where <code>covz</code>, <code>covp</code> and <code>covk</code> are the covariance of the zeros, poles and gain of <code>sys</code>.</td>
</tr>
<tr>
<td>canon</td>
<td>You can use the new function <code>canon</code> to transform <code>idss</code> models into various canonical forms. For more information, see <code>canon</code>.</td>
</tr>
<tr>
<td>findstates(idParametric)</td>
<td>You can now specify arbitrary prediction horizons for <code>findstates</code>. You can use an option set to specify the option for <code>findstates</code>. Use the new function <code>findstatesOptions</code> to create the option set. For more information, see <code>findstatesOptions</code>.</td>
</tr>
<tr>
<td>ffplot</td>
<td><code>ffplot</code> is no longer supported. Use <code>bodeplot</code> instead. Use <code>bodeoptions</code> to set the frequency units and scale.</td>
</tr>
<tr>
<td>setstruc</td>
<td><code>setstruc</code> is no longer supported. Use the <code>Structure</code> property of the <code>idss</code> model to configure the model parameters.</td>
</tr>
<tr>
<td>setpname</td>
<td><code>setpname</code> is no longer supported. Use the <code>Info.Label</code> field of the <code>Structure</code> property associated with the model parameter.</td>
</tr>
<tr>
<td>idprops</td>
<td><code>idprops</code> is no longer supported. For information regarding a model, enter <code>doc model_name</code>.</td>
</tr>
</tbody>
</table>
### What Has Changed in R2012a

**idhelp**

idhelp is no longer supported. For information regarding a model or function, enter `doc model_or_function_name`.

### Other Functionality Being Removed or Changed

<table>
<thead>
<tr>
<th>Functionality</th>
<th>What Happens When You Use This Functionality?</th>
<th>Use This Instead</th>
<th>Compatibility Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>sys.LinearModel</code>, for <code>idnlhw</code> model, <code>sys</code></td>
<td>Returns an <code>idpoly</code> model.</td>
<td>N/A</td>
<td>The <code>LinearModel</code> property of <code>idnlhw</code> models is no longer returned as a state-space model for multi-output models. Instead, <code>idnlhw</code> returns an <code>idpoly</code> model.</td>
</tr>
</tbody>
</table>
R2011b

Version: 7.4.3

Bug Fixes
R2011a

Version: 7.4.2

Bug Fixes
R2010b

Version: 7.4.1

No New Features or Changes
R2010a

Version: 7.4

New Features

Compatibility Considerations
New Ability to Use Discrete-Time Linear Models for Nonlinear Black-Box Estimation

You can now use the following discrete-time linear models for initializing a nonlinear black-box estimation.

<table>
<thead>
<tr>
<th>Discrete-time Linear Model</th>
<th>Use for Initializing...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-output polynomial model of ARX structure (idpoly)</td>
<td>Single-output nonlinear ARX model estimation</td>
</tr>
<tr>
<td>Multi-output polynomial model of ARX structure (idarx)</td>
<td>Multi-output nonlinear ARX model estimation</td>
</tr>
<tr>
<td>Single-output polynomial model of Output-Error (OE) structure (idpoly) or state-space model with no disturbance component (idss) object with K = 0</td>
<td>Single-output Hammerstein-Wiener model estimation</td>
</tr>
<tr>
<td>State-space model with no disturbance component (idss object with K = 0)</td>
<td>Multi-output Hammerstein-Wiener model estimation</td>
</tr>
</tbody>
</table>

During estimation, the software uses the linear model orders and delay as initial values of the nonlinear model orders and delay. For nonlinear ARX models, this initialization always provides a better fit to the estimation data than the linear ARX model.

You can use a linear model as an alternative approach to using model orders and delay for nonlinear estimation of the same system.

You can estimate or construct the linear model and then use this model for constructing (see idnlarx and idnlhw) or estimating (see nlarx or nlhw) the nonlinear model. For more information, see Using Linear Model for Nonlinear ARX Estimation, and Using Linear Model for Hammerstein-Wiener Estimation in the System Identification Toolbox User's Guide.

New Cell Array Support for B and F Polynomials of Multi-Input Polynomial Models

You can now use cell arrays to specify the $B$ and $F$ polynomials of multi-input polynomial models. The $B$ and $F$ polynomials are represented by the $b$ and $f$ properties of an idpoly object. These properties are currently double matrices.
For multi-input polynomial models, these polynomials will be represented by cell arrays only in a future version. If your code performs operations on the \( b \) and \( f \) properties, make one of the following changes in the code:

- When you construct the model using the `idpoly` command, use cell arrays to specify the \( B \) and \( F \) polynomials. Using cell arrays causes the \( b \) and \( f \) properties to be represented by cell arrays.

