

SYSTEM IDENTIFICATION MATLAB TOOLBOX

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System Identification Matlab Toolbox

- In order to practice the System Identification Toolbox under MATLAB ver. R2014A:
 - type the command `iddemo`
 - enter 1 for linear model and general toolbox features
 - select the example number 1 for a guided tour on the Graphical User Interface *GUI* (required)
 - select the example number 2 for building simple models from real laboratory process data (suggested)
 - select the example number 3 for comparing different identification methods (suggested)
- To open the System Identification Toolbox *GUI*, type the command `ident`

System Identification Toolbox GUI

- **Main steps** to solve the hair dryer identification problem:
 - 1) Open the System Identification Toolbox *GUI* typing the command `ident`
 - 2) Import the dryer data (click on *Import data* and select *Example*, then click on *Import* and *Close* in the *Import Data* window): the `Dryer` window will appear in the *Data Views* area and also as *Working Data* and *Validation Data* boxes
 - 3) Remove the mean value from the data (click on *Preprocess* operation and select *Remove means*): the `Dryerd` window will appear in the *Data Views*
 - 4) Make the data without mean as current working dataset, by clicking the `Dryerd` window in the *Data Views* and dragging it to the *Working Data* box
 - 5) Partition the whole dataset in two subsets, called estimation dataset (ES) and validation dataset (VS) (click on *Preprocess* and choose *Select range*; type 1 500 as Samples for the `Dryerde` dataset and click on *Insert*; type 501 1000 as Samples for the `Dryerdv` dataset and click on *Insert* and *Close*): the `Dryerde` and `Dryerdv` windows will appear in the *Data Views* and the corresponding data may be shown by clicking on the *Time plot* option

- 6) Set ES as the current working dataset and VS as the current validation dataset, by clicking the `Dryerde` and `Dryerdv` windows in the *Data Views* area and dragging them to the *Working Data* and *Validation Data* boxes, respectively
- 7) Perform the order selection for an ARX structure (click on *Estimate* and select *Polynomial Models*, then click on *Order Selection* and *Estimate*) in order to consider and compare different model selection criteria:

$$\mathbf{Best\ Fit} = 1 - \sqrt{\frac{MSE}{\frac{1}{N} \sum_{t=1}^N (y(t) - \bar{y})^2}} \quad (\text{index to be maximized})$$

$$\mathbf{AIC} = n \frac{2}{N} + \ln(MSE) \quad (\text{index to be minimized})$$

$$\mathbf{MDL} = n \frac{\ln(N)}{N} + \ln(MSE) \quad (\text{index to be minimized})$$

$$\text{with } MSE = \frac{1}{N} \sum_{t=1}^N (y(t) - \hat{y}(t))^2, \bar{y} = \frac{1}{N} \sum_{t=1}^N y(t) = \text{sample mean of } y,$$

$$n = \text{ARX model complexity (in prediction mode)} = \dim(\theta) = n_a + n_b$$

8) Identify several models of different orders and delays using the following structures:

- ARX (n_a, n_b, n_k), using $n_a=n_b=1, \dots, 4$ and $n_k=1, \dots, 3$
(and also the optimal values of n_a, n_b, n_k obtained from step 7)
- ARMAX (n_a, n_b, n_c, n_k), using $n_a=n_b=n_c=1, \dots, 4$ and $n_k=1, \dots, 3$
- OE (n_b, n_f, n_k), using $n_b=n_f=1, \dots, 4$ and $n_k=1, \dots, 3$

by clicking on *Estimate*, selecting *Polynomial Models*, choosing as *Structure* the desired model class, clicking on the *Order Editor* or specifying in *Orders* the model orders and the input-output delay, and finally clicking on *Estimate* in the *Polynomial Model* window: the corresponding window will appear in the *Model Views* area

9) Compare the identified models on the VS dataset considering both the Best Fit index, to be maximized (click on the *Model output* option), and the residual analysis (click on the *Model resids* option).

For the whiteness residual test of each model, the Autocorrelation plot has to be considered: the more residual values are inside the confidence interval, the better is the model; the number of residuals sufficiently outside the confidence interval have to be counted and compared with a threshold:

