ALGORITHMS FOR IDENTIFICATION OF LINEAR DYNAMIC CONTROL OBJECTS BASED ON THE PSEUDO-CONCEPT CONCEPT

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Abstract: *Regularized algorithms for identifying linear dynamic control objects based on the concept of pseudo inversion are given. The equation of the control object is focused on solving a number of applied problems and is selected in the form of a multidimensional dynamic regression equation. To solve the equation in question, we use differentiation formulas for quadratic functionals with respect to matrix variables and regularized algorithms based on non-orthogonal factorizations and pseudo in versions of square matrices. The obtained regular algorithms contribute to increasing the accuracy of estimating the parameters of the class of dynamic control objects under consideration.*

Keywords: *linear dynamic control objects, identification algorithms, regular estimation, matrix pseudo inverse*

I. INTRODUCTION

Currently, in connection with the development of technology, the complexity of managed objects in developed and designed control systems is significantly increased. The structure of most modern control objects is such that the exact mathematical description of the objects is either absent or varies widely. In such conditions, the incompleteness of information about the mathematical model imposes a significant limitation on the methods used for the synthesis of models and controls. One of the decisive steps in the identification process is the choice of the class of mathematical objects in which a representative is selected that is most suitable for some criterion of a real simulated dynamic system [1-11]. Since one of the main directions of the practical use of models is predicting the output signals of a real technological system, it is natural, when assessing the quality of conformity of a model to a real object, to take the result of comparing their outputs as a criterion for conformity.

II. FORMULATION OF THE PROBLEM

Consider a linear discrete dynamical system described by the equation

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$$y(t+1)=\sum_{i=0}^{p}\mathrm{A}_i y(t-i)+\sum_{j=0}^{q}\mathrm{B}_j \mathrm{u}(t-j)+\xi(t),\;\; t=1,2,\;...,\;N\;, \tag{1}$$

where y (t), u (t) are state and control vectors of dimension $(l,1),\;(m,1);\;A_i\,,i=0,1,...,p\;,\;B_j\,,\,j=0,1,...,q$ .The functioning of the system is carried out for $t=0,1,2,\;...,\;N$ based on management $\mathrm{u}(0),\mathrm{u}(1),...,\;\mathrm{u}(N-1)$; initial states are set $y(0),\,y(-1),\,...\,,\,y(-\mathrm{p})$ and initial management $\mathrm{u}(-1),\;...,\;\mathrm{u}(-q)$.

To solve the identification problem, difference vectors are written $\Delta(t, y, v, A, B)$

$$\Delta(t,y,v,A,B)=y(t+1)-\sum_{i=0}^{p}A_i y(t-i)-\sum_{j=0}^{q}B_j v(t-j)-\xi(t)$$

and the functional is formed $q(y, v, A, B)$ [2,3]

$$q(y,v,A,B)=\sum_{t=0}^{N-1}\Delta^T(t,y,v,A,B)\Delta(t,y,v,A,B)\,, \tag{2}$$

where $y,\,v,A,B$ - designations of sequences of vectors and matrices: $y=(y(-p),y(-p+1),...,y(N))$, $v=(v(-q),v(-q+1),...,v(N-1))$, $A=(A_1,...,A_p)$, $B=(B_1,...,B_q)$. Matrices: $A^0=(A_0^0,A_1^0,...,A_p^0)$, $B^0=(B_0^0,B_1^0,...,B_q^0)$, minimizing (2) are taken as a solution to the identification problem

$$(A^0,B^0)=\arg\left\{\min_{A,B}q(y,v,A,B)\right\}\;.$$

It can be seen that (2) is a quadratic form of the elements of the matrices A_i, B_j and is a system of linear equations.

We use the following notation:

$$\varphi_{\bar{i}}(t),\;\bar{i}=1,...,N_M\,,\;\;N_M=p+1+q+1+1\,,$$

$$\varphi_1(t)=y(t),\;\varphi_2(t)=y(t-1),\;...,\;\;\varphi_{p+1}(t)=y(t-p),$$

$$\varphi_{p+2}(t)=v(t),\;...,\;\;\varphi_{p+q+2}(t)=v(t-q),\;\varphi_{N_M}(t)=1.$$

Introducing the notation $\varphi_1(t)=y(t),\;\varphi_2=v(t),\;\varphi_3=1$ для $p = q = 0$, $N_M = 3$ you can write the following expressions:

$$G_{\bar{i},\bar{j}}=\sum_{t=0}^{N-1}\varphi_{\bar{i}}(t)\varphi_{\bar{j}}^T(t)\,,\;D_{\bar{i}}=\sum_{t=0}^{N-1}y(t+1)\varphi_{\bar{i}}^T(t)\,,\;\bar{i},\,\bar{j}=1,2,3\,. \tag{3}$$