- After you construct or estimate the model, use the new `setPolyFormat` command to:
  - Convert \( b \) and \( f \) properties to cell arrays.
  - Make the model backward compatible to continue using double matrices for \( b \) and \( f \) properties. This operation ensures that operations on \( b \) and \( f \) properties that use matrix syntax continue to work without errors in a future version.

When you use cell arrays, you must also update your code to use cell array syntax on \( b \) and \( f \) properties instead of matrix syntax.

**Note:** For single-input polynomial models, the \( b \) and \( f \) properties continue to be double row vectors.

### Functions and Function Elements Being Removed

<table>
<thead>
<tr>
<th>Function or Function Element Name</th>
<th>What Happens When you Use the Function or Element?</th>
<th>Use This Instead</th>
<th>Compatibility Considerations</th>
</tr>
</thead>
</table>
| Double matrix support for \( b \) and \( f \) properties of multi-input `idpoly` models. | Warns | Use cell array to specify the \( b \) and \( f \) properties of multi-input polynomial models. | If your code performs operations on the \( b \) and \( f \) properties, update the code to be compatible with a future release. See “New Cell Array Support for B and F Polynomials of Multi-Input Polynomial Models” on page 12-2.
R2009b

Version: 7.3.1

No New Features or Changes
R2009a

Version: 7.3

New Features
Enhanced Handling of Offsets and Trends in Signals

This version of the product includes new and expanded functionality for handling offsets and trends in signals. This data processing operation is necessary for estimating more accurate linear models because linear models cannot capture arbitrary differences between the input and output signal levels.

The previous version of the product let you remove mean values or linear trends from steady-state signals using the GUI and the `detrend` function. For transient signals, you had to remove offsets and trends using matrix manipulation.

The GUI functionality for removing means and linear trends from signals is unchanged. However, you can now do the following at the command line:

- Save the values of means or linear trends removed during detrending using a new `detrend` output argument. You can use this saved trend information to detrend other data sets. You can also restore subtracted trends to the output simulated by a linear model that was estimated from detrended data.

  For example, this syntax computes and removes mean values from the data, and saves these values to the output variable `T`: `[data_d, T] = detrend(data)`.

  `T` is an object with properties that store offset and slope information for input and output signals.

- Remove any offset or linear trend from the data using a new `detrend` input argument. This is useful for removing arbitrary nonzero offsets from transient data or applying previously saved trend information to any data set.

  For example, this syntax removes an offset or trend specified by `T`: `data_d = detrend(data, T)`.

- Add an arbitrary offset or linear trend to data signals. This is useful when you want to simulate the response of a linear model about a nonzero equilibrium input-output level and this model was estimated from detrended data.

  For example, this syntax adds trend information to a simulated model output `y_sim`, which is an `iddata` object: `y = retrend(y_sim, T)`.

  `T` specifies the offset and slope information for inputs and outputs.

For more information, see Handling Offsets and Trends in Data.
Ability to Get Regressor Values in Nonlinear ARX Models

The `getreg` command can now return the numerical values of regressors in nonlinear ARX models and provides an intermediate output of nonlinear ARX models.

This advanced functionality converts input and output values to regressors, and passes the regressor values to the `evaluate` command to compute the model response. This incremental step lets you gain insight into the propagation of information through the nonlinear ARX model.

For more information, see the `getreg` reference page. To learn more about the nonlinear ARX model structure, see Nonlinear Black-Box Model Identification.
R2008b

Version: 7.2.1

Compatibility Considerations
# Functions and Properties Being Removed

<table>
<thead>
<tr>
<th>Function or Property Name</th>
<th>What Happens When You Use Function or Property?</th>
<th>Use This Instead</th>
<th>Compatibility Considerations</th>
</tr>
</thead>
</table>
R2008a

Version: 7.2

New Features

Compatibility Considerations
Simulating Nonlinear Black-Box Models in Simulink Software

You can now simulate nonlinear ARX and Hammerstein-Wiener models in Simulink using the nonlinear ARX and the Hammerstein-Wiener model blocks in the System Identification Toolbox block library. This is useful in the following situations:

- Representing dynamics of a physical component in a Simulink model using a data-based nonlinear model
- Replacing a complex Simulink subsystem with a simpler data-based nonlinear model

**Note:** Nonlinear ARX Model and Hammerstein-Wiener Model blocks read variables from the MATLAB (base) workspace or model workspace. When the MATLAB workspace and model workspace contain a variable with the same name and this variable is referenced by a Simulink block, the variable in the model workspace takes precedence.