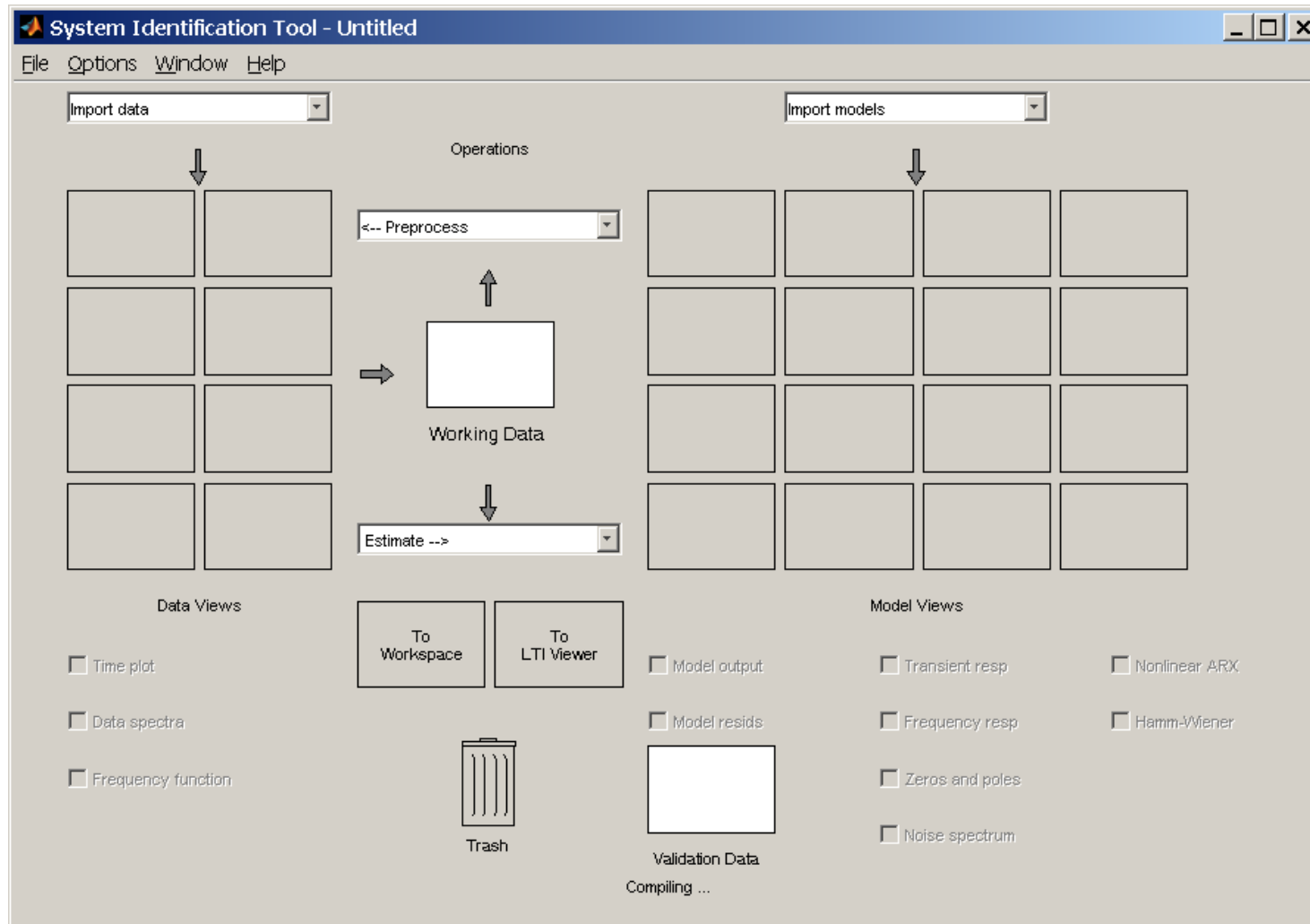
- if this number is greater than the threshold, then the model is wasted,
- otherwise, the model is considered for further analyses;

a reasonable threshold is 4 or 5, corresponding to a 95% confidence level (note that this threshold may be increased, depending on the case study!!)

10) Select and export the “best trade-off” model (click the corresponding window in the *Model Views* area and drag it to the *To Workspace* box)

System Identification Toolbox GUI in detail

1) Open the System Identification Toolbox *GUI* typing the command `ident`



2) Import the dryer data: click on *Import data* and select *Example*, then click on *Import* and *Close* in the *Import Data* window; the *Dryer* window will appear in the *Data Views* area and also as *Working Data* and *Validation Data* boxes

The screenshot displays the 'System Identification Tool - Untitled' window. The 'Import Data' dialog is open, showing the 'Data Format for Signals' set to 'Time-Domain Signals', 'Workspace Variable' with 'Input: u2' and 'Output: y2', and 'Data Information' with 'Data name: Dryer', 'Starting time: 0', and 'Sampling interval: 0.08'. The 'Import' button is circled with a red '3' and the 'Close' button with a red '4'. In the main workspace, the 'Import data' menu is open, with 'Example...' selected, circled with a red '2'. The 'Operations' area shows 'Preprocess' and 'Estimate -->' buttons. The 'Data Views' area has checkboxes for 'Time plot', 'Data spectra', and 'Frequency function'. The 'Model Views' area has checkboxes for 'Transient resp', 'Frequency resp', 'Zeros and poles', and 'Noise spectrum'. The 'Validation Data' area shows 'Model output', 'Model resids', and 'Compiling ...' options. A 'Trash' icon is also visible.

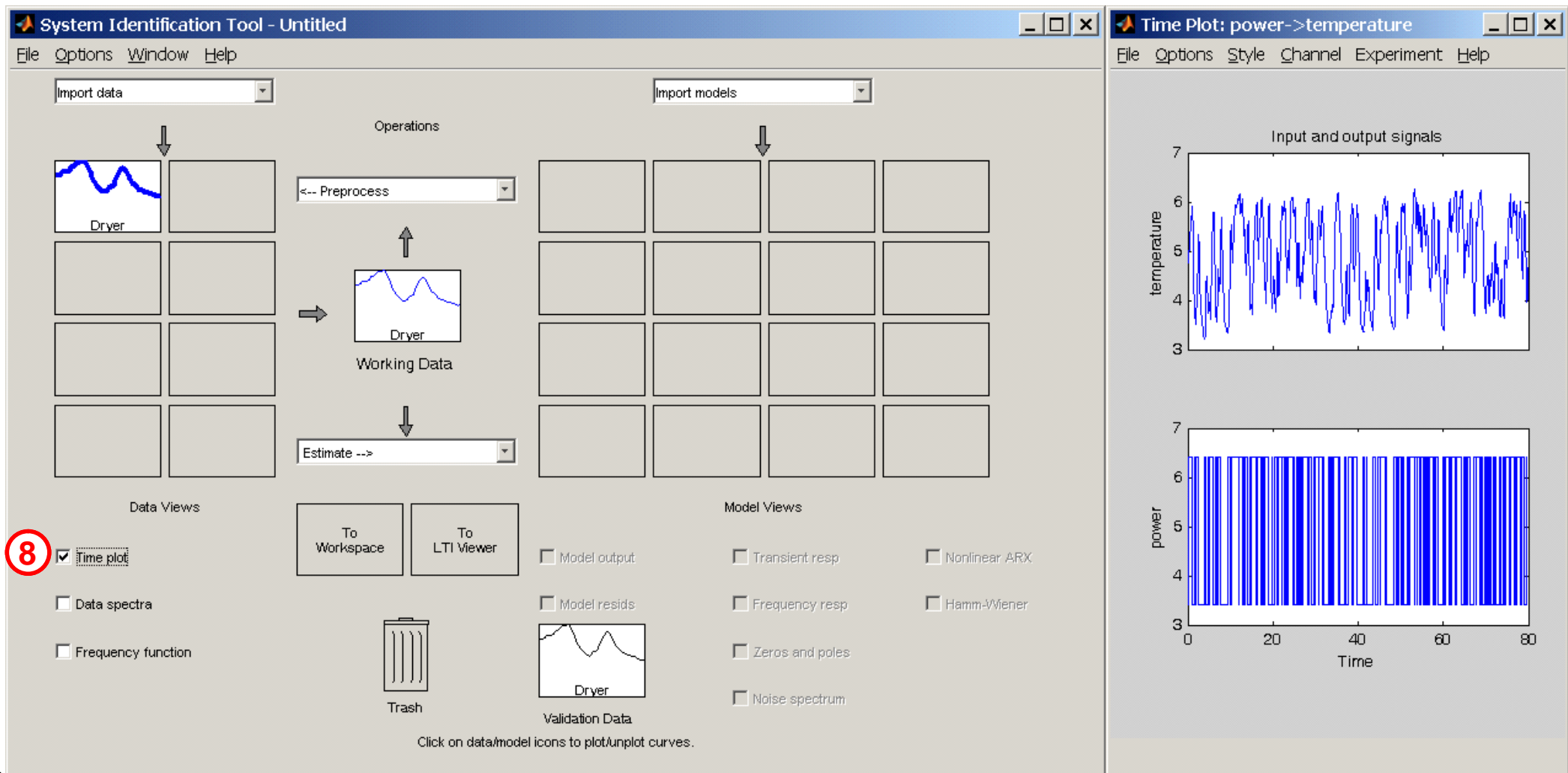
2) Import the dryer data: click on *Import data* and select *Example*, then click on *Import* and *Close* in the *Import Data* window; the *Dryer* window will appear in the *Data Views* area and also as *Working Data* and *Validation Data* boxes

