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System identification with IDA

Overview

Model structure

IDA allows the identification of linear systems based on measured input/output data. The input signal can be of any type. For identification the method of multiple integration is used which is especially characterized by its robustness against meaurement noise [5]. The identified system model has the following structure:

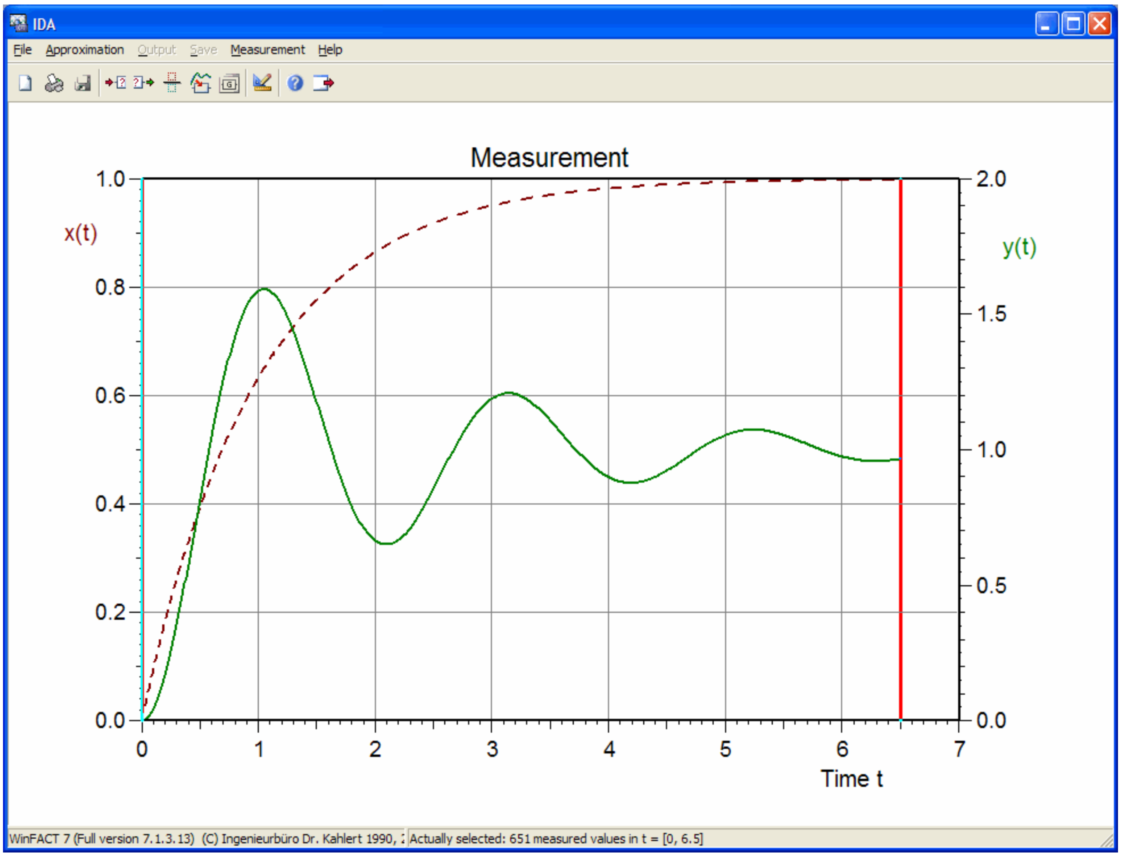
$$G(s) = \frac{b_m s^m + b_{m-1} s^{m-1} + \ldots + b_1 s + b_0}{s^n + a_{n-1} s^{n-1} + \ldots + a_1 s + a_0} e^{-T_t s} .$$

Numerator order m and denominator order n can be user-specified or determined automatically by the program. The dead time T_t also is calculated automatically within a lower and upper limit specified by the user.

Program options

Importing the measurement data

The measured data of the input and output signal of the system have to exist in two separated SIM-files, one file with the input data and one file with the output data. To let the identification algorithm work correctly it is most important that both signals were recorded at the same time values; so both files contain the same number of value pairs. Each value pair takes one line of the file, separated by a space. To read the input data, use the menu option FILE | INPUT SIGNAL X(T) or the  button of the toolbar. To read the output data, use the menu option FILE | OUTPUT SIGNAL Y(T) or the  button of the toolbar. The imported data are automatically displayed within the main window of IDA (see screenshot below).

