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Practical Calculation Approach to Automatic Control System Parameters of Linear Systems without Finite Zeros

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Abstract. The paper presents an approach of identifying linear systems without finite zeros. The identification of parameters for systems with one input and one output is observed. Using this approach, it is possible to identify the parameters of the system. The approach is practically verified on a series of identification examples, which confirm the justification of its application.

Key-words: Algorithm; computer; program; identification; numerical calculation; system.

1. Introduction

The paper examines the identification of linear systems without finite zeros. The identification is based on recording the input and response of the system from where the unknown coefficients of the transfer function are found. Before considering the main results of this work, an insight into the used literature will be given.

Reference [1] describes the fundamentals of fundamental theory in the area of transfer function identification using various aproaches. In [2], the elements of numerical analysis and mathematics are described. All this in the function of approximations and determination of various mathematical regularities. The theory of identification is described in [3] with some examples. In the elaboration, elementary mathematics is applied. In [4], a description of control theory is given, with particular emphasis on delay control systems. In [5], the theory of dynamic systems is described with some examples.

Reference [6] provides a description of continuous management systems. Contains elements of linear and non-linear systems. There are concrete solutions and tasks. Analysis of the stability of linear and non-linear control systems is presented. Reference [7] gives access to automatic control. The elements of modern mathematics are presented in a solid way. In [8], the basic elements of control in automatics are processed. The identification of the management system is also processed. Reference [9] deals with systems management theory. In particular, identification is presented with emphasis on iterative computation. In [10], the theory of continuous-time systems with real-time system identification is given.

Reference [11] describes the approaches of calculating identification elements using the Bayesian approach. In [12], the identification of transfer functions for models with multiple inputs is presented. In the doctoral thesis [13], an entry into identification and management systems is given. Reference [14] shows identification with the Box Jenkins model with the presence of a time delay. Reference [15] presents continuous identification with the application of an advanced model for industrial control.

The paper [16] presents a fuzzy control solution for telesurgical applications aiming to alleviate the effects of large latencies in the context of remote telesurgical robotics. The functional blocks of the system are introduced in details. The fuzzy control solution is supported by a cascade control system structure with two proportional-integral-derivative (PID) controllers in the inner and outer control loops.

The paper [17] presents a complete navigation and control system that integrates effective path optimization and motion control capabilities for mobile robots evolving in indoor static and dynamic environments. This system consists primarily of two layers. In the Optimization Layer (Global planner), a Deterministic Constructive Algorithm (DCA) quickly generates the shortest path, as a sequence of nodes, to get to the goal position while avoiding the static obstacles. In paper [18] presents a comparative analysis of two data-driven algorithm combinations. The objective of both data-driven combinations is to ascertain the tunable parameters through the resolution of an optimization problem and to streamline the heuristic procedures involved.

The paper [19] presents a new framework for the design of generic two-degree-of-freedom, linear and fuzzy, controllers dedicated to a class of integral processes specific to servo systems. The first part of the paper presents four 2-DOF linear PI controller structures that are designed using the Extended Symmetrical Optimum method to ensure the desired overshoot and settling time. In paper [20], the authors investigate the tracking control problem for a class of brush direct current motor systems driving a one-link robot manipulator subject to asymmetric full-state constraints. By constructing a state-dependent nonlinear transformation function, an adaptive robust dynamic surface control strategy is proposed to directly address both symmetric and asymmetric state constraints, so that there is no need to convert the problem of state constraint into the constraints on tracking errors as necessitated by the B. Lyapunov Function-based existing works.

The paper [21] presents a novel optimal reference tracking control approach resulted from the combination of a popular policy gradient Reinforcement Learning algorithm, namely Proximal Policy Optimization, and a meta heuristic Slime Mould Algorithm. One of the most important parameters in the PPO-based RL process is the learning rate, which has a big impact on how the parameters of the actor neural network are iteratively updated.

