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The Means of Identifying Dynamic Objects Using Matlab

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ABSTRACT: The article considers the issues of organization and application of the implemented tools (modules) of the MATLAB package for solving identification problems by means of an integral method. It is shown that in order to solve identification problems, the information technology means should include a number of functions that allow selecting model structures, provide parametric and nonparametric identification, recursive estimation of parameters, evaluation of identification quality, representation and mutual transformation of different types of models.

KEYWORDS: MATLAB package, Dynamic objects, System Identification Toolbox, identification, integral method.

I. INTRODUCTION

This software package contains an integrated package System Identification Toolbox, which is an interactive environment for building models of complex systems, taking into account noisy data. The System Identification package contains tools for creating mathematical models of dynamic systems based on observable input / output data. The package is equipped with a flexible graphical interface, which helps organize data and create models. Identification methods included in the package are applicable for a wide range of tasks (design of control systems, signal processing, time series analysis, vibration tasks).

Consider in this aspect the issues of organization and application of the implemented tools (modules) of the MATLAB package [1, 2] for solving identification problems, in particular, by means of the integral method under consideration.

II. THE MAIN CHARACTERISTICS OF THE PACKAGE, NECESSARY FOR THE IMPLEMENTATION OF THE INTEGRAL METHOD:

- Simple and flexible interface;
- Preliminary data processing, including pre-filtering, deletion of trends and offsets;
- Selection of a range of data for analysis;
- Autoregressive methods;
- Analysis of the response in the time and frequency domain;



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- Display of zeroes and poles of the transfer function of the system;
- Analysis of residuals when testing the model;
- User-friendly graphical interface, which simplifies the preliminary processing of data, as well as the dialog process of model identification.

With a certain modification, you can apply three ways to represent mathematical models in a package: the frequency format, the polynomial format, and the representation of the mathematical model in the state space.

III. METHODOLOGY

The System Identification Toolbox contains a number of tools for automatically selecting the structure of a mathematical model. In particular, a set of functions automatically selects the orders of the polynomials A and B and the retardation values for the ARX model with one input. The choice is made from the set given by the operator. To implement the algorithm of automatic selection of the structure of the ARX-model, first of all it is necessary to generate a whole set of structures using the function *struc*, which will be analyzed

$$mn = struc (na, nb, nk)$$

here *na*, *nb* and *nk* are vectors containing the set of possible values of the orders of polynomials A, B and delay, respectively. The result of this function is the matrix *mn*, which contains all possible combinations of these orders and delays.

The *arxstruc* function calculates the loss function for the analyzed ARX family

$$v = arxstruc (z, zv, mn)$$

The matrix *mn* contains a set of all analyzed structures and is obtained using the function *struc*. *z* and *zv* are objects of type *iddata* containing input and output data, while *zv* serves to verify the correctness of the model and can coincide with *z*. The result of the *arxstruc* function is the matrix *v*, the first line of which contains the calculated values of the loss function for each of the variants considered, and the remaining lines coincide with *mn*, the last column of the matrix *v* contains the number of dimensions in *z*.

Similarly, we can use the *ivstruc* function:

$$v = ivstruc (z, zv, mn)$$

The result of this function is the matrix *v*, the first line of which contains the output error, computed using the instrumental variables method for each of the options considered, the remaining lines are the same as *mn*. The last row of the matrix *v* contains the logarithms of the conditioning numbers for the matrices of instrumental variables, and the last column of the matrix *v* contains the number of measurements in the initial data *z*.

The best structure is selected using the *selstruc* function



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$nn = selstruc (v, C)$

Here v is the matrix obtained with the function *arxstruc* or *ivstruc* and containing information about the family of compared structures, the variable C allows you to choose comparison criteria. It is possible to automatically select a structure based on the *Akaike* information criterion, as well as automatic selection of the structure by the criterion of the maximally short description of *Riesen*.

