Journal of Academic Research and Trends in Educational Sciences
Journal home page:
http://ijournal.uz/index.php/jartes

CONTROL OF MULTIDIMENSIONAL DISCRETE OBJECTS BY A TERMINAL MANAGEMENT

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KEYWORDS

algorithm, terminal control, forecast synthesis, error values, control action, state variables, discrete transfer function

ABSTRACT

The article deals with the synthesis of the terminal control algorithm, focused on the synthesis of control actions modulated in amplitude and allowing to transfer, the control object to a given steady state and providing a stable and stable location of the object in the vicinity.

DOI: 10.5281/zenodo.7546675

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Introduction. The modern linear theory of automatic control is a fundamental science and solves a wide range of problems using modern mathematical tools. But on the other hand, management theory is constantly evolving, far from complete. A number of important problems of linear control theory are simple in their formulation, but effective methods for solving them that are guaranteed to lead to an exact solution (if any) with a given accuracy are unknown. These problems exist both in the classical and in the modern theory of linear systems.

The central problem of the synthesis of multidimensional control systems is the achievement of control autonomy. The problem of representing multidimensional control systems as a set of one-dimensional ones, first formulated by Professor IN Voznesensky, is currently open and its solution will allow applying the most powerful apparatus for synthesizing one-dimensional systems to multidimensional ones [1].

At present, a large number of different methods and schemes have been developed to manage multidimensional discrete dynamic objects [2-4].

At the same time, their use is complicated by the great laboriousness and cumbersomeness of computational procedures, the need to perform various kinds of simplifying assumptions and conditions. For example, when using compensation regulators very often, the structure of the regulator obtained as a result of synthesis is physically unrealizable.

Similar results can be obtained by using different methods for decoupling the transmission channels of a multidimensional control object, using auxiliary cross regulators [3-8]. Multidimensional polynomial aperiodic regulators [2-7] often give unacceptable results of control both in terms of the amount of overshoot and the unrealizable physical reasons for the calculated values of control actions.

Formulation of the problem. The paper describes the algorithm developed by the authors for the synthesis of discrete control actions modulated in amplitude, and allows calculating the values of control pulses with a constant period that transfer the control object to a new, required, steady state and ensuring a stable and stable location of the object in its vicinity.

The basis of the basic synthesis algorithm is the provision that after the necessary number of control cycles N, the state of the object must satisfy the conditions:

$$\begin{aligned} & y_i(N_u) = Z_i, \quad i=\overline{1,N}, \\ & y_i^{(k)}(N_u) = 0, \quad k=\overline{1,N_u-1}, \end{aligned} \qquad (1)$$

Here N is the number of output variables of the control object;

- values y_i of the i-th output variable at the end of the N_u th measure;

- the value of the k-th derivative of the i-th output variable;

Z_i - the required value (setpoint) of the i-th output variable.

Conditions (1) can be interpreted differently as follows:

$$y_i(N_u) = Z_i, \quad i = \overline{1, N},$$
$$y(N_u + j) = Z_i, \quad j = \overline{1, N_u - 1}, \qquad (2)$$

those, it is required after the N_u control cycles to reach the required required control action and then during the N_u cycles the output variable must be at the preset, level.

Unlike the basic one in the proposed control synthesis algorithm, the mathematical formulation of the control problem has the following form:

$$y_i(L + N_u) = E_i\left(L + N_u\right) = Z_i - y_i^*(L + N_u),$$
$$i = \overline{1, N}, U_k(L + j) = const, \qquad (3)$$
$$j = \overline{1, N_u - 1}, \quad k = \overline{1, M}$$

In the last expression: L - current time (quantization clock); M -is the number of input control actions; - the predicted value of the i-th input variable on N_u is so forward from the current time.

The analysis of conditions (3) allows us to conclude that, in the implementation of this algorithm, the control system does not tend to make the control object after a selected number of control cycles N_u be transferred to a new steady state characterized by constant and unchanged values y_i of the output variables. The algorithm only allows to calculate the values y_i of control actions, based on the condition of equality of the output variables after the expiration of the N_u control cycles to their required values. At the same time, in the current quantization cycle it is assumed that the values y_i of the control actions during the subsequent control interval will not change [5-7].

In fact, in each new cycle, the values y_i of the control actions for each input variable are recalculated. This approach ensures a stable, asymptotic movement of the control object to a new steady state and a stable finding of variables that characterize its behavior in a given control range. Such a gradual change in the output variables is due to the fact that in each subsequent cycle the amplitude of the change in the control pulses, subject to the invariance of the required values y_i (settings) and minor fluctuations in the operating conditions, changes by a relatively small amount that does not cause sudden movements of the object and the control system.

In condition (3), to determine the values y_k of y_i (N_u), we can use the expression:

$$y_i(L + N_u) = \sum_{j=1}^{M} \sum_{l=0}^{N_u - 1} U_j(l) \cdot \omega_{ij}(N_u - 1), \qquad i = \overline{1, N}; \quad k = \overline{0, N_u - 1} \qquad (4)$$

Here, U_j (l) is the desired value of the j-th control action in the l-th cycle;

ω_{ij} (n) - value of the k-th derivative of the weighting function of the channel j-th input - l-th output in the n-th clock.

Moreover, the weight function is defined as the response to a unit pulse of duration equal to the value of the quantization step

$\omega_{ij}(n) = h_{ij}(n) - h_{ij}(n-1)$ (5)

Where h_{ij} (n) is the value of the channel transition function j-th input - i-th output in the n-th quantization cycle.