In [22], there is a link with which the authors of this paper present a presentation of a theoretical identification. In this case, the response is found for the known coefficients of the transfer function. For that response, numerical output values are generated for given inputs. These values are entered into the identification program. As a result, transfer function coefficients are obtained. In addition, the attachment contains an original program package in a higher programming language for calculating the coefficients of the transfer function. This package receives data from experimental recordings of the system for identification. Reference [23] deals with a paper where a system with a computer for electrohydraulic control of flying cutting of steel pipes is designed. The control system, hardware and software for this automation are designed. From here, some numerical data are used to compare the accuracy of the identification of transfer function coefficients.

This paper examines the identification of linear systems without finite zeros. Identification is based on recording the input and response of the system from which the unknown parameters are found. In the field of identification, there are many approaches that determine the parameters of the system with the concept of bounce and impulse response. However, often times the systems are speed limited and it is impossible to perform the identification with bounce and impulse inputs. Based on the fact that simple instrumentation should be used for recording, a new approach is proposed in the paper. As a special case, the input of a sloping character is considered. Numerical integration is used for the calculation, for which an algorithm was created and a computer program was written that quickly calculates the elements of the system.

The approach for calculating the coefficients of the transfer function of the system to be identified will be discussed first. A numerical algorithm for integration known as Simpson's method will be used for the calculation. In order to apply this method, a program was written in Fortran, which is provided on the site as an attachment to the paper. To check the approach proposed in this paper, an electro-hydraulic control system example from practice was chosen. This example uses a servo valve, a servo pump and a power hydraulic cylinder. This system is described through the transfer functions of individual blocks. Based on numerical values for known controls, the response of the system was calculated and the equivalent coefficients were determined. The verification of the approach of this paper is performed by recording the response on a real system. On the basis of output values for known inputs from the program package, real coefficients of the transfer function are obtained. This data is used when setting the cutting system to obtain the correct lengths of the cut products. This enables adaptive monitoring in the entire speed range of the technological line.

The paper is organized as follows: in Section 2., the start consists of the differential equation that describes the selected system. By applying numerical mathematics, an algorithm is formed for calculating the transfer function coefficients. Simpson's method is used to calculate the coefficients. In Section 3., a practical system is selected on which the identification approach is tested. First, the system in practice is described and the theoretical response to the selected tilt input is derived. For practical numerical data, they are now inserted into our computer program for parameter identification. Similarly, it is tested using an already known system whose points are loaded into the computer program. In both cases, the coefficients of the transfer function are obtained with good accuracy. Section 4. gives and explains the final conclusions of the results of this paper.

2. Results and Discussion

The dynamic behavior of the control system can be described by the equation

$$a_n y^{(n)}(t) + a_{n-1} y^{(n-1)}(t) + \ldots + a_1 y'(t) + a_0 y(t) = x(t), \tag{1}$$

where $x(t)$ is the input to the control system and $y(t)$ is the output of the identified system. If the assumptions $\lim_{t\to\infty} x(t) = x(\infty)$ apply to the system

$$y(0) = y'(0) = \ldots = y^{(n-1)}(0) = 0 \tag{2}$$

and

$$y'(\infty) = y''(\infty) = \ldots = y^{(n)}(\infty) = 0. \tag{3}$$

In steady-state, (1) is transformed into

$$a_n y^{(n)}(\infty) + a_{n-1} y^{(n-1)}(\infty) + \ldots + a_1 y'(\infty) + a_0 y(\infty) = x(\infty). \tag{4}$$

Subtracting (1) from (4) gives

$$\begin{aligned} a_n\big[y^{(n)}(\infty) - y^{(n)}(t)\big] + a_{n-1}\big[y^{(n-1)}(\infty) - y^{(n-1)}(t)\big] + \ldots + \\ + a_1[y'(\infty) - y'(t)] + a_0[y(\infty) - y(t)] = x(\infty) - x(t). \end{aligned} \tag{5}$$