If you have installed Real-Time Workshop® software, you can generate code from models containing nonlinear ARX and the Hammerstein-Wiener model blocks. However, you cannot generate code when:

- Hammerstein-Wiener models use the customnet estimator for input or output nonlinearity.
- Nonlinear ARX models use custom regressors or use the customnet or neuralnet nonlinearity estimator.

You can access the new System Identification Toolbox blocks from the Simulink Library Browser. For more information about these blocks, see the IDNLARX Model (nonlinear ARX model) and the IDNLHW Model (Hammerstein-Wiener model) block reference pages.

Linearizing Nonlinear Black-Box Models at User-Specified Operating Points

You can now use the `linearize` command to linearize nonlinear black-box models, including nonlinear ARX and Hammerstein-Wiener models, at specified operating points. Linearization produces a first-order Taylor series approximation of the system about an operating point. An operating point is defined by the set of constant input and state values for the model.
If you do not know the operating point, you can use the findop command to compute it from specifications, such as steady-state requirements or values of these quantities at a given time instant from the simulation of the model.

For nonlinear ARX models, if all of the steady-state input and output values are known, you can map these values to the model state values using the data2state command.

linearize replaces lintan and removes the restriction for linearizing models containing custom regressors or specific nonlinearity estimators, such as neuralnet and treepartition.

If you have installed Simulink Control Design software, you can linearize nonlinear ARX and Hammerstein-Wiener models in Simulink after importing them into Simulink.

For more information, see:

• Linear Approximation of Nonlinear Black-Box Models about computing operating points and linearizing models
• Simulating Identified Model Output in Simulink about importing nonlinear black-box models into Simulink

Estimating Multiple-Output Models Using Weighted Sum of Least Squares Minimization Criterion

You can now specify a custom weighted trace criterion for minimization when estimating linear and nonlinear black-box models for multiple-output systems. This feature is useful for controlling the relative importance of output channels during the estimation process.

The Algorithm property of linear and nonlinear models now provides the Criterion field for choosing the minimization criterion. This new field can have the following values:

• det — (Default) Specify this option to minimize the determinant of the prediction error covariance. This choice leads to maximum likelihood estimates of model parameters. It implicitly uses the inverse of estimated noise variance as the weighting function. This option was already available in previous releases.
• trace — Specify this option to define your own weighing function that controls the relative weights of output signals during the estimation. This criterion minimizes the weighted sum of least square prediction errors. You can specify the relative weighting of prediction errors for each output using the new Weighting field of the Algorithm
property. By default, *Weighting* is an identity matrix, which means that all outputs are weighed equally. Set *Weighting* to a positive semidefinite symmetric matrix.

For more information about Algorithm fields for nonlinear estimation, see the *idnlarx* and *idnlhw* reference pages.

**Note:** If you are estimating a single-output model, *det* and *trace* values of the *Criterion* field produce the same estimation results.

**Improved Handling of Initial States for Linear and Nonlinear Models**

The following are new options to handle initial states for nonlinear models:

- For nonlinear ARX models (*idnlarx*), you can now specify a numerical vector for initial states when using *sim* or *predict* by setting the *Init* argument. For example:

  ```
  predict(model, data, 'init', [1; 2; 3; 4])
  ```

  where the last argument is the state vector.

  For more information, see the *sim* and *predict* reference pages.

- For Hammerstein-Wiener models (*idnlhw*), you can now choose to estimate the initial states when using *predict* or *nlhw* by setting INIT='e'.

  For more information, see the *predict* and *nlhw* reference pages.

If you want to specify your own initial states, see the corresponding model reference pages for a definition of the states for each model type.

If you do not know the states, you can use the *findop* or the *findstates* command to compute the states. For more information about using these commands, see the *findop(idnlarx)*, *findop(idnlhw)*, *findstates(idnlarx)*, and *findstates(idnlhw)* reference pages.

To help you interpret the states of a nonlinear ARX model, you can use the *getDelayInfo* command. For more information, see the *getDelayInfo* reference page.