The screenshot displays the 'System Identification Tool - Untitled' window. The interface is divided into several sections:

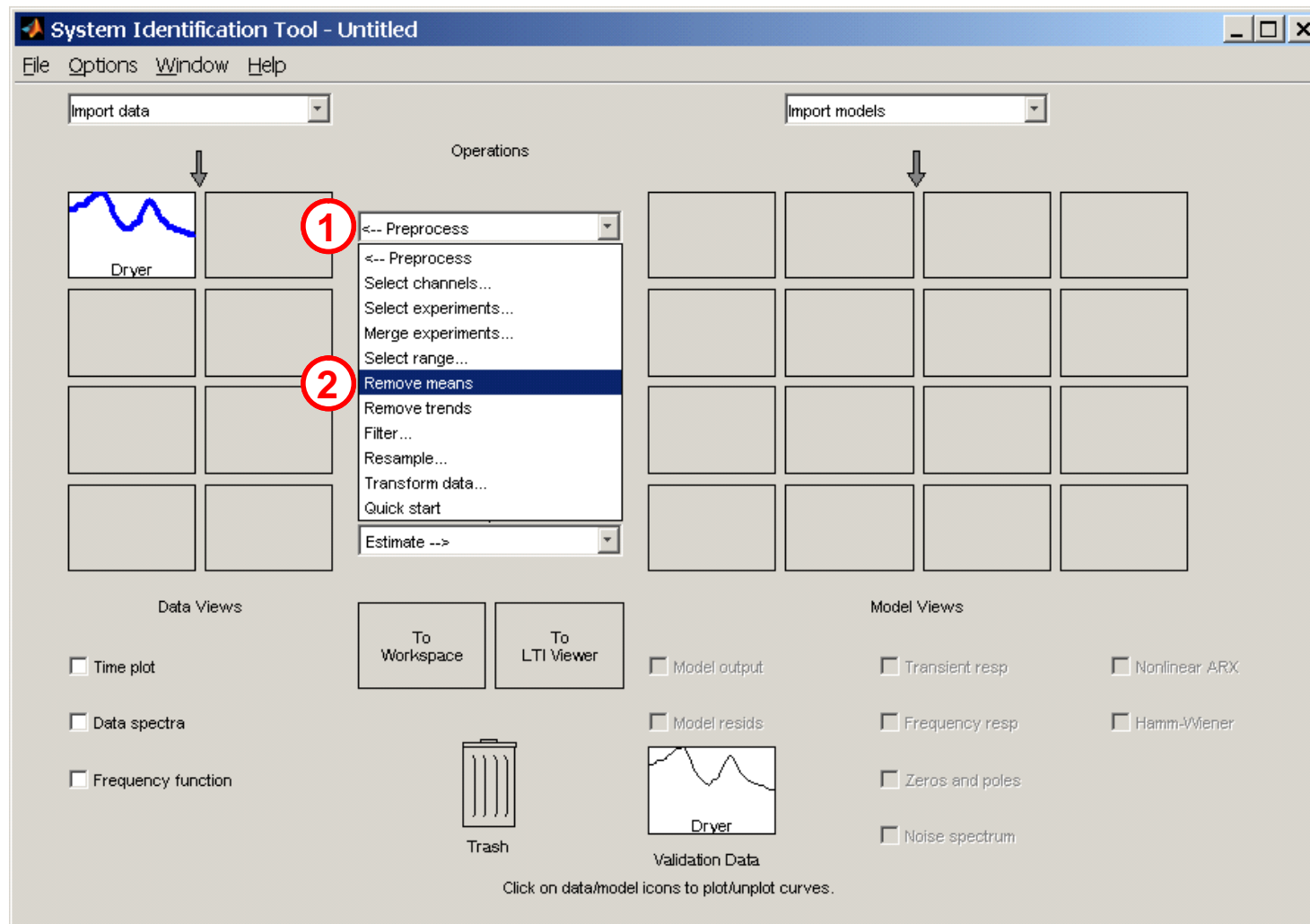
- Import data:** A dropdown menu with 'Import data' selected. Below it, a plot of a blue signal labeled 'Dryer' is shown, marked with a red circle '5'.
- Operations:** A central area with a dropdown menu set to '<-- Preprocess'. Below it, a plot of the same blue signal labeled 'Dryer' is shown, marked with a red circle '6'. Below this is a dropdown menu set to 'Estimate -->'.
- Data Views:** A section on the bottom left with three checkboxes: 'Time plot', 'Data spectra', and 'Frequency function', all of which are currently unchecked.
- Model Views:** A section on the bottom right with six checkboxes: 'Model output', 'Model resids', 'Transient resp', 'Frequency resp', 'Zeros and poles', and 'Noise spectrum', all of which are currently unchecked.
- Validation Data:** A plot of a black signal labeled 'Dryer' is shown, marked with a red circle '7'.
- Buttons:** 'To Workspace' and 'To LTI Viewer' buttons are located in the center-bottom area. A 'Trash' icon is also present.
- Status Bar:** At the bottom, it reads 'Data set Dryer inserted. Double click on icon (right mouse) for text information.'