The system transfer function coefficient is calculated from

$$a_0 = \frac{x(\infty)}{y(\infty)}, \tag{6}$$

where $x(\infty)$ and $y(\infty)$ are the input and output values of the system in steady state. Integrating (5) from 0 to $+\infty$, along with conditions (2) and (3), the equation is obtained

$$a_1 = \frac{1}{y(\infty)} \left\{ a_0 \int_0^\infty \big[y(\infty) - y(t)\big]\, dt - \int_0^\infty \big[x(\infty) - x(t)\big]\, dt \right\}. \tag{7}$$

Integrating relation (5) within the limits from t to $+\infty$ gives

$$\begin{aligned} &- a_n\big[y^{(n-1)}(\infty) - y^{(n-1)}(t)\big] - a_{n-1}\big[y^{(n-2)}(\infty) - y^{(n-2)}(t)\big] - \ldots - \\ &\quad - a_2[y'(\infty) - y'(t)] - a_1[y(\infty) - y(t)] + a_0 \int_t^\infty \big[y(\infty) - y(t)\big]\, dt \\ &\quad = \int_t^\infty \big[x(\infty) - x(t)\big]\, dt. \end{aligned} \tag{8}$$

Integrating expression (8) in the range from 0 to $+\infty$ with conditions (2) and (3) yields

$$\begin{aligned} a_2 = \frac{1}{y(\infty)} \Bigg\{ & a_1 \int_0^\infty \big[y(\infty) - y(t)\big]\, dt - a_0 \int_0^\infty \int_t^\infty \big[y(\infty) - y(t)\big]\, dt^2 + \\ & + \int_0^\infty \int_t^\infty \big[x(\infty) - x(t)\big]\, dt^2 \Bigg\}. \end{aligned} \tag{9}$$

An expression for the coefficient a_3 is obtained in an analogous way

$$\begin{aligned} a_3 = \frac{1}{y(\infty)} \Bigg\{ & a_2 \int_0^\infty \big[y(\infty) - y(t)\big]\, dt - a_1 \int_0^\infty \int_t^\infty \big[y(\infty) - y(t)\big]\, dt^2 + \\ & + a_0 \int_0^\infty \int_t^\infty \int_t^\infty \big[y(\infty) - y(t)\big]\, dt^3 - \int_0^\infty \int_t^\infty \int_t^\infty \big[x(\infty) - x(t)\big]\, dt^3 \Bigg\}. \end{aligned} \tag{10}$$

In the general case, the coefficient a_k, after integration and arrangement, becomes

$$a_k = \frac{1}{y(\infty)}\Bigg\{\sum_{i=0}^{k-1}(-1)^{k+i+1}a_i\int_0^\infty\int_t^\infty\ldots\int_t^\infty \big[y(\infty)-y(t)\big]\,dt^{k-1}+ \\ +(-1)^k\int_0^\infty\int_t^\infty\ldots\int_t^\infty \big[x(\infty)-x(t)\big]\,dt^k\Bigg\}. \tag{11}$$

Based on the transformation from [3], it is obtained that

$$\int_0^\infty\int_t^\infty\ldots\int_t^\infty \big[z(\infty)-z(t)\big]\,dt^{k-1} = \int_0^\infty\big[z(\infty)-z(t)\big]\frac{t^{k-i-1}}{(k-i-1)!}\,dt, \tag{12}$$

and replacing (12) in (11) gives the expression for the coefficient a_k

$$a_k = \frac{1}{y(\infty)}\Bigg\{\sum_{i=0}^{k-1}(-1)^{k+i+1}a_i\int_0^\infty\big[y(\infty)-y(t)\big]\frac{t^{k-i-1}}{(k-i-1)!}\,dt+ \\ +(-1)^k\int_0^\infty\big[x(\infty)-x(t)\big]\frac{t^{k-1}}{(k-1)!}\,dt\Bigg\}. \tag{13}$$

