SYSTEM IDENTIFICATION MATLAB TOOLBOX

Michele TARAGNA

Dipartimento di Elettronica e Telecomunicazioni
Politecnico di Torino
michele.taragna@polito.it

Master Course in Mechatronic Engineering
Master Course in Computer Engineering
01RKYQW / 01RKYOV “Estimation, Filtering and System Identification”
Academic Year 2019/2020
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 **Dryer_d** window will appear in the **Data Views**
  4) Make the data without mean as current working dataset, by clicking the **Dryer_d** 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 **Dryer_d** dataset and click on **Insert**; type **501 1000** as Samples for the **Dryer_dv** dataset and click on **Insert** and **Close**): the **Dryer_d** and **Dryer_dv** 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:

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

\[
\text{AIC} = n \frac{2}{N} + \ln(MSE)
\]  
(index to be minimized)

\[
\text{MDL} = n \frac{\ln(N)}{N} + \ln(MSE)
\]  
(index to be minimized)

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

\( n = \text{ARX model complexity (in prediction mode)} = \dim(\theta) = na + nb \)
8) Identify several models of different orders and delays using the following structures:

- ARX (na, nb, nk), using na=nb=1,...,4 and nk=1,...,3
  (and also the optimal values of na, nb, nk obtained from step 7)
- ARMAX (na, nb, nc, nk), using na=nb=nc=1,...,4 and nk=1,...,3
- OE (nb, nf, nk), using nb=nf=1,...,4 and nk=1,...,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.
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 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.
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.
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;
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;
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.
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.
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: 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.
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.
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
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
8) Identify several ARX \((na, nb, nk)\) models with \(na=nb=1,\ldots\) and \(nk=1,\ldots\): choose as Structure the ARX model class (click on the Order Editor or specify in Orders \(na, nb, nk\)), click on Estimate in the Polynomial Model window.
8) Identify ARMAX \((na, nb, nc, nk)\) models with \(na=nb=nc=1,\ldots\) and \(nk=1,\ldots\): choose as *Structure* the ARMAX model class (click on the *Order Editor* or specify in *Orders* \(na, nb, nc, nk\)), click on *Estimate* in the *Polynomial Model* window.
8) Identify several OE \((nb, nf, nk)\) models with \(nb= nf = 1, \ldots\) and \(nk = 1, \ldots\):
choose as Structure the OE model class (click on the Order Editor or specify in Orders \(nb, nf, nk\)), click on Estimate in the Polynomial Model window.
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
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
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