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Research Article

ON THE GENERALIZED ALGORITHM FOR OPTIMAL CONTROL OF SYSTEMS OF LINEAR DIFFERENTIAL-DIFFERENCE EQUATIONS

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ABSTRACT

This article presents a model for optimizing the number of control function parameters for objects with delay, which are expressed by a system of differential equations. It also discusses the model of the stability of the robot's motion trajectory after the practical process of a specific object, as well as algorithms for improving positional accuracy.

KEYWORDS

Control function parameters, optimal solution, kinematic chain, system of differential-difference equations.

INTRODUCTION

This article presents a generalized algorithm for optimizing the number of parameters of the control function in the optimal control of systems of linear differential-difference equations. The algorithm is built upon the "K-controllability" algorithm for autonomous control systems described in [1]. Starting from the second condition of the theorem provided in [2], the algorithm fully utilizes the procedure outlined in [1] (Figure 1). This includes finding the eigenvalues of the system matrix for "K-controllability" and transforming the system into Jordan normal form, as well as detailing the algorithms for achieving full controllability of the system.

The general form of a system of linear differential-difference equations is as follows:

$$\begin{cases} \dot{x}(t) = Ax(t-h) + Bu(t) \\ y(t) = Hx(t) \end{cases} \qquad (1)$$

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where: $x = x(t) - n -$ a vector representing the state of the system at time t;

A – constant matrices of specific dimensions; $(n \times n) -$ ўлчовли ўзгармас матрица;

$B - (n \times m) -$ A constant matrix with non-zero elements;;

$h -$ an infinitesimally small quantity;;

$u(t) - (1 \times m) -$ a control function vector; $h > 0,\ t_0 \le t \le T$;

$y(t) - n -$ a vector of specific dimensions depending on the state vector $-(1 \times n)$;

$H - (r \times n) -$ A constant matrix of specified dimensions.

The application of the second theorem on optimization provided in [2] to the process of industrial robot operation indicates that the selection of C_k and B_k matrices can be represented through an $(n \times n) -$ dimensional matrix expressed via an $((n+1) \times (n+1)) -$ dimensional matrix, based on the kinematic equations of the industrial robot's motion. The appearance of the C_k matrix is as follows:

$$C_k = \begin{bmatrix} C & 0 \\ 0 & 1 \end{bmatrix},$$

The appearance of the B_k matrix is as follows:

$$B_k = \begin{bmatrix} B & 0 \\ 0 & 1 \end{bmatrix}$$

To satisfy the first condition of the theorem, the P matrix is selected based on the technical and structural characteristics of the industrial robot. Then, it is verified that the equation $PB_k = C_k P$ holds true.

$$B_k = \begin{bmatrix} B & 0 \\ 0 & 1 \end{bmatrix},\ C_k = \begin{bmatrix} C & 0 \\ 0 & 1 \end{bmatrix}$$

The problem in [2], i.e., restoring damaged points using the recovery equation, similarly reduces to a system of linear equations, as in the first problem. Due to the repetitive nature of the algorithms constructed for this, we do not present the algorithms here.

1 - the beginning:

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2 - initial data: he dimension of the space under consideration (N), the initial and final time of the process: (t_0, T), the delay time (h), system matrices $(A=\{a_{ij}, i, j=\overline{1,N}\}; B=\{b_{i,j}, i=\overline{1,N}, j=\overline{1,M})(M \le N);$ $P=\{p_{i,j}, i, j=\overline{1,N}\})$; $C=\{c_{i,l}, i=\overline{1,N}, l=\overline{1,K}\}(K \le N)$ control function values $u_i(i=\overline{1,N})$, Additional matrices $B_k=\{b_{ij}, ij=\overline{1,N}\}; C_k=\{c_{ij}, ij=\overline{1,N}\}$, initial values of the system at $t=t_0$.

3 - Determining the direction of the damaged point in the system.

4 - transforming the matrix A, which represents the system's state, into its Jordan normal form $J(A)$.

5 - Generating the matrices PB_k, C_kP, BC.

6 - the condition $PB_k = C_kP$ is checked.

7 – If "yes", move to block 8; if "no", move to block 2.