Expanding expression (13) gives

$$a_k = \frac{1}{y(\infty)}\Bigg\{\int_0^\infty\big[y(\infty)-y(t)\big]\left[a_{k-1}+\sum_{i=0}^{k-2}a_i\frac{(-t)^{k-i-1}}{(k-i-1)!}\right]dt+ \\ +(-1)^k\int_0^\infty\big[x(\infty)-x(t)\big]\frac{t^{k-1}}{(k-1)!}\,dt\Bigg\}. \tag{14}$$

For the subintegral functions of expression (14), the relation holds

$$\int_0^\infty f(t)\,dt = \int_0^{t_n} f(t)\,dt + \int_{t_n}^\infty f(t)\,dt \tag{15}$$

where t with the value ∞ can be replaced by the value t_n provided that

$$\int_{t_n}^\infty f(t)\,dt \le \varepsilon, \tag{16}$$

for a preselected ε with a small value. Then based on relations (15) and (16), (14) becomes

$$a_k = \frac{1}{y(\infty)}\Bigg\{\int_0^{t_n}\big[y(\infty)-y(t)\big]\left[a_{k-1}+\sum_{i=0}^{k-2}a_i\frac{(-t)^{k-i-1}}{(k-i-1)!}\right]dt+ \\ +(-1)^k\int_0^{t_n}\big[x(\infty)-x(t)\big]\frac{t^{k-1}}{(k-1)!}dt\Bigg\}. \tag{17}$$

The integral values in (17) will be calculated by numerical integration using Simpson's method from [2]. Then (17) has the equality

$$a_k = \frac{1}{y(\infty)}\big[y_p(0)+y_p(t_n)+4\sigma_1+2\sigma_2+x_p(0)+x_p(t_n)+4\sigma_1'+2\sigma_2'\big], \tag{18}$$

where

$$y_p(0) = \big[y(\infty) - y(0)\big]\frac{a_{k-1}}{3}h, \tag{19}$$

$$y_p(t_n) = \big[y(\infty) - y(t_n)\big]\left[a_{k-1} + \sum_{i=0}^{k-2} a_i \frac{(-t_n)^{k-i-1}}{(k-i-1)!}\right]\frac{h}{3}, \tag{20}$$

$$\sigma_1 = \sum_{j=1}^{[n/2]} \big[y(\infty) - y(t_{2j-1})\big]\left[a_{k-1} + \sum_{i=0}^{k-2} a_i \frac{(-t_{2j-1})^{k-i-1}}{(k-i-1)!}\right]\frac{h}{3}, \tag{21}$$

$$\sigma_2 = \sum_{j=1}^{[n/2-1]} \big[y(\infty) - y(t_{2j})\big]\left[a_{k-1} + \sum_{i=0}^{k-2} a_i \frac{(-t_{2j})^{k-i-1}}{(k-i-1)!}\right]\frac{h}{3}, \tag{22}$$

$$x_p(0) = 0, \tag{23}$$

$$x_p(t_n) = (-1)^k\big[x(\infty) - x(t_n)\big]\frac{t_n^k}{(k-1)!}, \tag{24}$$

$$\sigma_1' = (-1)^k \sum_{j=1}^{[n/2]} \big[x(\infty) - x(t_{2j-1})\big]\frac{t_{2j-1}^k}{(k-1)!}, \tag{25}$$

$$\sigma_2' = (-1)^k \sum_{j=1}^{[n/2]} \big[x(\infty) - x(t_{2j})\big]\frac{t_{2j}^k}{(k-1)!}. \tag{26}$$

Identification is performed by recording input and output signals. Data are read in equal time intervals. With the input signal $x(t)$, there is one restriction that x has a finite value in the steady state. Figure 1 shows an example of an input and output signal. The curve $y(t)$ represents the response of the system to the input $x(t)$. For $x(t)$ it is true that

$$x(t) = \frac{x(\infty)}{\tau}t\ ;\ 0 < t < \tau \quad \text{and} \quad x(t) = x(\infty)\ ;\ t > \tau. \tag{27}$$