The corresponding data may be shown by clicking on the *Time plot* option:

- the input is the electric power (a Pseudo Random Binary Sequence)
- the output is the air temperature



3) Remove the mean value from the data: click on *Preprocess* operation and select *Remove means*; the *Dryerd* window will appear in the *Data Views* area; the corresponding data may be shown by clicking on the *Time plot* option



3) Remove the mean value from the data: click on *Preprocess* operation and select *Remove means*; the *Dryerd* window will appear in the *Data Views* area; the corresponding data may be shown by clicking on the *Time plot* option

The screenshot displays the 'System Identification Tool - Untitled' interface. The main workspace is divided into several sections:

- Operations:** A central area with a 'Preprocess' dropdown menu. A red circle with the number '3' highlights the 'Dryerd' data icon in the 'Data Views' section.
- Data Views:** Located at the bottom left, it contains a 'Time plot' checkbox which is checked and highlighted with a red circle and the number '4'. Other options include 'Data spectra' and 'Frequency function'.
- Model Views:** Located at the bottom right, it contains several unchecked checkboxes for model analysis options.
- Time Plot:** A separate window on the right titled 'Time Plot: power->temperature' shows two stacked plots. The top plot, 'Input and output signals', shows 'temperature' vs 'Time' with a blue input signal and a green output signal. The bottom plot shows 'power' vs 'Time' with a blue input signal and a green output signal.

At the bottom of the main window, there is a 'Trash' icon and a 'Validation Data' plot for the 'Dryer' model. A note at the bottom center reads: 'Click on data/model icons to plot/unplot curves.'

4) Make the data without mean as current working dataset, by clicking the `Dryerd` window in the *Data Views* area and dragging it to the *Working Data* box

The screenshot shows the 'System Identification Tool - Untitled' window. The interface is divided into several sections:

- Operations:** A central area with a dropdown menu set to '<-- Preprocess'. Below it is a 'Working Data' box containing a plot of a signal labeled 'Dryerd'. A red arrow points from the 'Dryerd' plot in the 'Data Views' section to the 'Working Data' box.
- Data Views:** Located at the bottom left, it contains three checkboxes: 'Time plot', 'Data spectra', and 'Frequency function'. A plot of a signal labeled 'Dryer' is visible.
- Model Views:** Located at the bottom right, it contains several checkboxes: 'Model output', 'Model resids', 'Transient resp', 'Frequency resp', 'Zeros and poles', 'Noise spectrum', 'Nonlinear ARX', and 'Hamm-Wiener'. A plot of a signal labeled 'Dryer' is visible.
- Other Elements:** 'Import data' and 'Import models' dropdowns at the top; 'To Workspace' and 'To LTI Viewer' buttons; a 'Trash' icon; and 'Validation Data' and 'Compiling ...' labels at the bottom.

5) Partition the whole dataset in two subsets, called estimation dataset (ES) and validation dataset (VS): at first, click on *Preprocess* and choose *Select range*; then, type 1 500 as Samples for the Dryerde dataset and click on *Insert*;

The screenshot shows the System Identification Tool interface. The main window is titled "System Identification Tool - Untitled" and has a menu bar with "File", "Options", "Window", and "Help". Below the menu bar are two dropdown menus: "Import data" and "Import models". The "Operations" section contains a grid of icons for various operations. A dropdown menu is open over the "Preprocess" icon, with "Select range..." highlighted. A red circle with the number "1" is around the "Preprocess" icon, and a red circle with the number "2" is around the "Select range..." option. The "Data Views" section has checkboxes for "Time plot", "Data spectra", and "Frequency function". The "Model Views" section has checkboxes for "Model output", "Model resids", "Transient resp", "Frequency resp", "Zeros and poles", "Noise spectrum", "Nonlinear ARX", and "Hamm-Wiener". There are also buttons for "To Workspace", "To LTI Viewer", "Trash", and "Validation Data". The "Validation Data" section shows a plot of "Dryer" and the text "Compiling ...".

The "Select Range: power->temperature" window is open on the right. It has a menu bar with "File", "Options", "Style", "Channel", and "Help". It contains two plots: "Input and output signals" (temperature vs Time) and "power" vs Time. The "Time span" is set to 0 79.92, and the "Samples" field is set to 11000. The "Data name" is "Dryerde". There are buttons for "Insert", "Revert", and "Close".

5) Partition the whole dataset in two subsets, called estimation dataset (ES) and validation dataset (VS): at first, click on *Preprocess* and choose *Select range*; then, type 1 500 as Samples for the Dryerde dataset and click on *Insert*;

The screenshot displays the System Identification Tool interface. The main window is titled "System Identification Tool - Untitled" and shows a workflow for data preprocessing. The "Operations" section includes a "Preprocess" dropdown menu, which is currently set to "Select range". The "Data Views" section has checkboxes for "Time plot", "Data spectra", and "Frequency function". The "Model Views" section has checkboxes for "Model output", "Model resids", "Transient resp", "Frequency resp", "Zeros and poles", "Noise spectrum", "Nonlinear ARX", and "Hamm-Wiener". The "Validation Data" section shows a plot of the "Dryer" model output. The "Select Range: power->temperature" dialog box is open, showing two plots: "Input and output signals" (temperature vs. time) and "power" vs. "Time". The "Samples" field is set to 1500, and the "Data name" is "Dryerde". The "Insert" button is highlighted.

5

3

4

Click on data/model icons to plot/unplot curves.

