

## COMPUTER TECHNOLOGY FOR SIMULATION OF BEHAVIOR OF NONLINER NON-STATIONARY SYSTEMS

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**Abstract.** Paper presents the analysis which allows to prove that all the computer technologies available nowadays possess the limited area of application for simulation of nonlinear non-stationary systems. The description of space of parameters increment is considered in which nonlinear non-stationary systems simulation is performed. New computer technology developed is proposed. It makes possible to model nonlinear non-stationary systems.

**Keywords:** computer technology, nonlinear non-stationary system, space of parameters increment

### 1. Introduction

Development of computer technology (CT) for simulation of behavior of nonlinear non-stationary systems (NNS) on the computer requires a great number of problems to be solved. Firstly, convenience provided for designer's interaction with computer technology that is convenience of plotting the block diagram for a nonlinear non-stationary system as well as introduction of initial parameters and conditions for modeling; secondary, conversion of the graphic pattern of a nonlinear non-stationary system to the mathematical one; thirdly, the problem of direct simulation. The present paper is dedicated to the description of the computer technology used for NNS behavior simulation.

### 2. Analysis of the present technology for nonlinear non-stationary systems behavior simulation

One of the main computer technologies used for NNS behavior simulation are software packages (SP) for simulation. They are DISPAS, MASS, MATLAB, MathCAD, DCNET and others. We will analyze some of them in detail.

MathCAD allows to perform simulation at a given set of initial parameters repeating it for each new set. It certainly results in increasing the period of time for solving the behavior analysis problem and rather rarely allows to estimate parameters changes influences the stability property by virtue of impossibility to simulate systems behavior with all elements of numerical sets providing the possible area of changing initial parameters of the system.

MATLAB represents software package as well as a definite programming language SP includes: Symulink, Symbolik, Neural Net, Fussy Logic Toolbox, Statistics, Control System, Robust Control and others. They make it possible to conduct rather difficult mathematical experiments in simulating control systems [1].

Toolbox Robust Control has got means for analyzing some multiparameter control system. Along there appear ones with pattern errors; their dynamic is not completely known and their parameters can be changed in the course of simulation. The methods algorithms used in SP allow to perform complicated calculations taking into account the parameters change of a system in time. As for SP used for automatic control system simulation its important properties are as fallows: synthesis of regulators based on uniform and integrated

norms minimization, formation of the condition space model, models conversion based on singular numbers, decreasing the model order and spectral factorization [1]. Besides, it is known from [2], that Robust Control Toolbox is based on the Control System Toolbox's functions and has a set of algorithms for automatic control systems simulation. It also allows to establish relations between modern theory of control and laboratory scientific research work with the aid of a large number of functions which can be realized by modern methods of simulation and analysis intended of multiparameter robust regulators. It is also mentioned in [1], that Robust Control enables to estimate the multiparameter border of stability at different non-stationary.

It should be noted that a large number of toolboxes as well as simulation aided by a new and rather difficult programming language give no opportunity to use MATLAB by an ordinary engineer who works at an industrial enterprise and has no practical experience in programming and manipulation with complicated software for automatic control systems to be studied. Therefore there appears a necessity for other specialists qualified for a position of a programmer to be a go between for an engineer and SP. Another reason for MATLAB application complexity of NNS studies is that the software package has no common methodology for NNS investigation. However, it allows to solve the problem of systems class analysis which is considered only for the limited and exactly given number of nonlinear non-stationary objects.

The software Package for DCNET simulation has been developed in Ukraine [3]. The distinction between this computer technology and those of presents earlier is that DCNET is oriented to system research with the aid of mathematical pattern of discrete and continuous networks.

Such a peculiarity as graphic introduction of discrete – continuous(DS) model of an object in the form of DC – networks enables to find out changes in the object structure within simulation as well we step-by-step simulation mode available for structure and state

modification of continuous parts of the object, thus making DCNET distinct from other computer technologies.