When (27) is taken into account, it is obtained that

$$(-1)^k \int_0^{t_n} \big[x(\infty) - x(t)\big]\frac{t^{k-1}}{(k-1)!}\,dt = (-1)^k\left\{\int_0^{\tau} \big[x(\infty) - x(t)\big]\frac{t^{k-1}}{(k-1)!}\,dt + \right.$$
$$\left. + \int_{\tau}^{t_n} \big[x(\infty) - x(t)\big]\frac{t^{k-1}}{(k-1)!}\,dt\right\}, \tag{28}$$

where the relation holds

$$(-1)^k \int_{\tau}^{t_n} \big[x(\infty) - x(t)\big]\frac{t^{k-1}}{(k-1)!}\,dt = 0. \tag{29}$$

If (28) and (29) are changed on the right side of equality (17), this results in

$$(-1)^k \int_0^{t_n} \big[x(\infty) - x(t)\big]\frac{t^{k-1}}{(k-1)!}\,dt = (-1)^k\tau^k\frac{x(\infty)}{(k+1)!}. \tag{30}$$

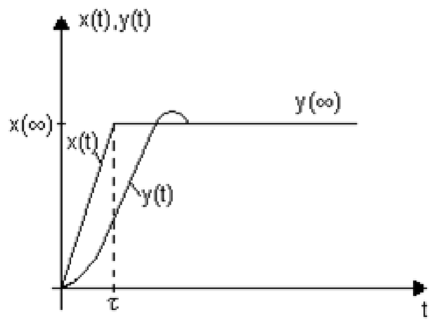

Fig. 1. Graphical representation of the input and output signals.

The sum of (23), (24) and (26) is calculated as the right side of equality (30). In this way, the identification approach for the slope input is presented as shown in Figure 1. The approach for $\tau = 0$ becomes the identification using the jump input. When decreasing τ with a constant sampling time interval, the accuracy of the calculation of the coefficients of the transfer function to be identified deteriorates. For smaller values of τ, the response establishment time is faster. Then a smaller time interval can be taken for the integration step. For the τ value of to be adopted depends on the performance of the control system to be identified. The sub-integral functions are divided into n equal segments in the observed interval. Numerical calculations are then performed using numerical mathematics.

The entire process of identifying the coefficients of the transfer function is algorithmic, which calculates the coefficients of the transfer function of the control system. What the order of the system will be is not known in advance, but it is concluded when significantly smaller values of the coefficients of a higher degree are obtained compared to the coefficients obtained in the lower degree of the transfer function.

For illustration, the pitch input signal and its velocity response are recorded from a real system. Figure 2 shows a recording from an oscilloscope. The filming was done during the regular process of manufacturing steel pipes.

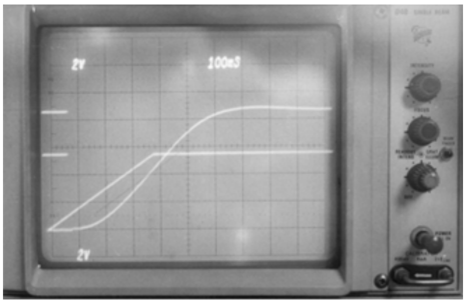

Fig. 2. Display of the graph of the input and output signal.

Reducing the value of τ by choosing a constant time interval negatively affects the accuracy of calculating the system parameters. This is because in this example of identification there is a speed limit. This limit is due to the response of the hydraulic system of the servo valve, servo pump and hydraulic cylinder. The hydraulic response cannot follow the rate of increase of the electronic signal that feeds the servo amplifier. For each identification, the system must first be studied. Then it is possible to perform the identification.

The choice of the value for τ to be selected for identification depends on the performance of the system to be identified. The sub-integral functions are divided into n equal segments, for a given time interval, which will be calculated on numerical calculations.

