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ROBUST DECENTRALIZATION OF INFORMATION MANAGEMENT SYSTEMS

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Abstract. *An approach to determining control influences for a decentralized information management system that ensure its robustness to structural disturbances is considered. An algorithm for selecting a suboptimal strategy for forming controls over system objects is proposed.*
Key words: *information management system decentralization, model decomposition, robust algorithms, local subsystem, model reduction*

Introduction.

Currently, in a number of system studies of complex information and control systems (IMS) of various functional purposes, much attention is paid to the development of reduced models of controlled objects while maintaining stability.

The problem of reducing the dimensionality of models used in IMS can often be solved by decentralizing the source systems, taking into account the relationships between local subsystems [1]. However, there is an ambiguous problem of simplified representation of individual processes in IMS, which guarantees the stability of the functioning of the entire system. The solution to this problem can be implemented using robust algorithms based on the analysis of the stability of reduced models.

The purpose of this paper is to explore some key issues of this problem.

Main text.

Let us consider a discrete system, the dynamics of which can be described using equations of the form:

Let us consider a discrete IMS, the dynamics of which can be described using equations of the form:

$$x(k+1) = Ax(k) + Bu(k) = f(x,u,k) , \quad (1)$$

where $x(k), u(k)$ – vectors of state and control variables, respectively ($x(k) \in R^n$, $u(k) \in R^m$); A, B – matrices of dimension ($n \times n$) and ($n \times n$), respectively; k – discrete time.

If the matrix B is diagonal, then system (1) can be decomposed into subsystems S_i, $i = \overline{1,N}$, connected by means of connection functions $z_i(x', u', k)$, the control of which according to a given quadratic criterion can be satisfactorily carried out using coordination methods [2].

Let's set the problem of determining the influence of interactions $z_i(x', u', k)$ on the stability of each subsystem. It is obvious that this task can be reduced to the estimation of eigenvalue matrices A_{ij}; $i, j = \overline{1, N}$.

At; the complete system can be represented by standard equations of the form:

$$x(k+1) = Ax(k) + Bu(k) , \quad (2)$$

$$y(k) = Cx(k) , \quad (3)$$

where $y(k)$ is the output of the systems; A, C, B - matrices of coefficients of the dimension model.

It is obvious that the stability of the system (2), (3) is determined only by the eigenvalues of the diagonal blocks A_{ii}.

Let us set the problem of synthesis of a decentralized control law that guarantees the location of the poles of a closed system within the unit circle.

If we assume a complete interruption of the interconnections between the subsystems, then the matrix A in equation (2) is transformed into a reduced matrix

A^0 whose elements correspond to the multipliers A_{ij}; $i, j = \overline{1, N}$ in equation (1).

Let us consider the solution of the standard problem of optimal control of the system.

It is obvious that for system (2) with a reduced matrix A^0, the optimal controls without taking into account interactions between subsystems are equal to:

$$u_i^0(k) = -K_i^0 x_i(k),$$

where $K_i^0 = R_i^{-1} B_i^T P_i^0$, P_i^0 is a positive definite solution of Rikkata's matrix equation for the i-th subsystem.

At the same time, the quality indicator (5) will take some positive value. Let us assume that the original system with a full matrix A, taking into account all the relationships between subsystems, is asymptotically stable and fully controllable. Since in the general case the obvious inequality $J \geq J^0$ holds , it is reasonable to consider the possibility of eliminating individual interconnections between subsystems without breaking stability, in accordance with the inequality of the form:

$$J \leq (1+\alpha) J^0, \quad \forall A_{ii} \in [0,1), \tag{4}$$

where α is the index of suboptimality.

Using the Lyapunov function

$$V_i(x_i(k)) = \|x_i(k)\|_{P_i}^2, \quad i = \overline{1, N}, \tag{5}$$

we can determine the conditions under which a partially reduced system will be suboptimal with index α.

It can be shown that condition (4) will be satisfied if

$$\sum_{i=1}^{N} \sum_{j=1}^{N} \gamma_{ij} \leq \frac{0.5\alpha \min\limits_i \lambda_{\min}(W_i)}{(1+\alpha) \max\limits_i \lambda_{\max}(P_i)}. \tag{6}$$

To reduce the value of the suboptimality index, it is necessary to introduce additional controls of the form:

$$u_{Дi}(k) = -\sum_{j=1}^{N} A_{ij} K_{Дij} x_j(k).$$

According to (5), the index α is a function of the norm γ_{ij} of the interaction matrix. The interaction matrix corresponds to the difference $(A_{ij} - B_i K_{дij})$, and to minimize γ_{ij} the value $K_{дij}$, it is calculated as

$$K_{дij} = B_i^* A_{ij}, \quad (7)$$

where B_i^* is the generalized inverse matrix of B_i.

If the matrix B_i has full rank, then B_i^* is defined as $B_i^* = (B_i^T B_i)^{-1} B_i^T$. If the rank of the matrix $[B_i, A_{ij}]$ is equal to the rank of B_i, then this situation leads to $\gamma_{ij} = 0$. Clearly, using the given system of conditions, one can determine the possibility of eliminating one or more interrelations between subsystems from the original dynamic discrete model.

Summary and conclusions.

The approach considered allows for the reduction of a complete decentralized model of a discrete IMS. A robust solution to the problem is determined, guaranteeing asymptotic stability and suboptimality of the reduced system. The presented results can be used to formalize suboptimal control problems for IVS objects using reduced models.

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