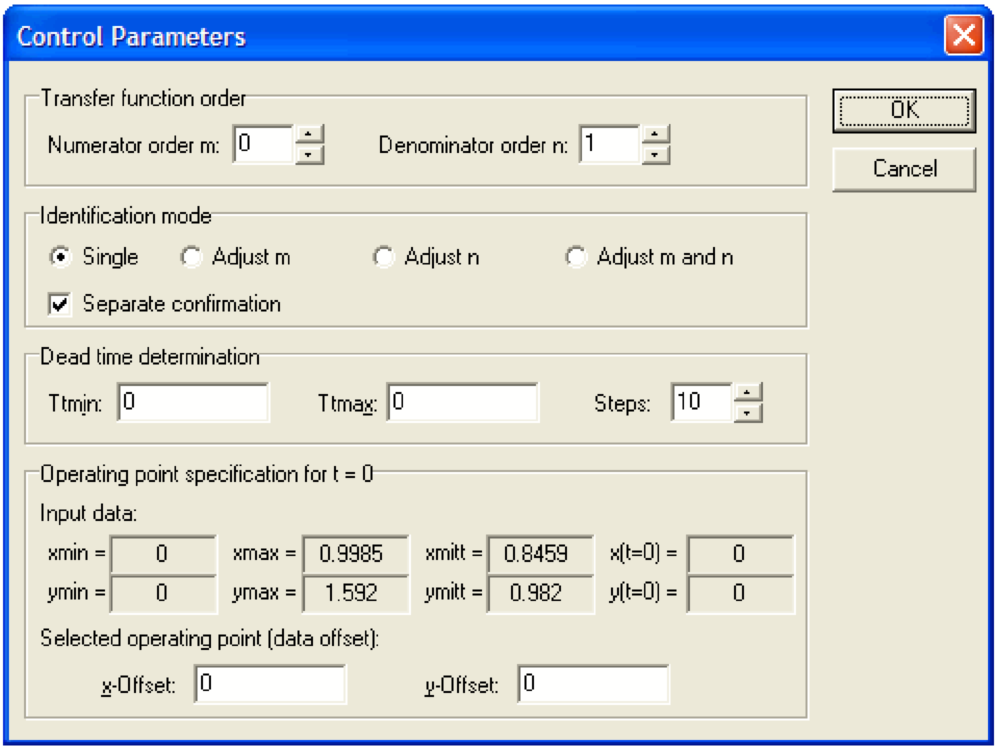


Main window of IDA after importing the measurement data from the sample files EX1_X.SIM resp. EX1_Y.SIM. The input signal is represented by a dashed red curve, the output signal by a solid green curve.

The quality of the determined model depends considerably on the resolution of the input and output signal, i. e. the number of measured values. Therefore 500 measurement values or more should be used for identification.

Control parameters for identification

After importing the input/output data the control parameters for the identification have to be specified via the FILE | CONTROL PARAMETERS... menu option resp. the button of the toolbar.



Control parameter dialog

This dialog box includes the following options:

Numerator order m — (Maximum) numerator order of the transfer function

Denominator order n — (Maximum) denominator order of the transfer function

Identification mode — If the mode *single* is selected, the identification is only executed for the values of *m* resp. *n* specified in the corresponding edit fields. If one of the other identification modes is chosen, the identification is executed for all values of the numerator resp. denominator order starting at 0 up to the value specified in the corresponding edit fields. In this way the optimal combination of *m* and n can be determined automatically. This automatical identification can be terminated by the user after each step.

Dead time determination

If a system has to be identified that supposable contains a dead time, this dead time can be determined by corresponding settings within this group box. *Ttmin* specifies the smallest, *Ttmax* the biggest value of the dead time that is tested by IDA. The value of the *Steps* field specifies the intermediate steps within this range.

Example: For *Ttmin* = 0, *Ttmax* = 1 and 4 intermediate steps dead times *Tt* of 0, 0.2, 0.4, 0.6, 0.8 and 1 are tested. The value of *Tt* that leads to the best identification result is determined as the correct one.