3. Application of Algorithms for Calculating the Transfer Function on a Practical System

A new approach for identifying the parameters of an automatic control system has been presented previously. In this part of the paper, a practical identification of the system parameters without trailing zeros will be carried out. First of all, the recording will be performed on a real control system for cutting steel pipes in motion on technological lines for the production of steel pipes. For the control input, which is of a tilting nature, until the reference value is reached, the outputs are recorded as shown in Figure 1. The outputs from the identified system represent the speed of the pipe cutting tool in motion. Table 1 provides an overview of these numerical results.

Table 1. Values of the system's response to the input of the slope character

N_0 1	System response control	N_0 2	System response control
1	0.016	22	6.750
2	0.032	23	7.000
3	0.075	24	7.375
4	0.125	25	7.750
5	0.250	26	8.000
6	0.475	27	8.250
7	0.625	28	8.375
8	1.000	29	8.575
9	1.250	30	8.725
10	1.625	31	8.750
11	2.000	32	8.875
12	2.375	33	8.950
13	2.750	34	8.950
14	3.250	35	8.950
15	3.750	36	8.950
16	4.125	37	8.925
17	4.500	38	8.900
18	5.000	39	8.900
19	5.375	40	8.875
20	6.000	41	8.875
21	6.375	42	8.750

Columns N_0 1 and N_0 2 represent the serial numbers of the recorded inputs and are directly proportional to the time t. The other two columns, represented by the voltage values recorded by the memory oscilloscope, represent the analog values of the tester speed $v\left(\frac{m}{s}\right)$. There is such a relationship that, for example, a speed of $1\frac{m}{s}$ corresponds to a voltage signal of 6 volts. A speed of $1\frac{m}{s}$ converted to $m/\min$ is $60\frac{m}{\min}$.

These numerical values will be used to implement the algorithm of this paper for identifying the system parameters. For illustration, Figure 3 shows a graph where time t is used on the abscissa and speed is shown on the ordinate with analog voltage values in volts. In order to compare the obtained results, this will be done by taking the theoretical results obtained by calculation. For a more precise definition of this approach, the following coupled transfer is expressed:

$$W_1(s) = \frac{k}{as^2 + bs + 1}, \tag{31}$$

where s is the Laplace differentiation operator. In the case of identification, there will be identification parameters whose coupled transfer is given by the relation

$$W_2(s) = \frac{k}{a_2 s^2 + a_1 s + a_0}. \tag{32}$$

Therefore, the last relation must be adjusted to the coupled transfer obtained theoretically. This is done by dividing the whole fraction of a_0 by $W_2(s)$, which gives

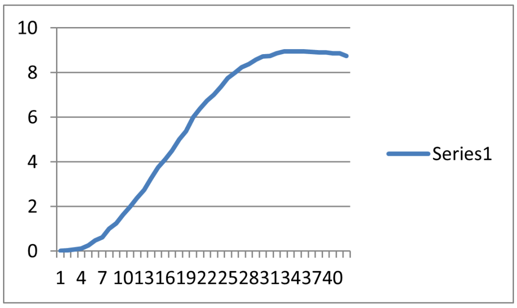

Fig. 3. A plot of the tester's speed as a response of the system to be identified (the abscissa is time in s, the ordinate is speed in $10 \times \frac{m}{\min}$).

$$W_2(s) = \frac{\frac{k}{a_0}}{\frac{a_2}{a_0}s^2 + \frac{a_1}{a_0}s + 1}. \tag{33}$$

The following relations can be written:

$$a = \frac{a_2}{a_0}, \quad b = \frac{a_1}{a_0}, \quad k_1 = \frac{k}{a_0}. \tag{34}$$

From reference [23], the relations for regulating the cutting of steel pipes by an electrohydraulic control system are known:

$$a = \frac{1}{\omega_n^2} \quad \text{and} \quad b = \frac{2\vartheta}{\omega_n}. \tag{35}$$