Mark time span using mouse (draw rectangle) or keyboard.

type 501 1000 as Samples for the Dryerdv dataset; finally, click on *Insert* and *Close*; the Dryerde and Dryerdv windows will appear in the *Data Views* area and the corresponding data may be shown by clicking on the *Time plot* option

The screenshot displays the System Identification Tool interface, divided into two main windows. The left window, titled "System Identification Tool - Untitled", contains a workflow area with "Import data" and "Import models" dropdowns. Below these are icons for data sets: Dryer (blue), Dryerd (green), Dryerde (red), and Dryerdv (cyan). A red circle with the number 8 highlights the Dryerdv icon. An arrow points from this icon to a "Working Data" box containing a green waveform. Below the workflow are "Data Views" options: Time plot, Data spectra, and Frequency function. The right window, titled "Select Range: power->temperature", shows two plots: "Input and output signals" (temperature vs. time) and "power" vs. "Time". A red circle with the number 6 highlights the "Samples" input field, which contains "501 1000". A red circle with the number 7 highlights the "Insert" button. The "Data name" field contains "Dryerdv". The "Time span" is set to "0 39.92". The bottom of the right window displays the message "New data sets may now be chosen."

type 501 1000 as Samples for the Dryerdv dataset; finally, click on *Insert* and *Close*; the Dryerde and Dryerdv windows will appear in the *Data Views* area and the corresponding data may be shown by clicking on the *Time plot* option

The screenshot displays the System Identification Tool interface, divided into two main windows: "System Identification Tool - Untitled" and "Time Plot: power->temperature".

System Identification Tool - Untitled:

- Import data:** A dropdown menu.
- Operations:** A central area with a flow diagram. It includes a "Preprocess" dropdown, a "Working Data" box containing a green waveform, and an "Estimate -->" dropdown.
- Data Views:** A grid of icons for data sets: Dryer (blue), Dryerd (green), Dryerde (red), and Dryerdv (cyan). A red circle with the number "9" highlights the "Time plot" checkbox, which is checked. Other options include "Data spectra" and "Frequency function".
- Model Views:** A grid of checkboxes for model types: "Model output", "Transient resp", "Nonlinear ARX", "Model resids", "Frequency resp", "Hamm-Wiener", "Zeros and poles", and "Noise spectrum".
- Validation Data:** A box labeled "Dryer" with a waveform icon.
- Buttons:** "To Workspace" and "To LTI Viewer".
- Trash:** A trash can icon.
- Footer:** "Click on data/model icons to plot/unplot curves."

Time Plot: power->temperature:

- Input and output signals:** A plot showing "temperature" vs "Time". The y-axis ranges from -2 to 8. The x-axis ranges from 0 to 60. It displays three signals: a blue signal (power) oscillating between 4 and 6, a red signal (temperature) oscillating between -1 and 1, and a cyan signal (temperature) oscillating between -1 and 1.
- power:** A plot showing "power" vs "Time". The y-axis ranges from -2 to 8. The x-axis ranges from 0 to 60. It displays three signals: a blue signal (power) oscillating between 4 and 6, a red signal (power) oscillating between -1 and 1, and a cyan signal (power) oscillating between -1 and 1.

6) Set ES as the current working dataset and VS as the current validation dataset, by clicking the Dryerde and Dryerdv windows in the *Data Views* area and dragging them to the *Working Data* and *Validation Data* boxes, respectively

The screenshot displays the 'System Identification Tool - Untitled' window. The interface is divided into several sections:

- Operations:** Contains a 'Preprocess' dropdown menu and a 'Working Data' box.
- Data Views:** Located on the left, it shows four data plots: 'Dryer' (blue), 'Dryerd' (green), 'Dryerde' (red), and 'Dryerdv' (cyan). Below these are checkboxes for 'Time plot', 'Data spectra', and 'Frequency function'.
- Model Views:** Located on the right, it shows a grid of empty model view boxes and checkboxes for 'Model output', 'Model residuals', 'Transient resp', 'Frequency resp', 'Zeros and poles', 'Noise spectrum', 'Nonlinear ARX', and 'Hamm-Wiener'.
- Validation Data:** A box at the bottom right containing a plot of 'Dryerdv' data.
- Buttons:** 'To Workspace' and 'To LTI Viewer' are located in the center.
- Other:** A 'Trash' icon is at the bottom center, and 'Estimate -->' is a dropdown menu at the bottom.