Given (3) and based on the structure of functional (2), we can write the following expressions for the matrices $G_{\bar{i},\bar{j}}$ и $D_{\bar{i}}$, $\bar{i},\;\bar{j}=1,...,N_M$:

$$G_{\bar{i},\bar{j}}=\sum_{t=0}^{N-1}\varphi_{\bar{i}}(t)\varphi_{\bar{j}}^T(t)\,,\;D_{\bar{i}}=\sum_{t=0}^{N-1}y(t+1)\varphi_{\bar{i}}^T(t)\,. \tag{4}$$

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Then one can form block matrices ***G***, ***D***,and***X*** as follows [3]: the matrix ***G***is composed of N_M^2 matrices $G_{\bar{i},\bar{j}}^T$; matricesD is made up of N_M matrices $D_{\bar{i}}^T$, located by column; matrix ***X***composed of N_M matrices $A_0^T, ..., A_p^T, B_0^T, ..., B_q^T$, disposable column. Matrices ***G***, ***D***, ***X***have dimensions $(N_{qp}, N_{qp}), (N_{qp}, l), (N_{qp}, l)$, where $N_{qp} = l(p+1) + m(q+1) + 1$.

$$G = \left(\begin{array}{c|c|c|c} G_{11}^T & G_{12}^T & \cdots & G_{1,N_M}^T \\ \hline G_{21}^T & & & \\ \hline G_{31}^T & & & \\ \hline \vdots & \vdots & \vdots & \vdots \\ \hline \vdots & \vdots & \vdots & \vdots \\ \hline \vdots & \vdots & \vdots & \vdots \\ \hline G_{N_M,1}^T & \cdots & \cdots & G_{N_M,N_M}^T \end{array}\right), \quad D = \left(\begin{array}{c} D_1^T \\ \hline D_2^T \\ \hline D_3^T \\ \hline \vdots \\ \hline \vdots \\ \hline \vdots \\ \hline D_{N_M}^T \end{array}\right), \quad X = \left(\begin{array}{c} A_0^T \\ \hline \vdots \\ \hline A_p^T \\ \hline B_0^T \\ \hline \vdots \\ \hline B_q^T \\ \hline C \end{array}\right). \tag{5}$$

Thus, the identification algorithm in this case is reduced to finding matrices $G_{\bar{i},\tilde{j}}$, $D_{\bar{i}}$ on formulas(4); the formation of block matrices G, D (5); calculating the matrix parameters of the system forming the block matrix X, based on the solution of the matrix system

$$GX=D,$$

decaying into l systems of dimension N_{qp}:

$$Gx_k = d_k, \quad k = 1,2,...,l. \tag{6}$$

III. DECISION BASED ON THE REGULAR METHOD

The system of equations (6) can be poorly conditioned, i.e. small changes to the source data may respond to large changes to the solution. The aforementioned circumstance when solving equation (6) leads to the necessity of using regularization methods [9, 12, 13].

In addition, in practical problems, elements, for example, matrices, are often known to us approximately. In these cases, instead of a matrix, we are dealing with some other matrix $\tilde{G}$ such that $\|\tilde{G} - G\| \le h$, where the meaning of the norms is usually determined by the nature of the task. Having instead of matrix G matrix $\tilde{G}$, all the more so, we cannot make a definite judgment on the degeneracy or non-degeneracy of the matrix G. But such matrices $\tilde{G}$ infinitely many, and within the framework of the level of error known to us, they are indistinguishable. Among such “possible exact systems” there may be degenerate ones.

To give numerical stability to the matrix inversion procedure, it is advisable to use the concepts of regular and stable estimation methods [12, 13]. Below is an algorithm for estimating the inverse matrix G^{-1} in equation (6).