Operating point specification for t = 0

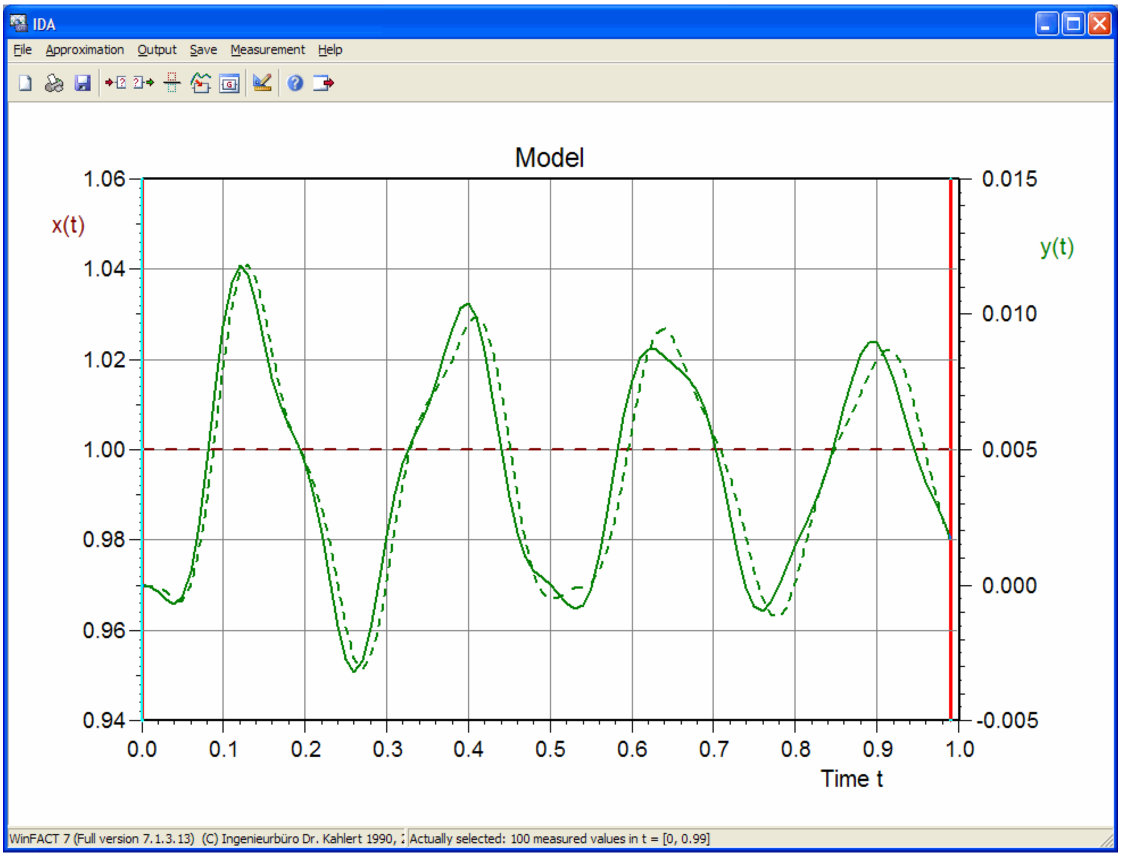
Within this group box the operating point of the system can be specified for the moment when the input signal is switched on; this operating point is automatically eliminated later during the identification process. Initial value, minimum and maximum as well as the mean value of input and output signal are displayed for user information.

Identification

After having specified all control parameters the identification can be started via the APPROXIMATION | APPROXIMATION... menu option resp. the button of the toolbar. The computation time for each identification step depends on the specified orders of the transfer function and the number of measurement data; normally it does not exceed some seconds. If the dead time adjustment is activated, the identification naturally needs more time.

If the identification is complete, the results are displayed automatically:

- the measured course of the input signal (red dashed line)
- the measured course of the output signal (green dashed line)
- the course of the output signal of the determined model (green solid line)