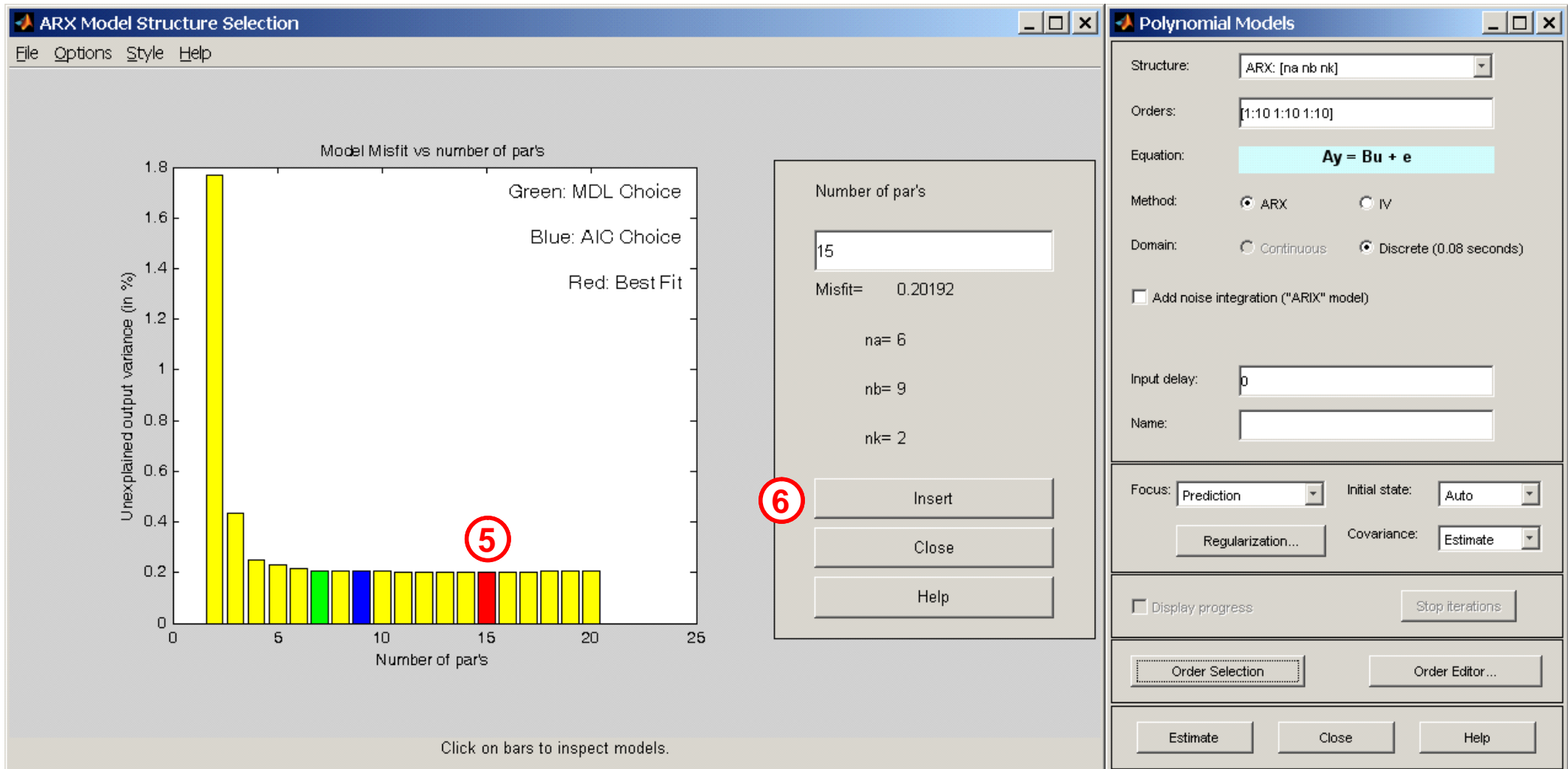
Red annotations highlight the workflow: a red arrow labeled '1' points from the 'Dryerde' plot in the Data Views area to the 'Working Data' box; a red arrow labeled '2' points from the 'Dryerdv' plot in the Data Views area to the 'Validation Data' box.

7) Perform the order selection for an ARX structure: click on *Estimate* and select *Polynomial Models*, then click on *Order Selection* and *Estimate*, in order to consider and compare different model selection criteria: Best Fit, AIC, MDL

The screenshot displays the System Identification Tool interface. The main workspace shows data plots for 'Dryer', 'Dryerd', 'Dryerde', and 'Dryerdv'. A context menu is open over the 'Estimate -->' button, with 'Polynomial Models...' selected. The 'Polynomial Models' dialog box is open on the right, showing the following settings:

- Structure: ARX: [na nb nk]
- Orders: [4 4 1]
- Equation: $Ay = Bu + e$
- Method: ARX IV
- Domain: Continuous Discrete (0.08 seconds)
- Add noise integration ("ARX" model)
- Input delay: 0
- Name: arx441
- Focus: Prediction
- Initial state: Auto
- Regularization... button
- Covariance: Estimate
- Display progress
- Stop iterations button
- Order Selection button (circled 3)
- Order Editor... button
- Estimate button (circled 4)
- Close button
- Help button

7) Perform the order selection for an ARX structure: click on *Estimate* and select *Polynomial Models*, then click on *Order Selection* and *Estimate*, in order to consider and compare different model selection criteria: Best Fit, AIC, MDL



7) Perform the order selection for an ARX structure: click on *Estimate* and select *Polynomial Models*, then click on *Order Selection* and *Estimate*, in order to consider and compare different model selection criteria: Best Fit, AIC, MDL

The screenshot shows the 'ARX Model Structure Selection' software interface. On the left, a bar chart titled 'Model Misfit vs number of par's' plots 'Unexplained output variance (in %)' against 'Number of par's'. The chart shows a sharp decrease in misfit as the number of parameters increases from 1 to 10, after which it levels off. A red circle with the number '7' highlights the bar at 10 parameters. A legend indicates: Green: MDL Choice, Blue: AIC Choice, Red: Best Fit. The bar at 10 parameters is green. To the right of the chart is a configuration panel for 'Polynomial Models' with the following settings:

- Structure: ARX: [na nb nk]
- Orders: [1:10 1:10 1:10]
- Equation: $Ay = Bu + e$
- Method: ARX IV
- Domain: Continuous Discrete (0.08 seconds)
- Add noise integration ("ARIX" model):
- Input delay: 0
- Name: (empty)
- Focus: Prediction Initial state: Auto
- Regularization... Covariance: Estimate
- Display progress: Stop iterations: (button)
- Order Selection (button) Order Editor... (button)
- Estimate (button) Close (button) Help (button)

Below the chart, a text prompt reads: 'Press Insert to estimate model, or click on other bar.' A red circle with the number '8' highlights the 'Insert' button in the configuration panel.

7) Perform the order selection for an ARX structure: click on *Estimate* and select *Polynomial Models*, then click on *Order Selection* and *Estimate*, in order to consider and compare different model selection criteria: Best Fit, AIC, MDL

The screenshot displays the ARX Model Structure Selection software interface. The main window is titled "ARX Model Structure Selection" and contains a bar chart titled "Model Misfit vs number of par's". The y-axis is "Unexplained output variance (in %)" ranging from 0 to 1.8. The x-axis is "Number of par's" ranging from 0 to 25. The chart shows a sharp decrease in misfit as the number of parameters increases, with a red circle highlighting the bar at 9 parameters. A legend indicates: Green: MDL Choice, Blue: AIC Choice, Red: Best Fit. The bar at 9 parameters is green. To the right of the chart is a panel for "Number of par's" with a text box containing "7", "Misfit= 0.20694", and parameters "na= 3", "nb= 4", "nk= 2". Below this panel are buttons for "Insert", "Close", and "Help", with a red circle containing the number "10" next to the "Insert" button. The bottom of the chart area says "Press Insert to estimate model, or click on other bar."