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Let the matrix $G=[g_{ij}],\ i,j=1,2,...,n$, non-degenerate. Denote by G_k its upper left part, i.e.. $G_k=[g_{ij}],\ i,j=1,2,...,k$. Matrices $G_k,\ k=1,2,...,n$, non-degenerate. We represent them in the form

$$G^{(k)}=\left[\begin{array}{c|c} G_{11}^{(k-1)} & G_{12}^{(k)} \\ \hline G_{21}^{(k)} & G_{22}^{(k)} \end{array}\right],\ k>1,\ G_{11}^{(1)}=G_{22}^{(1)}=g_{11},\ \ G_{12}^{(1)}=0,\ \ G_{21}^{(1)}=0\,.$$

Following [14,15] of the bordering method, the inverse matrix can be written in the following form

$$\left[G^{(k)}\right]^{-1}=\left[\begin{array}{c|c} P^{(k-1)} & R^{(k)} \\ \hline N^{(k)} & V^{(k)} \end{array}\right].$$

while

$$V^{(k)}=\left[G_{22}^{(k)}-G_{21}^{(k)}\left[G_{11}^{(k-1)}\right]^{-1}G_{12}^{(k)}\right]^{-1},$$

$$R^{(k)}=-V^{(k)}\left[G_{11}^{(k-1)}\right]^{-1}G_{12}^{(k)},\ \ N^{(k)}=-V^{(k)}G_{21}^{(k)}\left[G_{11}^{(k-1)}\right]^{-1}, \tag{7}$$

$$P^{(k-1)}=\left[G_{11}^{(k-1)}\right]^{-1}+V^{(k)}\left[G_{11}^{(k-1)}\right]^{-1}G_{12}^{(k)}\,G_{21}^{(k)}\left[G_{11}^{(k-1)}\right]^{-1}.$$

Performing calculations by formulas (7) at, we can obtain $G_n^{-1}=G^{-1}$.

In the case under consideration, it is advisable to use the Gauss method [14,16-18] to invert the matrix, according to which a sequence of matrices is constructed $G^{(k)},\ k=0,1,...,\ G^{(0)}=G$, on

$$G^{(k)}=\left[\begin{array}{c|c} G_{11}^{(k)} & G_{12}^{(k)} \\ \hline G_{21}^{(k)} & G_{22}^{(k)} \end{array}\right],$$

где $G_{11}^{(k)}$ – обратимая матрица размера $k\times k$.

Для этого на *k*-м шаге у имеющейся клетки $G_{22}^{(k)}$ ищется ведущий τs -й элемент

$$\left|g_{\tau s}^{(k)}\right|=\max_{k<i\le n,k<j\le m}\left|g_{ij}^{(k)}\right|,$$

where $g_{ij}^{(k)}$ if*ij*-йэelement of matrix $G^{(k)}$

If $\left|g_{\tau s}^{(k)}\right|>\varepsilon$, then permutation is done τ -йstrings and*s*- th column with $(k+1)$ - mi row and column matrix $G^{(k)}$. Then it is recalculated according to the cell obtained after rearrangements

$$G_{22}^{(k)}=\left[\begin{array}{c|c} g_{k+1,k+1}^{(k)} & d^{(k)} \\ \hline \vartheta^{(k)} & W^{(k)} \end{array}\right]$$

matrix $G^{(k+1)}$, while

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$$G^{(k+1)} = \left[\begin{array}{c:c} G_{11}^{(k)} & G_{12}^{(k)} \\ \hdashline G_{21}^{(k)} & \left[\begin{array}{c:c} g_{k+1,k+1}^{(k)} & d^{(k)} \\ \hdashline \alpha^{(k)} & G_{22}^{(k+1)} \end{array}\right] \end{array}\right],$$

где $G_{22}^{(k+1)} = W^{(k)} - \alpha^{(k)} d^{(k)}$, $\alpha^{(k)} = \left(g_{k+1,k+1}^{(k)}\right)^{-1} \vartheta^{(k)}$.

If $\left|g_{\tau s}^{(k)}\right| \le \varepsilon$, then the factorization process is terminated and non-orthogonal matrix factorization is determined*G*in the form

$$G_{\varepsilon} = U_k R_k,\ U_k^T = \left[U_1^T \vdots U_2^T\right],$$

$$R_k = \left[R_1 \vdots R_2\right],\ U_2 = G_{21}^{(k)},$$

$$R_2 = G_{12}^{(k)}, \quad U_1 = \begin{bmatrix} 1 & 0 & \dots & 0 \\ g_{21}^{(k)} & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ g_{k1}^{(k)} & g_{k2}^{(k)} & \dots & 1 \end{bmatrix}, \quad R_1 = \begin{bmatrix} g_{11}^{(k)} & g_{12}^{(k)} & \dots & g_{1k}^{(k)} \\ 0 & g_{22}^{(k)} & \dots & g_{2k}^{(k)} \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & g_{kk}^{(k)} \end{bmatrix}.$$

The approximation for a pseudoinverse matrix is constructed in this way [13,17]:

$$G_{\varepsilon}^{+} = R_k^{+} U_k^{+}. \qquad (8)$$

Calculation R^{+} and U^{+} in (8) when R and U^T accordingly, upper trapezoidal matrices are effectively carried out by orthogonal factorization $R = SP$ using Givens or Householder transformations [15,17], where*S* – lower triangular square, *P* – orthogonal matrix. Then $R^{+} = P^T S^{-1}$.