The *findstates* command is available for all linear and nonlinear models. Also see the *findstates(idnlgrey)* reference page.
Improved Algorithm Options for Linear Models

The following improvements are available for the Algorithm property of linear models to align linear and nonlinear models (where appropriate) and improve robustness for default settings:

- The SearchDirection field (model.Algorithm.SearchDirection) has been renamed to SearchMethod (model.Algorithm.SearchMethod) to be consistent with the nonlinear models, where the corresponding field is SearchMethod.
- The new lsqnonlin option for specifying SearchMethod is available. model.Algorithm.SearchMethod='lsqnonlin' uses the lsqnonlin optimizer from the Optimization Toolbox™ software. You must have Optimization Toolbox software installed to use this option.
- The improved gn algorithm (subspace Gauss-Newton method) is available for specifying SearchDirection. The updated gn algorithm better handles the scale of the parameter Jacobians and is also consistent with the algorithm used for nonlinear model estimation.
- The default values for the LimitError field of the Algorithm property (modelname.Algorithm.LimitError) is changed to 0, which is consistent with the corresponding option for estimating nonlinear models. In previous releases, LimitError default value was 1.6, which robustified the estimation process against data outliers by associating a linear penalty for large errors, rather than a quadratic penalty. Now, there is no robustification by default (LimitError=0). You can estimate the model with the default setting and plot the prediction errors using pe(data.model). If the resulting plot shows occasional large values, repeat the estimation with model.Algorithm.LimitError set to a value between 1 and 2.
- The model.Algorithm.Advanced property has a new tolerance field GnPinvConst corresponding to the gn SearchMethod. GnPinvConst specifies that singular values of the Jacobian that are smaller than GnPinvConst*max(size(J))*norm(J)*eps are discarded when computing the search direction. You can assign a positive real value for this field. Default value is 1e4.
- The default value of model.Algorithm.Advanced.Zstability property has been changed from 1.01 to 1+sqrt(eps). The new default reduces the possibility of a situation where the estimation algorithm does not converge (predictor becomes unstable) while still allowing enough flexibility to capture lightly damped modes.
New Block Reference Pages

New documentation for System Identification Toolbox blocks is provided. For more information, see Block Reference in the System Identification Toolbox reference documentation.

Functions and Properties Being Removed

<table>
<thead>
<tr>
<th>Function or Property Name</th>
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</tr>
</thead>
<tbody>
<tr>
<td>lintan</td>
<td>Still runs</td>
<td>linearize(idnlhw) linearize(idnlarx)</td>
<td>See “Linearizing Nonlinear Black-Box Models at User-Specified Operating Points” on page 16-2.</td>
</tr>
<tr>
<td>gns option of model.Algorithm. SearchDirection</td>
<td>Still runs</td>
<td>gn</td>
<td>See “Improved Algorithm Options for Linear Models” on page 16-5.</td>
</tr>
</tbody>
</table>
R2007b

Version: 7.1

New Features
New Polynomial Nonlinearity Estimator for Hammerstein-Wiener Models

You can now estimate nonlinearities for Hammerstein-Wiener models using a single-variable polynomial at either the input or the output. This nonlinearity estimator is available at the command line.

For more information, see the poly1d reference pages. For more information about estimating Hammerstein-Wiener models, see Identifying Hammerstein-Wiener Models in the System Identification Toolbox documentation.
R2007a

Version: 7.0

New Features

• “New Nonlinear Black-Box Modeling Options” on page 18-2
• “New Nonlinear Grey-Box Modeling Option” on page 18-2
• “New Getting Started Guide” on page 18-3
• “Revised and Expanded User's Guide” on page 18-3
New Nonlinear Black-Box Modeling Options

You can now estimate nonlinear discrete-time black-box models for both single-output and multiple-output time-domain data. The System Identification Toolbox product supports the following types of nonlinear black-box models:

- Hammerstein-Wiener
- Nonlinear ARX

To learn how to estimate nonlinear black-box models using the System Identification Tool GUI or commands in the MATLAB Command Window, see the System Identification Toolbox documentation.

Note: You can estimate Hammerstein-Wiener black-box models from input-output data only. These models do not support time-series data, where there is no input.

New demos are available to help you explore nonlinear black-box functions. For more information, see the collection of demos in the Tutorials on Nonlinear ARX and Hammerstein-Wiener Model Identification category.

New Nonlinear Grey-Box Modeling Option

You can now estimate nonlinear discrete-time and continuous-time models for arbitrary nonlinear ordinary differential equations using single-output and multiple-output time-domain data, or time-series data (no measured inputs). Models that you can specify as a set of nonlinear ordinary differential equations (ODEs) are called grey-box models.

To learn how to estimate nonlinear grey-box models using the commands in the MATLAB Command Window, see System Identification Toolbox documentation.