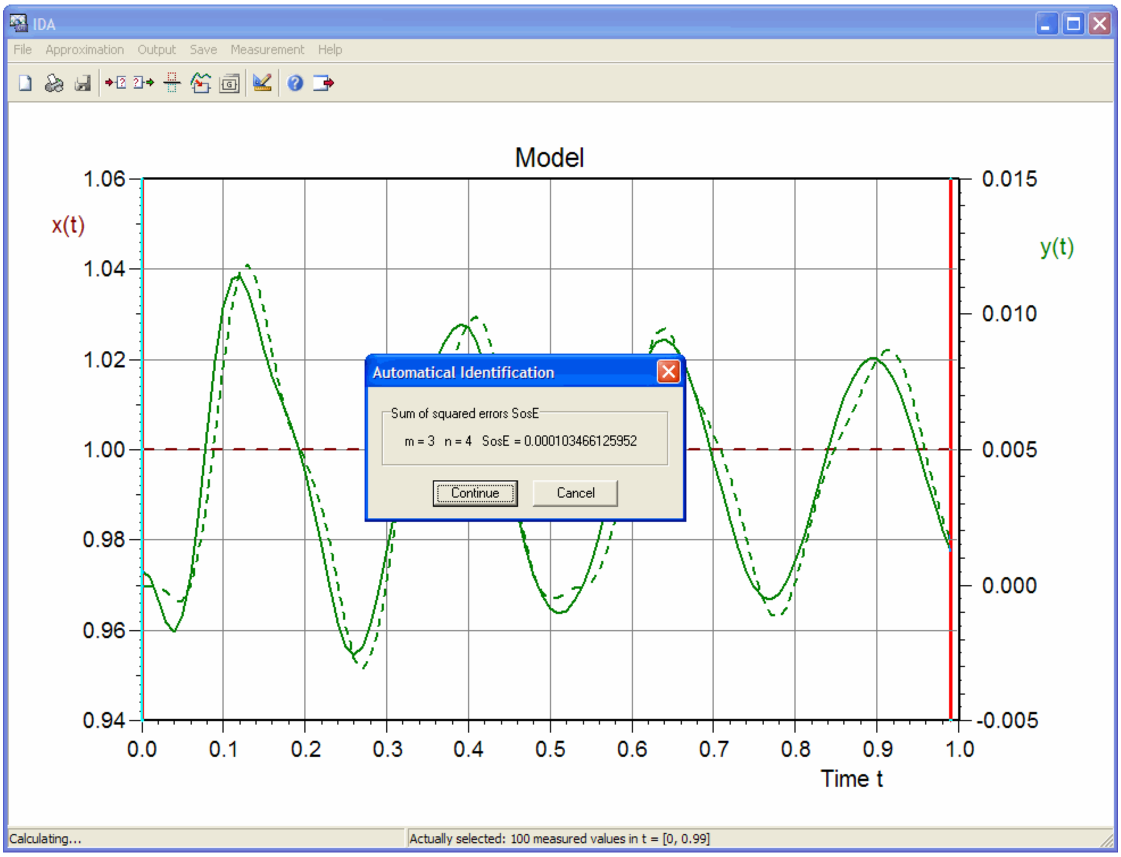


Graphical representation of results

If another identification mode than *single* was selected, after each identification run the result is displayed graphically on one side and numerically in form of the sum of squared errors SOSE on the other side. SOSE is defined as

$$SOSE = \sum_{i=1}^{m} \left(y_{i,Meas} - y_{i,Model} \right)^2$$

where m is the number of measured data, $y_{\mathrm{i,Meas}}$ the measured output value at time t_{i} and $y_{\mathrm{i,Model}}$ the output value at time t_{i} calculated by the identified model.



Automatical identification

The identified transfer function can be displayed via the OUTPUT | SHOW TRANSFER FUNCTION... menu option resp. the button of the toolbar. By the OUTPUT | COPY menu option the transfer function can be copied to the Windows clipboard, e. g. for a later usage by other WinFACT modules.