Unfortunately there is no opportunity at present to use the majority of the software packages mentioned above with the exception of MATLAB, MathCAD and DCNET due to their orientation to out of date computers. And, so stated above all the SP have some limited area of application for nonlinear non-stationary systems simulation and they are not combined by common methodology. The disadvantage can by far be overcome by making a new space available for description of nonlinear non-stationary systems behavior, i.e. the space of parameters increment [4].

### **3. Description of space of parameters increment**

The present methods of analyzing automatic control systems mentioned above can solve the problem of studying nonlinear non-stationary systems for some set of values of a common array. Its structure determines the character of the transient state array. However, in design of a wide class of systems it is often advisable to solve the reverse problem of robust stability, i.e. to define a set of values of initial parameters of a system, with them the stability being kept unchanged. It should be noted that more often the relation between the initial system parameters being analyzed and the components values of the general array of a system is of the implicit nonlinear character. It gives no opportunity to estimate the initial parameters changed other than the values of array components of the system, the former influencing the property of stability and the parameter.

Thus, it is necessary to develop the new space for behavior description of nonlinear non-stationary systems in which it would be possible to evaluate the changed initial parameters of the wide class of systems influencing their properties.

It is shown in [4] that vector  $X(t)$ ,  $P(t)$  and  $Z(t)$  are in part continuous functions given on an initial of time  $[t_0, T]$ . Thus the descriptions of

system behavior in the spacious increments of parameters are given of the form:

$$m^* = \langle Y'_k(\bullet), X(\bullet), P(\bullet), Z(\bullet), P_0 \rangle \in \\ \in L_\infty([t_0, T]; R^{n \times p}) \times L_\infty([t_0, T]; R^n) \times \\ \times L_\infty([t_0, T]; R^p) \times L_\infty([t_0, T]; R^k) \times R^p, \quad (1)$$

where  $t$  is current time;  $t_0$  is starting time of system research;  $P_0$  is a finite dimensional vector of some primary parameters initial values of a system within  $(1 \times p)$ ;  $x(t)$  is a finite dimensional vector of influence values of  $(1 \times n)$ ;  $P(t)$  is a finite dimensional vector of primary parameters values of a system of  $(1 \times p)$ ;  $Z(t)$  is a finite dimensional vector of coordinates of  $(1 \times k)$  dimension;  $Z(t)$  - is a finite dimensional vector of coordinates of  $(1 \times k)$  dimension;  $Y'_k$  - is a derivative of represent  $Y_k$  (piece - continuous functions (Nemitsky operator) defined on the time interval  $t \in [t_0, T]; L_\infty([t_0, T]; \bullet)$  i.e. space of essentially limited vector - functions which are measurable.

If the function  $Y(X(t), P(t), t)$  is continuous and its partial continuous derivates are  $Y_a(X(t), P(t), t)$  and  $Y_p(X(t), P(t), t)$  so, in this case the description of system behavior is of the form:

$$m^{**} = \left\langle \frac{\partial Y(X(\bullet), P(\bullet))}{\partial P(\bullet)}, X(\bullet), P(\bullet), Z(\bullet), P_0 \right\rangle \in \\ \in C([t_0, T]; R^{n \times p}) \times C([t_0, T]; R^n) \times \\ \times C([t_0, T]; R^p) \times C([t_0, T]; R^k) \times R^p. \quad (2)$$

The description of nonlinear non-stationary systems in (1) and (2) enables to analyze their behavior not in the space of variable conditions of a system as in a classical case, but in another space termed in [4] the space of parameter increment. The term is due to the fact that the behavior of system in (1) and (2) are considered as for their increment of variable conditions caused by an increment of initial parameters of a system.

It has been emphasized in [4] that the description of the system in (1) and (2) is performed by the unit of sensitivity theory. The unit enables to proceed from nonlinear non-stationary differential equations which describe behavior of system in the space of variable conditions to linear non-stationary differential equations concerning the increments variables

of condition due to changing primary parameters of the system which facilitates considerably behavior simulation of a class of systems to be considered.

