Nonlinear control object identification problems: methods and approaches

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Abstract. In the study of nonlinear systems, the development of control descriptions in accordance with the model of the process depends on the tasks of solving the problems of identification of control objects. Control object modeling is limited to using the same methods for both linear and nonlinear types. Non-linear control is complicated due to the scope of application of object identification methods and the nature of their use algorithms. In the article, modern methodological approaches to the research of the identification system of nonlinear control objects are considered. The importance of building an interpolator based on the principle of obtaining its original description and transition to an image based on the acquired digital information about the object in the discretely determined system is explained. In the process of research, the authors pay attention to the possibility of creating a mathematical description in several variants of this method and distinguishing the optimal one. In this comparison, the linearized model of technological objects is based on maintaining the dominance feature.

1 Introduction

Modern production means a fully automated integrated system [1]. Today, in the field of automation and management of technological processes, a new era is taking place, with the use of improved technical and software tools in our country, as well as the adoption of foreign best practices.

The application of modern technologies in the field of production creates the need to train qualified personnel and increase their potential in this process. In this regard, sufficient practical works are being carried out in our country. In particular, to cultivate qualified mature personnel, for this purpose, to integrate technical education with production, to direct scientific research to a real object in a real process, to update the content of educational literature with modern technologies, tools, methods, modern theories and other basic It is possible to perform a number of tasks, such as ensuring the availability of subjects. In this sense, it is seen that the issue of providing educational literature in the educational process has its own topical aspects.

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The stage of improvement of the control system that is used in the same time processes is the digital control system. In general, a digital control system can be considered as a representation of the existence of a computerized system [2].

The identification of the control object is the process of determining the mathematical model that represents the behavior of the system to be controlled. However, there are several challenges that can make the identification process difficult. Some of the common problems include:

Nonlinearity: Many physical systems exhibit nonlinear behavior, which can make it challenging to accurately model and control them. Nonlinear systems are often characterized by complex, nonlinear relationships between the system's inputs and outputs.

Time-varying dynamics: Some systems may exhibit time-varying dynamics, which means that the system's behavior changes over time. This can make it difficult to develop a single model that accurately captures the system's behavior.

Limited data: In many cases, the amount of data available for identifying the control object may be limited. This can make it difficult to accurately estimate the model parameters [3].

Uncertainty: Many physical systems are subject to uncertainty, which can arise from a variety of sources such as measurement noise, parameter uncertainty, and external disturbances. This uncertainty can make it challenging to accurately model and control the system [4].

Coupling between variables: In some systems, the variables that need to be controlled may be coupled, which means that changes in one variable can affect the behavior of another. This coupling can make it difficult to develop a single model that accurately captures the system's behavior.

Overall, the identification of the control object can be a challenging task, and requires careful consideration of these and other factors to ensure that the resulting control system is effective and robust.

2 Materials and methods

The identification of nonlinear control objects is an important research area in control theory and has applications in a wide range of fields, including engineering, economics, and biology. One approach to this problem is to use the interpolation method, which involves fitting a model to a set of data points obtained from the system.

Numerous scientific works have investigated the use of the interpolation method for the identification of nonlinear control objects. These works typically involve the development of new algorithms or the refinement of existing ones to improve the accuracy and efficiency of the identification process.

Some of the key findings from these works include:

- The interpolation method can be an effective tool for the identification of nonlinear control objects, particularly when the data set is large and complex [5].
- The accuracy of the interpolation method can be improved through the use of advanced algorithms and techniques, such as neural networks and genetic algorithms [6, 7].
- The choice of interpolation function can have a significant impact on the accuracy and performance of the identification process. Different functions, such as cubic splines, B-splines, and radial basis functions, have been investigated in various studies [8, 9].
- The identification of nonlinear control objects using the interpolation method can be challenging, particularly when dealing with noisy or incomplete data. Techniques such as data smoothing and filtering may be necessary to improve the accuracy of the identification process [10, 11].

- The ease of identification of non-linear control objects using the interpolation method depends on several factors, including the complexity of the non-linear system and the quality of the data used for identification [10-12].

Overall, the identification of nonlinear control objects using the interpolation method is a promising research area with significant potential for practical applications. Ongoing research is likely to further improve the accuracy and efficiency of the interpolation-based identification process, leading to new and improved control strategies for a wide range of systems.