The right-hand window is titled "Polynomial Models" and shows the following configuration:

- Structure: ARX: [na nb nk]
- Orders: [1:10 1:10 1:10]
- Equation: $Ay = Bu + e$
- Method: ARX IV
- Domain: Continuous Discrete (0.08 seconds)
- Add noise integration ("ARIX" model)
- Input delay: 0
- Name: (empty)
- Focus: Prediction Initial state: Auto
- Regularization... Covariance: Estimate
- Display progress Stop iterations
- Order Selection Order Editor...
- Estimate Close Help

To compare the identified models on the VS dataset considering:

- the Best Fit index (to be maximized), click on the *Model output* option
- the residual analysis, click on the *Model resids* option

The screenshot displays the 'System Identification Tool - Untitled' interface. The main workspace is divided into several sections:

- Operations:** A central area with a 'Preprocess' dropdown menu and a 'Working Data' plot showing a signal labeled 'Dryerde'.
- Data Views:** A grid of plots for 'Dryer', 'Dryerd', 'Dryerde', and 'Dryerdv'. Below this are checkboxes for 'Time plot', 'Data spectra', and 'Frequency function'.
- Model Views:** A grid of plots for 'arx692', 'arx542', and 'arx342'. Below this are checkboxes for 'Transient resp', 'Frequency resp', 'Zeros and poles', 'Noise spectrum', 'Nonlinear ARX', and 'Hamm-Wiener'.
- Validation Data:** A plot for 'Dryerdv' and a 'Trash' icon.
- Buttons:** 'To Workspace' and 'To LTI Viewer' buttons are present.
- Model Output Panel:** A separate window titled 'Model Output: temperature' shows a plot of 'Measured and simulated model output' over time (40 to 80). The plot displays measured data (black dots) and simulated data (red line). A 'Best Fits' table is shown on the right:

Best Fits	
arx692:	89.78
arx342:	89.64
arx542:	89.61

A red circle with the number '11' is overlaid on the 'Model output' checkbox in the Model Views section.

To compare the identified models on the VS dataset considering:

- the Best Fit index (to be maximized), click on the *Model output* option
- the residual analysis, click on the *Model resids* option

The screenshot displays the 'System Identification Tool - Untitled' window. The main workspace is divided into several sections:

- Operations:** A central workflow area with 'Import data' and 'Import models' dropdowns. It shows a sequence of data plots (Dryer, Dryerd, Dryerde, Dryerdv) leading to 'Working Data' and then to 'Estimate -->'.
- Model Views:** A grid of model plots including 'arx692', 'arx542', and 'arx342'. Below this grid are checkboxes for 'Model output', 'Model resids' (highlighted with a red circle containing the number 12), 'Transient resp', 'Frequency resp', 'Zeros and poles', 'Noise spectrum', 'Nonlinear ARX', and 'Hamm-Wiener'.
- Data Views:** Checkboxes for 'Time plot', 'Data spectra', and 'Frequency function'.
- Buttons:** 'To Workspace', 'To LTI Viewer', 'Trash', and 'Validation Data' (containing a 'Dryerdv' plot).

On the right side, a separate window titled 'Residual Analysis: power->temperature' displays two plots:

- Autocorrelation of residuals for output temperature:** A plot showing the autocorrelation of residuals over time, with a y-axis ranging from -0.2 to 0.2 and an x-axis from -20 to 20. Dashed red lines indicate a confidence interval.
- Cross corr for input power and output temperature resids:** A plot showing the cross-correlation between input power and output temperature residuals, with a y-axis ranging from -0.2 to 0.2 and an x-axis from -20 to 20. Dashed blue lines indicate a confidence interval.

At the bottom of the main window, a note reads: 'Click on data/model icons to plot/unplot curves.'

8) Identify several ARX (n_a, n_b, n_k) models with $n_a=n_b=1, \dots$ and $n_k=1, \dots$: choose as *Structure* the ARX model class (click on the *Order Editor* or specify in *Orders* n_a, n_b, n_k), click on *Estimate* in the *Polynomial Model* window

The screenshot shows the System Identification Tool interface. The main window displays data plots and model selection options. The 'Polynomial Models' window is open, showing the 'Structure' set to 'ARX: [na nb nk]' (1), 'Orders' set to '2 2 3', and 'Equation' set to $Ay = Bu + e$. The 'Method' is set to 'ARX' and 'Domain' is 'Discrete (0.08 seconds)'. The 'Order Editor' window is also open, showing the 'Common poles' set to 'na=2' (3), 'From power' set to 'nf=0, nb=2, nk=3' (4), and 'Delay' set to 'nk=3' (5). The 'Estimate' button is highlighted in the 'Polynomial Models' window (6). The 'Order Editor' window also has 'Close' and 'Help' buttons. The main window shows a 'Working Data' plot and an 'Estimate -->' button. The 'Polynomial Models' window also has 'Regularization...', 'Covariance: Estimate', 'Display progress', 'Stop iterations', 'Order Selection', and 'Order Editor...' buttons. The 'Order Editor' window has 'Close' and 'Help' buttons.

8) Identify ARMAX (n_a, n_b, n_c, n_k) models with $n_a=n_b=n_c=1, \dots$ and $n_k=1, \dots$: choose as *Structure* the ARMAX model class (click on the *Order Editor* or specify in *Orders* n_a, n_b, n_c, n_k), click on *Estimate* in the *Polynomial Model* window

The screenshot shows the System Identification Tool interface. The main window displays data plots for 'Dryer', 'Dryerd', 'Dryerde', and 'Dryerdv'. The 'Operations' section shows a 'Preprocess' step and a 'Working Data' plot. The 'Polynomial Models' window is open, showing the 'Structure' set to 'ARMAX: [na nb nc nk]' (1), 'Orders' as '2 2 2 3', and the equation 'Ay = Bu + Ce'. The 'Method' is 'Prediction error method' and the 'Domain' is 'Discrete (0.08 seconds)'. The 'Order Editor' window is also open, showing the equation 'Ay = Bu + Ce' and the following parameters: 'Common poles: na=2' (3), 'From power: nf=0, nb=2' (4), 'nk=3' (6), and 'Noise input: nd=0, nc=2' (5). The 'Estimate' button (7) is highlighted in the Polynomial Models window.