It is known from [5] that rather complete information about behavior of nonlinear systems without direct integration of differential equations is easy to be obtained due to phase trajectories. The latter could be easily platted by some simulation means. The description in (2) for the systems of the second order allows to plot trajectories similar to the phase ones as well as to estimate the changed primary nonlinear system parameters influencing the change in quality parameters of NNS. Note, that for continuous systems of the second order in case of describing their behavior as in (1), phase trajectories represent relations  $\frac{dY}{dt} = f(Y)$  and for the second order systems in case of their description as in (2), similar phase trajectories represent relations:

$$\frac{dy}{dp_i} = f_j(y), (j = \overline{1, P}).$$

The received analogues enable to study definite points on the plane similar to that of phase using the well developed methods of analysis of nonlinear systems in space of variable conditions. Besides, with the help of an analogue being considered it is possible to investigate behavior of systems close to the equilibrium position using the well developed methods of nonlinear system analysis as well as methodology proposed in [4, 5, 6].

As is known from [5], for making the block diagram of the system being analyzed it is necessary to get some a prior information both on nonlinear non-stationary controlled object and on the system to solve the corresponding classes of problems and to decompose the entire system into separate units. Thus, to gat mathematical models of units which make the block diagram is known it is advisable to choose the appropriate variable conditions taking into account that the choose is not considered to be a strictly determined procedure. Then a corresponding system of differential equations should be made regarding the variables.

To solve the problem of analysis as for the behavior of nonlinear non-stationary systems after getting the system description in the space of its parameters increment in the form of a system of linear non-stationary differential equations it is necessary to solve the new obtained set of equations. The analysis of the solution obtained enables to define the boundary of the systems stability area in the space of its parameters increment. The area boundaries being known, it makes if possible to define the areas of changing primary parameters of systems, the stability properties of the considered class of the system being preserved, i.e. to solve the reverse problem of robust stability.

The above stated enables to divide the simulation process into separate subtasks in the CT environment. The subtasks can be solved by NNS simulation. They are:

- to set a problem for NNS studding and making the initial block diagram of a system;
- to make a graphic block diagram of a system being investigated;
- to introduce initial parameters of components in the NNS graphic model;
- direct simulation of a system being investigated. Thus, simulation can be carried out by two approaches. First, the classical approach, i.e. to find the common transfer function of a system, to make a set of differential equations and to solve them by one of the well-known numerical Euler's and Runge – Kutta methods or by prognosis and correct: second, simulation in the space of parameters increment;
- to analyze the result of simulation, to determine NNS stability and is quality parameters as well as further investigation planned.

To combine five tasks to constitute a whole enables to propose the general structure of computer technology for NNS too be investigated by the computer (figure 1).

#### 4. Graphic interface of developed technology

Using new space of parameters increment [4] and taking into account some opportunities of

modern computer technologies allowed to develop new CT for simulation of NNS behavior.

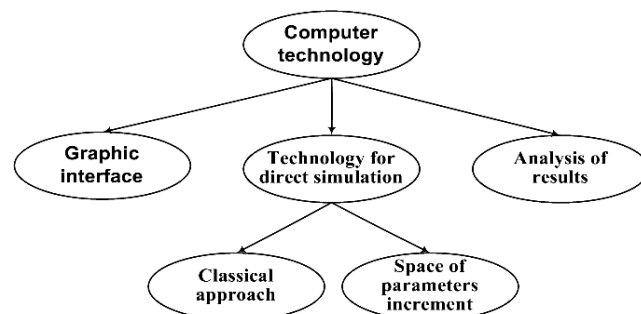


Figure 1. General structure of computer technology for NNS.

The very computer technology makes it possible to make the block diagram for a system more conveniently, to execute transformation from the graphic pattern to the mathematical one, to do experimental research within given entry data and to get results both in the graphic form and in the table while describing the systems being studied.