Unstable systems

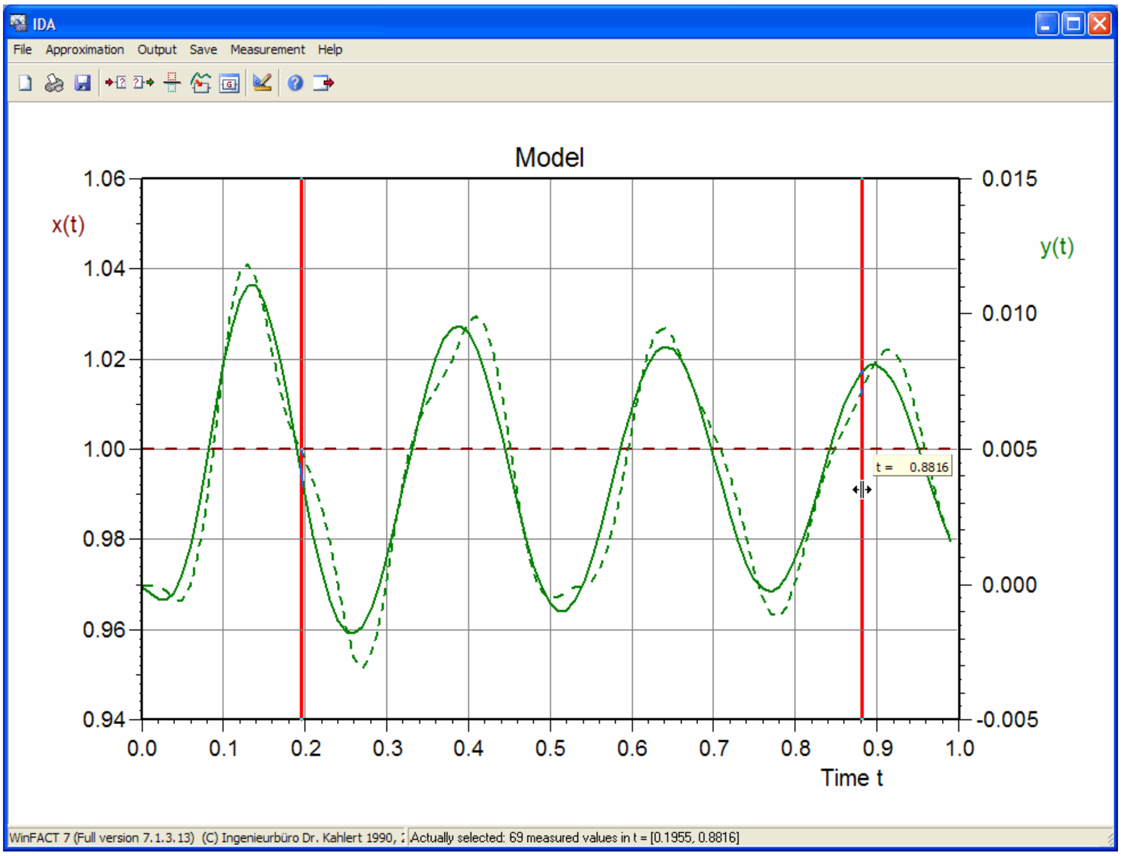
If a unstable system or a nearly unstable system is to be identified, the identification can lead to an unstable model. This unstable model can result in very large output values during the following simulation; so in these cases the simulation is stopped automatically to prevent a range overflow. Although the simulation is not complete in these cases, the transfer function nevertheless is determined correctly!

To save the transfer function in a separate UFK-file, use the menu option SAVE | SAVE... resp. the button of the toolbar.

Selecting a time window

By default the identification is executed based on the complete time range covered by the input data. In some cases it can be useful to specify a (smaller) time window within this range and execute the identification based only on this window.

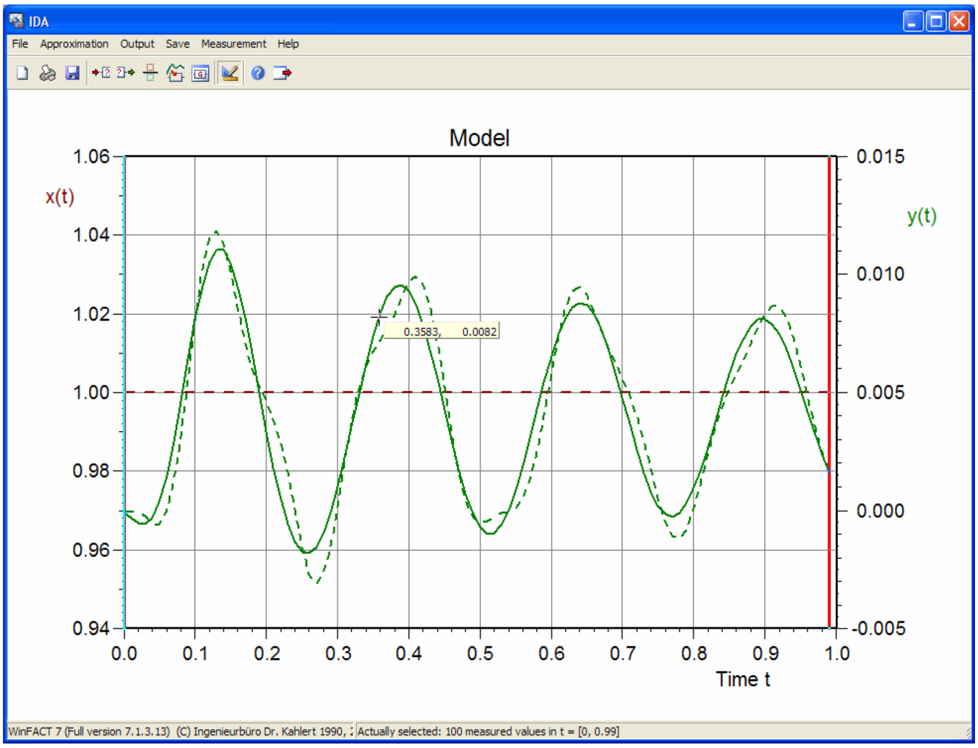
To define such a time window you can use the two red marker located at the left resp. right margin of the coordinate system after program start; these marker can easily be moved by selecting them with the left mouse key and moving the mouse while keeping the key pressed. The right panel of the status bar displays the actually selected range and the number of measurement values within it.