8) Identify several OE (n_b, n_f, n_k) models with $n_b=n_f=1, \dots$ and $n_k=1, \dots$: choose as *Structure* the OE model class (click on the *Order Editor* or specify in *Orders* n_b, n_f, n_k), click on *Estimate* in the *Polynomial Model* window

The screenshot displays the System Identification Tool interface. The main window shows a workflow from data import to model estimation. The **Polynomial Models** window on the right is configured with the following settings:

- Structure:** OE: [nb nf nk] (circled 1)
- Orders:** 1 1 2
- Equation:** $y = [B/F]u + e$
- Method:** Prediction error method
- Domain:** Discrete (0.08 seconds)
- Name:** oe112

The **Order Editor** window is open, showing the model equation $y = [B/F]u + e$ and the following parameters:

- Common poles:** na=0
- Poles:** (empty)
- Zeros+1:** nb=1 (circled 4)
- Delay:** nk=2 (circled 5)
- From power:** nf=1 (circled 3)
- Noise input:** nd=0, nc=0

Red circles with numbers 1 through 7 highlight key elements: 1 (Structure dropdown), 2 (Order Editor button), 3 (nf=1), 4 (nb=1), 5 (nk=2), 6 (Estimate button), and 7 (oe112 model thumbnail).

9) Compare the identified models on the VS dataset considering:

- the Best Fit index (to be maximized), by clicking on the *Model output* option
- the residual analysis, by clicking on the *Model resid*s option

The screenshot shows the 'System Identification Tool - Untitled' interface. The main workspace is divided into several sections:

- Operations:** A central area with a 'Preprocess' dropdown menu and a 'Working Data' plot showing a red signal.
- Data Views:** A grid of data plots for 'Dryer', 'Dryerd', 'Dryerde', and 'Dryerdv'. Below this are checkboxes for 'Time plot', 'Data spectra', and 'Frequency function'.
- Model Views:** A grid of model plots for 'arx692', 'arx542', 'arx342', 'arx223', 'amx2223', and 'oe112'. Below this are checkboxes for 'Model output' (checked and circled in red), 'Model resid's', 'Transient resp', 'Frequency resp', 'Zeros and poles', 'Noise spectrum', 'Nonlinear ARX', and 'Hamm-Wiener'.
- Buttons:** 'To Workspace', 'To LTI Viewer', and a 'Trash' icon.
- Validation Data:** A plot for 'Dryerdv' with the text 'The character is not a valid hotkey' below it.

On the right, a window titled 'Model Output: temperature' displays a plot of 'Measured and simulated model output' over time (40 to 80). The plot shows multiple overlapping signals in different colors. To the right of the plot is a 'Best Fits' table:

Model	Best Fit Index
arx692	89.78
arx342	89.64
arx542	89.61
amx2223	89.26
arx223	89.02
oe112	61.01

9) Compare the identified models on the VS dataset considering:

- the Best Fit index (to be maximized), by clicking on the *Model output* option
- the residual analysis, by clicking on the *Model resids* option

The screenshot displays the System Identification Tool interface, divided into two main windows: "System Identification Tool - Untitled" and "Residual Analysis: power->temperature".

System Identification Tool - Untitled:

- Operations:** A workflow diagram showing data flow from "Import data" to "Preprocess" (with a dropdown menu) to "Working Data" (containing a plot of "Dryerde") and finally to "Estimate -->".
- Import data:** A dropdown menu.
- Import models:** A dropdown menu.
- Data Views:** A grid of data plots for "Dryer", "Dryerd", "Dryerde", and "Dryerdv".
- Model Views:** A grid of model plots for "arx692", "arx542", "arx342", "arx223", "amx2223", and "oe112".
- Buttons:** "To Workspace", "To LTI Viewer", "Trash", and "Validation Data" (containing a plot of "Dryerdv").
- Checkboxes:** "Time plot", "Data spectra", "Frequency function", "Model output", "Model resids" (checked and circled in red with a '2'), "Transient resp", "Frequency resp", "Zeros and poles", "Noise spectrum", "Nonlinear ARX", and "Hamm-Wiener".
- Instructions:** "Click on data/model icons to plot/unplot curves."

Residual Analysis: power->temperature:

- Autocorrelation of residuals for output temperature:** A plot showing the autocorrelation of residuals for output temperature, with a y-axis from -0.5 to 1 and an x-axis from -20 to 20. The plot shows a sharp peak at 0 and smaller oscillations.
- Cross corr for input power and output temperature resids:** A plot showing the cross-correlation of residuals for input power and output temperature, with a y-axis from -1 to 0.5 and an x-axis from -20 to 20. The plot shows a peak at 0 and smaller oscillations.

10) Select and export the “best trade-off” model: click the corresponding window in the *Model Views* area and drag it to the *To Workspace* box

The screenshot shows the 'System Identification Tool - Untitled' interface. The 'Model Views' area on the right contains a grid of model windows. A red box highlights the 'oe112' model window, and a red arrow points from it to the 'To Workspace' button in the 'Data Views' section. The 'Working Data' section shows a 'Dryerde' plot. The 'Operations' section has a '<-- Preprocess' dropdown. The 'Estimate -->' dropdown is also visible. The 'Data Views' section includes checkboxes for 'Time plot', 'Data spectra', and 'Frequency function'. The 'Model Views' section includes checkboxes for 'Model output', 'Model resids', 'Transient resp', 'Frequency resp', 'Zeros and poles', 'Noise spectrum', 'Nonlinear ARX', and 'Hamm-Wiener'. A 'Trash' icon and a 'Validation Data' plot are also present. A status bar at the bottom indicates 'Model oe112 inserted. Double click on icon for text information.'