The interpolation method involves collecting input-output data from the non-linear system at different operating points and then fitting a mathematical model to the data. The model is then used to predict the system's output for any given input.

One of the main challenges in identifying non-linear systems is that the system's response is not always predictable or consistent, especially for input values that are far from the system's operating points. In such cases, the interpolation method may not be able to accurately capture the non-linear behavior of the system [10].

Another challenge is the curse of dimensionality, which refers to the fact that the number of data points required to accurately model a non-linear system increases exponentially with the number of input variables. This means that for systems with many input variables, it may be impractical or even impossible to collect enough data for accurate identification using the interpolation method.

Despite these challenges, the interpolation method can be a useful tool for identifying non-linear control objects, especially for systems with relatively simple dynamics and a limited number of input variables. However, for more complex systems, other identification methods such as neural networks or fuzzy logic may be more appropriate.

3 Results

One of the main problems of analog signal discretization is the choice of the discretization and quantization step size. Because, the smaller the analog signal discretization step is, that is, if the number of time axis divisions is increased, the information accuracy will increase, but it will have a negative effect on the transmission and transfer process due to the increase in the number of digital signals.

During the sampling period, the count values of the signal are different. It is possible to convert the numerical values of the signal into digital signals by the method of quantization according to the signal level. The main problem is signal recovery. This aspect is important to consider when identifying a nonlinear control object.

Below is a table of information for the control object (Table 1).

Table 1. Discrete output signals of the technological object in the control cycle.

t	1	2	3	4	5	6	7	8	9
u(t)	0.57	0.59	0.68	0.72	0.75	0.82	0.88	0.95	0.97

This discrete definition provides an opportunity to create an identification model using the following real variable models:

Exponential model. Appearance of the model:

$$U(t) = 0.4768 \cdot e^{0.0791 \cdot t} \tag{1}$$

The level of adequacy of this model is qualitatively high, i.e., the probability of origin of signal variance u(t) from model (1) is higher than 82% (0.823).

Linear model. Appearance of the model:

$$U(t) = 0.0552 \cdot t + 0.4497 \quad (2)$$

The level of adequacy of this model is qualitatively high, i.e., the probability of origin of signal variance u(t) from model (2) is higher than 88% (0.886). The results for both models are given in Figure 1.

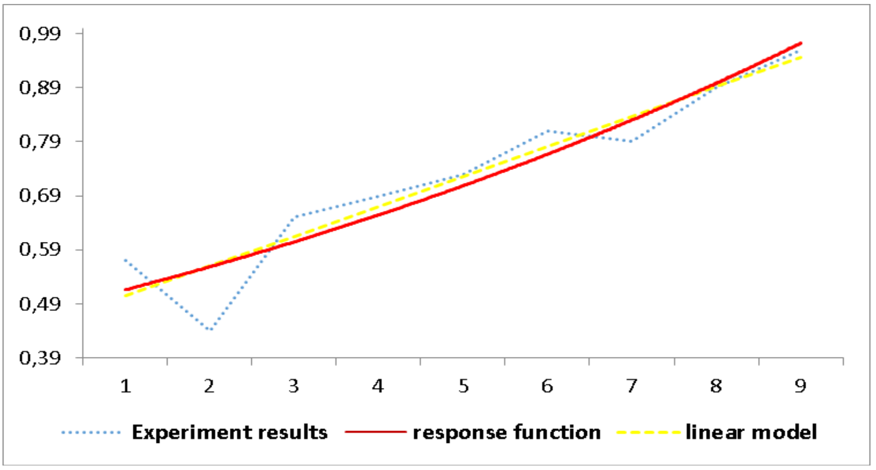

Fig. 1. Interpolation options for a discretely defined control object.

The results show that both models are usable, but we only have the option to use one. Therefore, there is no need to check other criteria of adequacy. Because, in this situation where the number of discretes is limited, the concept of approximation solves almost everything. According to it, for model 1 it is equal to 3.47%, for model 2 it is 4.81%.

Based on the obtained models, we determine the transfer function of the object that is most likely to be compatible (in our opinion, at the level of identification accuracy).

According to the identified models, the transfer function view has the following views, respectively:

$$W_1(s) = \frac{0.4768}{s-0.0791}, \quad W_2(s) = \frac{0.0552+0.4497 \cdot s^2}{s^2} \quad (3)$$

In both cases, fractional rational functions arise.