Selecting a time window for identification

Measurement mode

The MEASUREMENT | ACTIVATE MEASUREMENT MODE menu item or the  toolbar button can be used to activate the measurement mode of IDA. If this mode is active the mouse cursor is followed by a small hint window (tooltip window) containing the coordinates of the actual mouse position.



Main window with activated measurement mode

Using IDA for model reduction

As well as for identification purposes IDA can be used for *model reduction*. The aim of a model reduction is to replace a system

$$G(s) = \frac{b_m s^m + b_{m-1} s^{m-1} + \ldots + b_1 s + b_0}{s^n + a_{n-1} s^{n-1} + \ldots + a_1 s + a_0}$$

with a low-order system

$$\tilde{G}(s) = \frac{d_p s^p + d_{p-1} s^{p-1} + \ldots + d_1 s + d_0}{s^q + c_{q-1} s^{q-1} + \ldots + c_1 s + c_0}$$

with

$$p + q < m + n ,$$

which has an optimal similarity to the original high-order system:

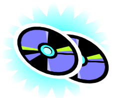
$$G(s) \approx \tilde{G}(s) .$$

To solve such problems with the help of IDA, you first have to simulate e. g. the step response of the original (e. g. with the WinFACT module LISA) and save the input and output signal into SIM-files. These files are in the second step imported to IDA. After specifying the desired numerator and denominator orders *p* resp. *q* of the reduced order model as the control parameters for the identification, the identification of the coefficients of the reduced-order model can be executed.

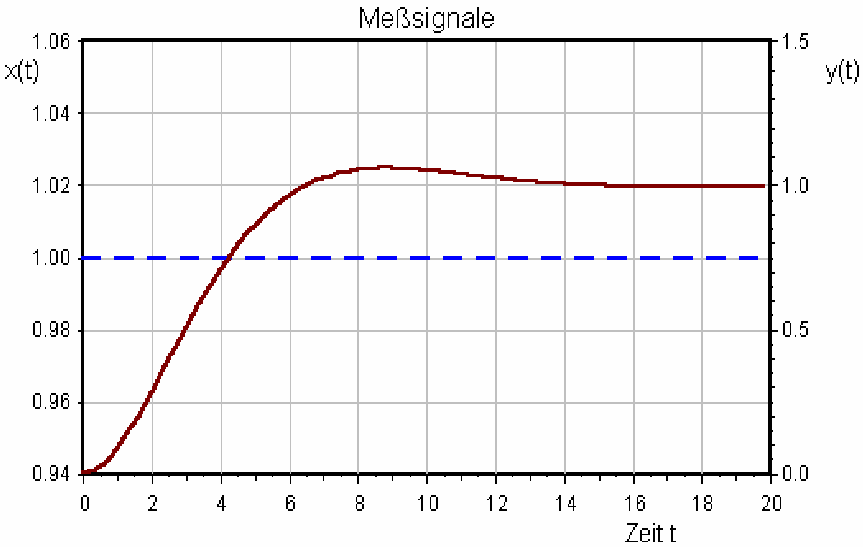
Program constants

Maximum number of measurements:	unlimited
Maximum order of model:	20

Sample application



Given are the following measured input resp. output data of a system (see sample files VZ2_X.SIM resp. VZ2_Y.SIM within the Examples-directory):