There are elementary transformations

$$\omega_n = \frac{1}{\sqrt{a}}; \quad \vartheta = \frac{b}{2\sqrt{a}}. \tag{36}$$

The system's response to the proposed input is

$$v_1(t) = k_1\left(t - \frac{2\vartheta}{\omega_n} + \frac{1}{p_1\omega_n}\exp(-\vartheta\omega_n t)\sin(\omega_n p_1 t - \varnothing)\right) - \\ - k_1\left(t - \tau - \frac{2\vartheta}{\omega_n} + \frac{1}{p_1\omega_n}\exp(-\vartheta\omega_n(t-\tau))\sin(\omega_n p_1(t-\tau) - \varnothing)\right)u(t-\tau), \tag{37}$$

where $p_1 = (1-\vartheta^2)^{0.5}$. It is in the previous formula for speed

$$u(t-\tau) = 0,\ t < \tau, \qquad u(t-\tau) = 1,\ t > \tau.$$

According to the proposed algorithm for identifying system parameters, a program in a high-level programming language for a computer was created. This program is shown in [23]. The program was tested by recording data for the output as a function of the input quantity. The recording was performed for several speeds of the flying saw on production lines for steel pipes. The output data shows the same values for the system parameters. A second-order system without final zeros is identified. The following data are obtained for the coefficients according to [23]:

$$a_0 = 117.67915; \quad a_1 = 15.03579; \quad a_2 = 1.00012. \tag{38}$$

Relations (33) and (34) lead to

$$a = 0.008499; \quad b = 0.127735. \tag{39}$$

Relation (36) leads to

$$\omega_n = 10.847; \quad \vartheta = 0.6928, \tag{40}$$

which represents the identified parameters of the control system. By comparison with the theoretically calculated values during the design of the technological line

$$\omega_n = 12.55; \quad \vartheta = 0.7, \tag{41}$$

comparison (40) and (41) proves a certain difference. This difference causes deviations in the accuracy of the cut pipes along the length.

Therefore, identification based on readings of actual responses is justified because first-class products are obtained because they are significantly more accurate in length. In order to confirm the reliability and accuracy of the identification, a new experiment was performed. It consists of the known coefficients that generated the response in Table 2.

Table 2. Data generation for practical identification

$\tau(s)$	Coefficient a_0	Coefficient a_1	Coefficient a_2
0.4	0.4	1.3	1.0
0.5	0.3	1.1	1.0
0.3	0.3	1.1	1.0
0.5	0.5	1.5	1.0
0.2	0.2	0.9	1.0
1.0	2.0	3.0	1.0
0.3	2.0	3.0	1.0
3.0	30.0	11.0	1.0

Table 3. Calculated coefficients from the applied identification

$\tau(s)$	Coefficient a_0	Coefficient a_1	Coefficient a_2
0.4	0.399	1.299	1.001
0.5	0.300	1.099	1.000
0.3	0.300	1.099	1.000
0.5	0.500	1.499	1.000
0.2	0.199	0.899	1.003
1.0	2.000	2.999	0.999
0.3	2.000	2.999	1.002
3.0	30.00	10.99	0.996

Based on the given coefficients, a response was generated from which samples were taken. The identification results are presented in Table 3. The obtained transfer coefficients are take almost the same value. Such high accuracy justifies and confirms the proposed new implemented identification of the control system.

4. Conclusions

The proposed approach allows for system identification by recording inputs and responses. Using numerical mathematics, the necessary equations were derived. The equations led to the finalization of this identification package through programming. Given that the approach is algorithmic, a computer program was written for the calculation, which is provided on the website related to this work. Using the computer program, several examples of system identification were checked. Testing on several examples showed that the approach gives good results, and the authors consider that it will be useful to researchers and engineers for identifying the coefficients of the transfer functions of control systems.

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