Specify the ODE in a function or a MEX-file. The template file for writing the MEX-file, IDNLGREY_MODEL_TEMPLATE.c, is located in matlab/toolbox/ident/nlident.

To estimate the equation parameters, first construct an idnlgrey object to specify the ODE file and the parameters you want to estimate. Use pem to estimate the ODE parameters. For more information, see the idnlgrey and pem reference pages.

New demos are available to help you explore nonlinear grey-box functions. For more information, see the collection of demos in the Tutorials on Nonlinear Grey-Box Model Identification category.
Optimization Toolbox Search Method for Nonlinear Estimation Is Supported

If you have Optimization Toolbox software installed, you can specify the lsqnonlin search method for estimating black-box and grey-box nonlinear models in the MATLAB Command Window.

model.algorithm.searchmethod='lsqnonlin'

For more information, see the idnlarx, idnlhw, and idnlgrey reference pages.

New Getting Started Guide

The System Identification Toolbox product now provides a new Getting Started Guide. This guide introduces fundamental identification concepts and provides the following tutorials to help you get started quickly:

- Tutorial – Identifying Linear Models Using the GUI — Tutorial for using the System Identification Tool graphical user interface (GUI) to estimate linear black-box models for single-input and single-output (SISO) data.
- Tutorial – Identifying Low-Order Transfer Functions (Process Models) Using the GUI — Tutorial for using the System Identification Tool graphical user interface (GUI) to estimate low-order transfer functions to fit single-input and single-output (SISO) data.

Revised and Expanded User's Guide

The System Identification Toolbox documentation has been revised and expanded.
R2006b

Version: 6.2

New Features
MATLAB Compiler Support

The System Identification Toolbox product now supports the MATLAB Compiler product.

You can use MATLAB Compiler to take MATLAB files as input and generate redistributable, standalone applications that include System Identification Toolbox functionality, including the following:

• Creating data and model objects
• Preprocessing and manipulating data
• Simulating models
• Transforming models, including conversions between continuous and discrete time and model reduction
• Plotting transient and frequency response

To use these features, write a function that uses System Identification Toolbox commands. Use the MATLAB Compiler software to create a standalone application from the MATLAB Compiler file. For more information, see the MATLAB Compiler documentation.
Standalone applications that include System Identification Toolbox functionality have the following limitations:

- No access to the System Identification library in the Simulink software (slident)
- No support for model estimation
New Features

Compatibility Considerations

• “balred Introduced for Model Reduction” on page 20-2
• “Search Direction for Minimizing Criteria Can Be Computed by Adaptive Gauss-Newton Method” on page 20-2
• “Maximum Number of Bisections Used by Line Search Is Increased” on page 20-2
**balred Introduced for Model Reduction**

Use balred to perform model reduction instead of `idmodred`.

**Search Direction for Minimizing Criteria Can Be Computed by Adaptive Gauss-Newton Method**

An adaptive Gauss-Newton method is now available for computing the direction of the line search for cost-function minimization. Use this method when you observe convergence problems in the estimation results, or as an alternative to the Levenberg-Marquard (`lm`) method.

The `gna` search method was suggested by Adrian Wills, Brett Ninness, and Stuart Gibson in their paper "On Gradient-Based Search for Multivariable System Estimates", presented at the IFAC World Congress in Prague in 2005. `gna` is an adaptive version of `gns` and uses a cutoff value for the singular values of the criterion Hessian, which is adjusted adaptively depending on the success of the line search.

Specify the `gna` method by setting the `SearchDirection` property to `'gna'`. For example:

```matlab
m = pem(data,model_structure,'se','gna')
```

The default initial value of `gamma` in the `gna` search is $10^{-4}$. You can set a different value using the `InitGnaTol` property.

**Maximum Number of Bisections Used by Line Search Is Increased**

The default value for the `MaxBisections` property, which is the maximum number of bisections along the search direction used by line search, is increased from 10 to 25. This increases the number of attempts to find a lower criterion value along the search vector.
Functions and Properties Being Removed

<table>
<thead>
<tr>
<th>Function or Property Name</th>
<th>What Happens When You Use Function or Property?</th>
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</tr>
</thead>
<tbody>
<tr>
<td>idmodred</td>
<td>Still runs</td>
<td>balred</td>
<td>See “balred Introduced for Model Reduction” on page 20-2.</td>
</tr>
</tbody>
</table>
R14SP3

Version: 6.1.2

No New Features or Changes
R14SP2

Version: 6.1.1

No New Features or Changes