The determination $u_j(1), \quad j = \overline{1, M}$ must be preceded by the determination of the values y_i of the vector E in accordance with the actual state of the control object. This is due to the fact that the actual state of the control object due to the inaccuracy of the mathematical model, errors in the implementation of the calculated control actions, the presence of various perturbing factors acting on the real object practically never coincides with the state calculated only by the model.

To determine the predicted values y_i of the vector E, under the assumption that the control actions do not change during the subsequent control interval, one can use the control object model in the space of state variables:

$$X(N_u \times T_0) = F(N_u \times T_0) \times X(N_u \times T_0)$$

$$Y(N_u \times T_0) = C \times X(N_u \times T_0) \quad (6)$$

Where $X(N_u \times T_0)$- the value of the state vector of the control object at the timet $= N_u \times T_0$;

$F(N_u \times T_0)$ - value of the fundamental (transitive) matrix of the control object, for the value of the argument $t = N_u \times T_0$;

C - output matrix:

Y - is the vector of the output variables of the control object.

To implement the expression (6) when predicting the output variables of an object, the required number of cycles is required, first, to use one more kind of model - the control object model represented in the state variables space and, secondly, to determine the values y_i of state variables from known values y_i of the output variables it is necessary to use a state observer, for example the Calman filter. Two of these circumstances significantly increase the cumbersomeness of the algorithm and entail additional errors.

Therefore, in order to determine the predicted error values, or, what is the same, the predicted values y_i of the output variables, an approach based on the use of discrete transfer functions of the control object is proposed [2-4]. We denote by

$$W_{ij}(z) = \frac{B_{ij}(z)}{A_{ij}(z)} \quad (7)$$

discrete channel transfer function j-th input - the i-th output, $B_{ij(z)}$ and $A_{ij(z)}$ are polynomials in powers of degrees respectively n_{ij}^{+} and n_{ij}^{-}. Then the Z-transformation of the output variable can be represented as:

$$y_i(z)=\sum_{j=1}^{M}\frac{B_{ij}(z)}{A_{ij}(z)}\times u_j(z) \quad (8)$$

Substituting the right-hand side of expression (8) to the common denominator, we obtain:

$$y_{ij}(z)\times\prod_{j=1}^{M}A_{ij}(z)=$$

$$=\sum_{j=1}^{M}\left(\left(B_{ij}(z)\times\prod_{k=1;\ k\neq j}A_{ik}(z)\right)\times u_j(z)\right) \quad (9)$$

or in another form:

$$y_{ij}(z)\times C_i(z)=\sum_{j=1}^{M}D_{ij}(z)\times u_j(z) \quad (10)$$

Where

$$C_i(z)=\prod_{j=1}^{M}A_{ij}(z)\,;$$

$$D_{ij}(z)=B_{ij}(z)\times\prod_{j=1;\ k\neq j}^{M}A_{ij}(z) \quad (11)$$

Dividing the left and right sides of (10) by $c_i(0)\cdot z^{n_s}$, we obtain:

$$y_i(z)\times R_i(z^{-1})=\sum_{j=1}^{M}P_{ij}(z^{-1})\times u_j(z) \quad (12)$$

Where $R_i(z^{-1})$ и $P_i(z^{-1})$ - polynomials in inverse powers of the operator Z of the form:

$$R_i(z^{-1})=1+\sum_{k=1}^{n_s}r_i(k)\times z^{-k}$$
$$P_{ij}(z^{-1})=\sum_{k=0}^{n_s}p_{ij}(k)\times z^{-k} \quad (13)$$
$$r_i(k)=\frac{c_i(k)}{c_i(0)};\quad P_{ij}(k)=\frac{d_{ij}(k)}{c_i(0)}$$

On the basis of expression (12), taking into account (13), a recurrence formula is easily obtained for predicting the output values y_i of the control object:

$$y_i^*(L+1)=\sum_{k=1}^{n_s}r_i(k)\times y_i(L+1-k)+$$
$$+\sum_{j=1}^{M}\sum_{k=1}^{n_s}p_{ij}(k)\times u_j(L-k+1) \quad (14)$$

Here n_1 is the total order of the transfer functions associated with the i-th output variable. Performing the procedure (14) Nu times and taking into account that $и_j(L)=u_j(L+1)=\ldots=u_j(L+N_u-1)$ = const, you can obtain an expression for calculating the predicted value of the output variable in (L+ N_u)- th cycle.

$$y_i^*(L+N_u)=-\sum_{k=1}^{n_s}q_i(k)\times y_i(L)+\sum_{j=1}^{M}y_j\times u_j(L) \quad (15)$$

Taking into account condition (3), it is possible to obtain a system of linear equations of the M^{th} order for calculating control actions at the current time

$$\sum_{j=1}^{M}y_j\times u_j(L)=Z_i+\sum_{k=1}^{n_s}q_i(k)\times y_i(L);\quad i=\overline{1,N} \quad (16)$$

Conclusion

The considered synthesis of the terminal control algorithm, focused on the synthesis of amplitude-modulated control actions, allows you to transfer the control object to a given steady state and provides a stable and cardinal location of the object in the vicinity. The algorithm makes it possible to synthesize a control action for technological objects operating under conditions of uncertainty and in the presence of restrictions on the amplitude of control actions.

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