The proposed CT presents the original and convenient graphic interface which can solve the following problems:

- to make the NNS graphic block diagram;
- to introduce parameters of systems and object being studied taking into account non-stationeries;
- to introduce parameters and conditions of simulation;
- representation of simulation results.

The following interface structure (figure 2) is proposed for solving the problem stated above.

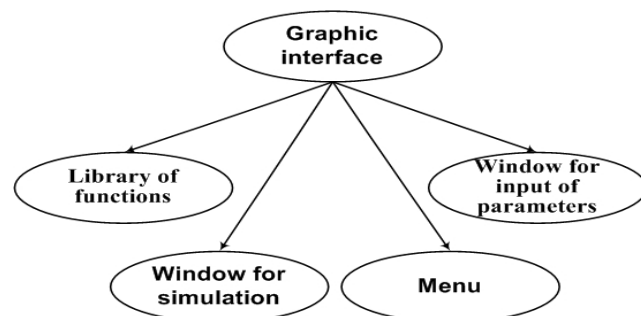


Figure 2. Structure of CT graphic interface for NNS behavior simulation.

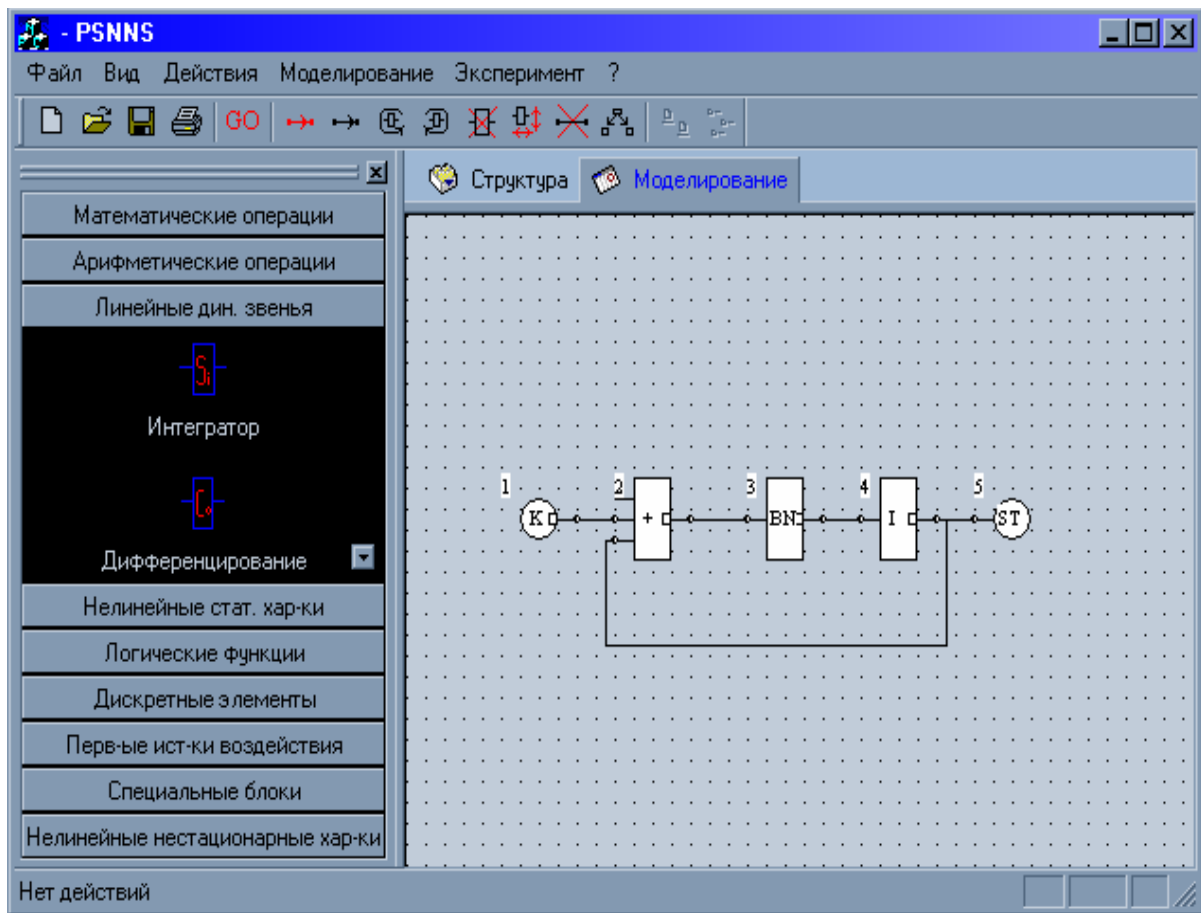


Figure 3. An example of the block diagram made by the CT graphic interface.

Figure 3 shows the main window of the graphic interface. It helps to make a graphic block diagram of the system being studied via library units and library functions. The CT is distinguished by simplicity of application and capability of solving a great number of problems.

Figure 3 shows an example of the block diagram made by the CT graphic interface. Each step by making the block diagram, location, combination and edition of components have been carried out with the help of the appropriate library of functions.

The NNS analysis shows that for stationary and non-stationary linear components to be entirely described up to 4 parameters are used. Therefore, CT allows to introduce initial data in the form of constant or allows of change for 4 parameters.

The introduction of the laws changing the component parameters is a common set of

laws. The latter help to describe the changing parameter of a system component. For example, under the influence of electromagnetic high-power noise the circuit parameters can be changed according to harmonic laws.

For the description of nonlinear non-stationary components it is necessary to enter a large number of parameters. Therefore, CT allows to enter up to 10 parameters for such components.

### 5. Algorithm of transition from the graphic pattern to the mathematical one

For computer technology it appeared to be rather difficult to develop an algorithm of an automatic transition from the block diagram graphic representation to the mathematical pattern.