8 – the second condition of the theorem is checked based on the algorithm provided in [2].

9 – end.

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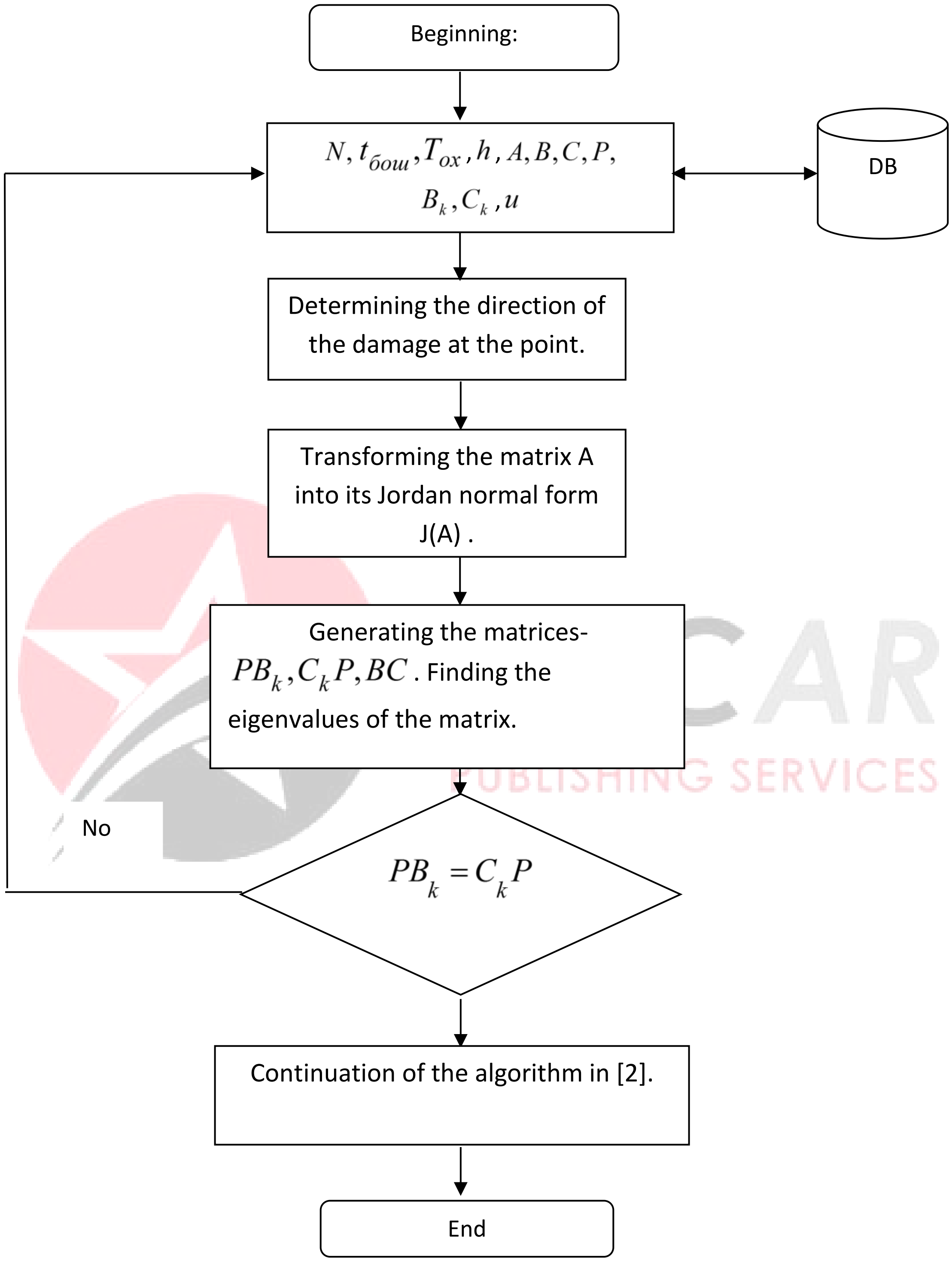

Figure 1. Block diagram of the optimization algorithm for the number of control function parameters in the control of a system of linear differential equations.

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