IV. Conclusion

The presented regularized identification algorithms based on non-orthogonal factorizations and pseudoinversions of square matrices increase the accuracy of estimating the parameters of the class of dynamic control objects under consideration and predicting the output variables of a real technological system.

References

[1] Emelyanov S.V., Korovin S.K., Rykov A.S. and other Methods of identification of industrial facilities in control systems. Kemerovo: Kuzbassvuzizdat, 2007.- 307 p.

[2] Ljung L. Identification of systems. Theory for the user / Transl. from English / Ed. Ya.Z. Tsypkina. - M.: Science. 1991.- 432 p.

[3] Getmanov V.G., Zhirov M.V., Shakhovskoy A.V. Identification Algorithm for a Linear Discrete Dynamic Control System // Automation and Automation, No. 4, 2001. –p. 27-34.

[4] Zhirov M.V. Identification and adaptive control of technological processes with non-stationary parameters / M.V. Zhirov, V.V. Makarov, V.V. Soldiers - M.: Publishing House of MSTU. N.E. Bauman, 2011.- 203 p.

[5] Igamberdiev H.Z., Sevinov J.U., Zaripov O.O. Regular methods and algorithms for the synthesis of adaptive control systems with customizable models. - T.: TashGTU, 2014.- 160 p.

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[6] Gubarev V.F., Gummel A.V., Melnichuk S.V., Tochilin P.A. Identification of multidimensional systems. Problems of correctness and control // XII All-Russian meeting on management problems of the VSPU-2014. Moscow June 16-19, 2014. –P.2635-2645.
[7] Kantor O.G., Spivak S.I., Talipova R.R. Parametric identification of mathematical models of chemical kinetics // Systems and Tools Inform., No. 3 (27), 2017. –P.145–154.
[8] Karabutov N.N. Adaptive System Identification: Information Synthesis. Publishing stereotype. URSS 2016.- 384 p.
[9] Voskoboinikov Yu.E. Stable methods and algorithms for parametric identification. - Novosibirsk: NGASU (Sibstrin), 2006.-180 p.
[10] Igamberdiyev H. Z.,Yusupbekov A. N., Zaripov O. O., Sevinov J. U., Algorithms of adaptive identification of uncertain operated objects in dynamical models // Procedia Computer Science. Volume 120, 2017, Pages 854-861. https://doi.org/10.1016/j.procs.2017.11.318.
[11] Yusupbekov N.R., Igamberdiev H.Z., Mamirov U.F., Algorithms of sustainable estimation of unknown input signals in control systems, in Autom. Mob. Rob. Intell. Syst. 2018, Vol. 12, Issue 4, -pp. 83–86. https://doi.org/10.14313/JAMRIS_4-2018/29.
[12] Tikhonov A.N., Goncharsky A.V., Stepanov V.V., Yagola A.G. Numerical methods for solving ill-posed problems, Moscow: Nauka, 1990.
[13] Kabanikhin S.I. Inverse and incorrect tasks. - Novosibirsk: Siberian Scientific Publishing House, 2009. - 457 p.
[14] Gantmakher F.R. Matrix theory. - M.: Nauka, 2010.- 560 p.
[15] Horn R., Johnson C. Matrix analysis: Per. from English –M.: Mir., 1989. –655p.
[16] Demmel J. Computational linear algebra. Theory and applications: Per. from English –M.: Mir, 2001 – 430 p.
[17] Lawson Ch., Henson R. Numerical solution of problems of the least squares method / Per. from English – M.: Science. Ch. ed. Phys.-Math. lit., 1986. –232 p.
[18] Meleshko V.I. On regularized nonorthogonal factorizations and pseudoinversions of perturbed matrices // Journal of Computational Mathematics and Mathematical Physics. Volume 26, 1986, No. 4. –p.485-498.
[19] Sirak, S.V., Shchetinin, E.V., Mikhalchenko, A.V., Bykova, N.I., Mikhalchenko, D.V. Local therapy of chronic recurrent aphthous stomatitis (Clinical-and-biochemical aspects)(2018) International Journal of Pharmaceutical Research, 10 (4), pp. 159-163. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85056113741&partnerID=40&md5=5107358bc8424780aad1879a0439011b

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