4 Discussion

Values for the transfer function built (determined) according to the exponential model have a maximum deviation interval of 3.51, and the result of the linearized model is 2.97. In this respect, the level of the linearized model is high, but this does not mean the rate of stabilization. Therefore, it is necessary to pay attention to the relative degree of their deviation from the real process (Table 2).

Table 2. The degree of deviation of the management based on the identified models from the real process.

Tactics	1	2	3	4	5	6	7	8	9	10	11
$W_2(s)$	-1.21	-0.12	-0.77	-0.19	-0.26	-0.15	0.13	-0.11	0.10	-0.08	0.06
$W_1(s)$	-1.92	0.03	-1.44	0.00	-0.64	0.00	-0.59	0.00	-0.19	0.00	0.00

If the state of stabilization of the control system based on the linearized model is observed in the 10th control cycle, according to the exponential model, this indicator occurs after the 11th cycle. In general, the results of these transfer functions are presented in Figure 2. According to it, the stabilization feature is clearly observed for both models from the 14th stroke of the control. However, the above facts show that the results of linearization are slightly superior in terms of accuracy.

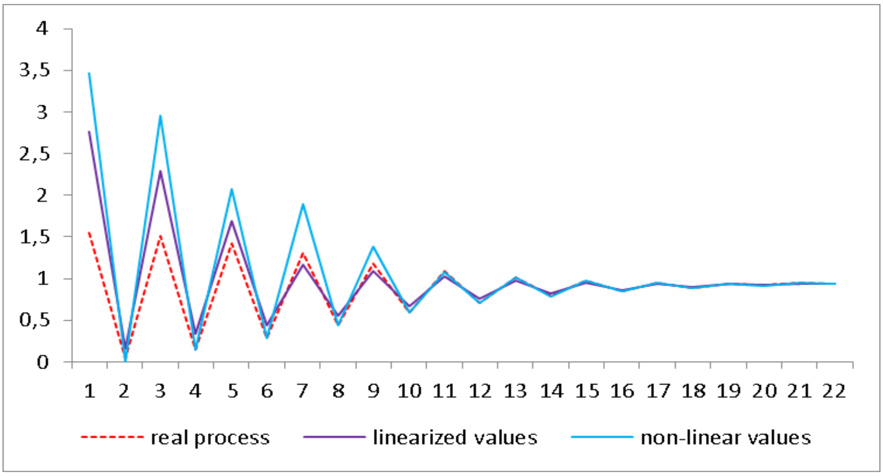

Fig. 2. Stabilization interval based on control models.

The research results can be seen as another source confirming the dominance of polynomial approaches in the identification of non-linear control objects. Also, unlike complex systems with a high social, uncertain, stochastic character, it is very important that the empirical models describing the technological processes are adequate in terms of the level of approximate significance [12].

5 Conclusion

Controlling a non-linear object based on an identified model can be a challenging task, as non-linear systems often exhibit complex and unpredictable behaviors. However, the interpolation method can be a useful tool for controlling non-linear systems based on a model.

The interpolation method involves constructing a model of the non-linear system based on a set of measured input-output data points. This model can then be used to predict the system's behavior for any given set of inputs, allowing for control actions to be taken to achieve a desired output.

To control the non-linear system based on the interpolated model, the following steps can be taken:

Collect input-output data points: To construct the interpolated model, a set of input-output data points needs to be collected from the non-linear system. This data can be collected through experimentation or simulation.

Construct the model: Once the input-output data points are collected, an interpolated model can be constructed using techniques such as polynomial interpolation, spline interpolation, or radial basis function interpolation.

Validate the model: The accuracy of the interpolated model should be validated by comparing its predictions to additional input-output data points not used in the model construction. If the model is accurate, it can be used for control.

Design a control strategy: Based on the interpolated model, a control strategy can be designed to achieve a desired output. This may involve feedback control, feedforward control, or a combination of both.

Implement the control strategy: The designed control strategy can be implemented in the non-linear system to achieve the desired output. The accuracy of the control should be monitored and adjusted as necessary.

Overall, the interpolation method can be a powerful tool for controlling non-linear systems based on an identified model. However, it is important to note that the accuracy of the interpolated model is crucial for effective control, and validation of the model is essential before it is used for control purposes.

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