Sample measurement data

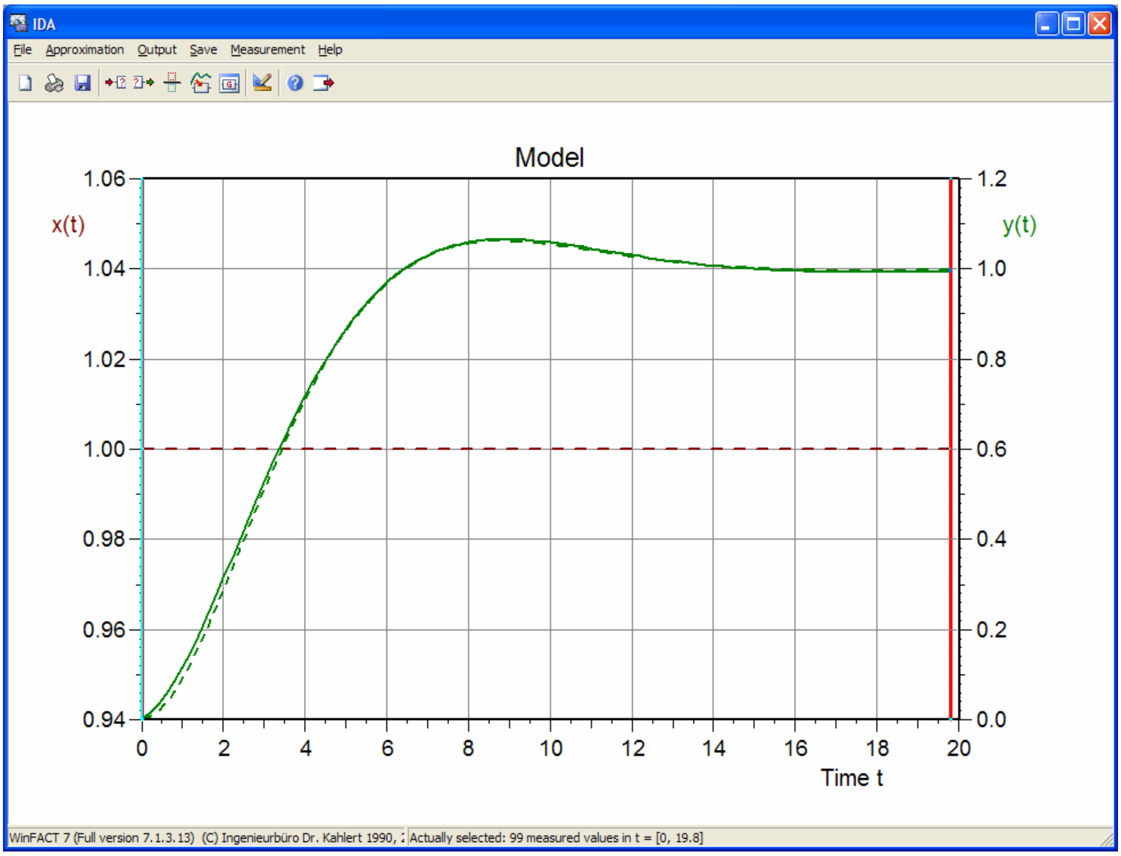
The system shows typical PT2-behaviour and therefore has to be approximated by a model of the form

$$G(s) = \frac{b_0}{s^2 + a_1 s + a_0}$$

The identification for $m = 0$ and $n = 2$ delivers the resulting model

$$G(s) = \frac{0.21}{s^2 + 0.59s + 0.21} \quad .$$

The screenshot below shows the identification result graphically.



Identification result

The Examples-directory of your WinFACT installation contains five more examples:

CHEN3_X.SIM, CHEN3_Y.SIM:

Sample system with $m = 6$ and $n = 8$, may be approximated well with $m = 3$, $n = 4$.

EX1_X.SIM, EX1_Y.SIM:

Sample system from [5] with $m = 1$ and $n = 2$, the input signal is an exponential signal here.

N4_X.SIM, N4_Y.SIM:

Sample system with all-pass character ($m = 2$ and $n = 4$).

RAUSCH_X.SIM, RAUSCH_Y.SIM:

Sample system with heavy measurement noise ($m = 0$ and $n = 2$).

SIN_X.SIM, SIN_Y.SIM:

Sample system with sinusoidal input signal ($m = 0$ and $n = 2$).