The CT presents an approach to NNS simulation. It uses a consecutive function

analysis. The functions describe each component of the block diagram of the system, the reaction of each component to the input effect being defined. Therefore, NNS block diagram is divided into the sections which are studied at each simulation step separately.

The simulation performed by the approach requires to determine the graph of connecting components, to find the transfer function for each component separately with the help of the transfer functions library as well as to analyze the appropriate transfer functions at each step with the aid of the already found graph [7].

The next step of NNS simulation is the comparison of initial signals with the functions describing the next component to be simulated at each step. For this purpose a separate subroutine is made in CT. It involves the library of functions describing the components.

## 6. Operation of the developed computer technology

A software testing is done to check correctness of work. Figure 3 shows the structure of the nonlinear non-stationary system developed for the testing.

For checking the results obtained simulation was performed analytically. Figure 4 shows the results of comparer analytical calculations received by CT simulation.

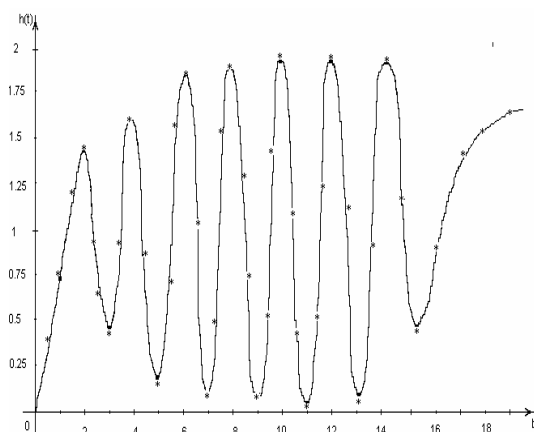


Figure 4. Results of comparer analytical calculations received by CT simulation (\* - analytical calculation).

## 7. Conclusions

1. The analysis of existing computer technologies which proves limitation of their use for modeling nonlinear non-stationary systems was considered.
2. For modeling behavior of nonlinear non-stationary systems it is offered to use space of an increment of parameters.
3. Subtasks which are solved with computer technology were described.
4. The graphic interface of computer technology was considered.
5. The example of modeling of systems with the help developed computer technology was shown.

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