If a variable C is assigned a numerical value, the best structure is chosen by minimizing the expression where d is the number of parameters to be evaluated, v is the loss function of the corresponding model, and n is the number of measurements in the original data in $\left(1 + \frac{C \cdot d}{n}\right)v$

where d is the number of parameters to be evaluated, v is the loss function of the corresponding model, and n is the number of measurements in the original data.

The vector nn chooses the structure of the model best by the accepted criterion and then can be used for parametric identification

A distinctive feature of the System Identification Toolbox is the developed means of nonparametric identification of mathematical models. Let us consider how it is possible to organize process of non-parametric identification, allowing receiving model of type *idfrd*.

In order to calculate the prediction function and noise spectrum of a linear system of the form (3.1), there is the functions *spa*

$$g = spa (data)$$

$$g = spa (data, M, w)$$

The identification result is placed in the g variable of type *idfrd*. The values of the frequency transfer function and noise spectrum will be calculated for the frequency values specified by the vector w . By default, $w = [1: 128] / 128 * pi / Ts$, where Ts is the sampling period

The calculation algorithm, implemented in this function, is based on the Hamming frequency window. The parameter M specifies the length of the window and by default $M = \min (30, \text{length} (data) / 10)$.

Another approach to solving the problem of nonparametric identification is realized in the function *etfe*, where an empirical evaluation of the transfer function is calculated

$$g = etfe (data)$$



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Note that the function *etfe* allows you to work with systems that have only one input, or with time series. For time series, the result of this function is the periodogram (the normalized square of the Fourier transform) of the original data. To the same group of functions we can include the function *covf*, which allows us to calculate the estimate of the covariance function for the matrix of initial data. Calling to the function *covf*:

$$R = \text{covf}(\text{data}, M)$$

Here, *M* is an integer equal to the maximum delay minus one, for which the covariance function is also estimated.

Evaluation of identification results. Having identified for models of different structures, the user has the problem of choosing in some sense the best model from the available set. The problem of choice is one of the main problems arising in the identification of dynamic systems. For this purpose, we can use a number of functions that implement algorithms for estimating and comparing different models.

The *pe* function calculates the prediction error *E*

$$E = \text{pe}(m, \text{data})$$

Here, *data* is the initial data (object of *iddata* type), obtained as a result of measuring output and input variables, *m* is the mathematical model obtained as a result of identification (object of type *idmodel*).

The *predict* function calculates the prediction of the output value by *k* steps ahead (*k*-step forecast)

$$yp = \text{predict}(m, \text{data}, k)$$

Here, *data* is the initial data (object of *iddata* type) obtained as a result of measuring output and input variables, *m* is the mathematical model obtained as a result of identification (object of type *idmodel*), *k* is the depth of the forecast (by default, *k* = 1). The values of the output variables for are used to predict the output at a time. The vector *yp* contains the predicted value of the output signal.

The *compare* function allows to compare the predicted value of the output signal with the measured value of *y*, which is specified in *data* (an object of the *iddata* type):

$$[yh, fit] = \text{compare}(\text{data}, m, k)$$

The parameter *k* is the depth of the forecast, by default *k* = *inf*, which corresponds to pure system modeling. The array *yh* contains the predicted values of the output signal. The value of *fit* is an estimation of the model's correspondence to the initial data and is calculated from formula

$$fit = 100 * (1 - \text{norm}(yh-y) / \text{norm}(y - \text{mean}(y)))$$



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With the command

compare (data, m, k)

a plot is constructed depending on the time of the measured value of the output y and the predicted value of the output y_h .

The *compare* function can also be used to compare several models with the original data:

[yh, fit] = compare (data, m1, ..., mN)

or

compare (data, m1, ..., mN)

To calculate the final error of the *Akaike* forecast and the information criterion of the *Akaike* of the evaluated model, the functions *fpe* and *aic* are used, respectively:

am = fpe (m)

am = aic (m)

where m is the mathematical model obtained as a result of identification (object of type *idmodel*).

IV. CONCLUSION

Thus, based on the effective use of the technological platform of the MATLAB system, the technological means that implement an integrated method for identifying dynamic objects with the adaptation of formats for representing mathematical representations and data, as well as functions for controlling the computing process have been created.

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