ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 8 , August 2019

Algorithms for Parametric Identification of the Object of Management and Evaluation of the Regulator in a Closed Control System

Igamberdiev Husan Zakirovich, Sevinov Jasur Usmonovich, Djurayev Farrukh Dustmirzayevich

Professor, Department of Information processing and control systems, Faculty Electronic and Automatic, Tashkent State Technical University, Uzbekistan
Professor, Department of Information processing and control systems, Faculty Electronic and Automatic, Tashkent State Technical University Uzbekistan,
Scientific adviser, Department of Information processing and control systems, Tashkent State Technical University, Tashkent, Uzbekistan

ABSTRACT: The results of the formation of regular algorithms for identifying the parameters of an object and a controller in a closed-loop control system are presented. Taking into account that the initial system of equations for estimating the parameters of an object and a controller is, as a rule, poorly conditioned, it becomes necessary to use methods for solving incorrect problems. To stabilize the solution of the considered estimation problem, the concepts of the principle of iterative regularization using the method of variational inequalities are used. Algorithms for the iterative sequence and stopping the iterative process are provided that ensure the convergence of the desired estimates of the parameters of the object and the controller almost certainly to the true values.

KEY WORDS: closed dynamic system, control object, identification, iterative regularization principle, variational inequality method, incorrectly posed problem, regularization.

I. INTRODUCTION

A promising direction for creating a general method for the synthesis of operational identification algorithms can be the basic provisions according to which the identification system should be presented in the form of a closed dynamic system in which the object model is the structure of the object model [1-3]. This approach gives positive results in the formation of structures of filtering algorithms and dynamic observers.

Based on the theoretical provisions [4,5] and developments on the synthesis of state observers [6], it seems appropriate to consider the identifier structure in the form of a closed dynamic system. The control object in this case is a model of an object of a given structure with unknown parameters, and parametric control is developed by the regulator from the condition of minimizing the norm from the output effects of the model and the full-scale object [7]. With this representation of the identifier structure for the synthesis of the regulator, one can use well-developed methods of control theory. The meaningful statement of the problem in this case is reduced to the following scheme.

The general structure of the identifier is given in the form of a closed dynamic system (see Fig. 1); many structures of object models, assignment to error properties ε_Y . It is necessary to synthesize identification algorithms.

The presented statement of the problem differs in that it is proposed to synthesize a dynamic feedback system for identifying the coefficients. Moreover, in the synthesis of identification algorithms, models and algorithms of the theory of automatic regulation are used.

It is precisely this formulation of the problem that makes it possible to fully utilize the achievements of the modern theory of automatic control and expand the list of object models, including dynamic objects of complex structure.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 8 , August 2019

When solving such problems, it is often not possible to open feedback due to the fact that it is an integral part of the system under study or for safety reasons, when an open circuit is unstable or stringent requirements are imposed on the system not to leave its parameters for some given area. In addition, the data obtained from the results of the operation of the system in a closed loop more accurately reflect the real situation compared with the data obtained by opening the feedback [1,8].

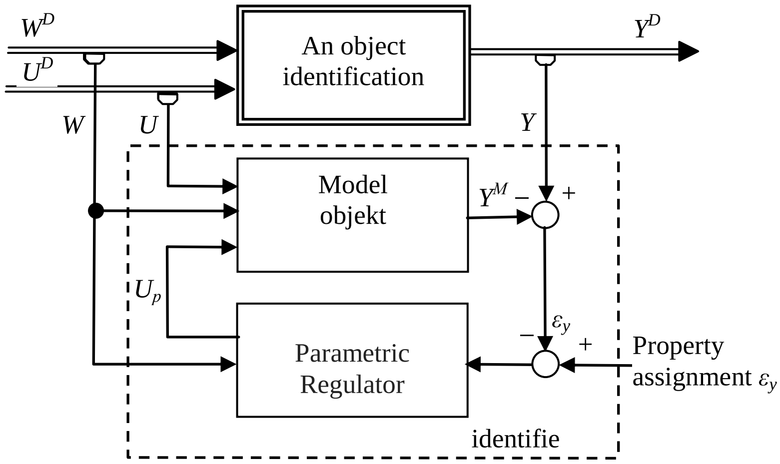

Fig. 1. General identifier structure: W, U, Y – measured external, control and output actions; U_p – parametric control action on the object model; ε_Y – modeling error.

Currently, there is no universal approach to the identification of closed systems. In each case, different models, methods, techniques and algorithms are used [9-12].

II. FORMULATION OF THE PROBLEM

Consider the class of models with noise in the object and control device, which is widely used in practical problems. This class of control systems with noise in the object and the control device can be described by equations of the form [2,3]:

$$\begin{aligned} y_n &= \sum_{i=1}^{p} a_i y_{n-i} + \sum_{i=1}^{q} b_i u_{n-i} + \sigma_1 v_{1n}, \\ u_n &= \sum_{i=1}^{\mu} c_i y_{n-i} + \sum_{i=1}^{\upsilon} d_i u_{n-i} + \sigma_2 v_{2n}, \end{aligned} \tag{1}$$

where $\{u_n\}$, $\{y_n\}$ – observed sequences at the input and output of the object, respectively; $\{v_{1n}\}$, $\{v_{2n}\}$ – Gaussian sequences with zero expectation and unit dispersion; joint distribution is Gaussian. Wherein

$$M[v_{1k}\, v_{1j}] = M[v_{2k}\, v_{2j}] = \delta_{kj}, \quad M[v_{1n}\, y_{n-j}] = M[v_{2n}\, y_{n-j}] = 0,\ M[v_{1n}\, u_{n-j}] = M[v_{2n}\, u_{n-j}] = 0,$$

$M[v_{1n}\, u_{2m}] = \rho\delta_{nm} \quad (j \ge 1), \quad 1 > \rho > -1,\ \delta_{nm}$ – Kronecker symbol. It is necessary to evaluate the parameters of the object $\{a_i\}, \{b_i\}$ and control device $\{c_i\}, \{d_i\}$ according to the observation $\{u_n\}, \{y_n\}$, where $n = 0, 1, \dots, N$.

Based on [2,3,13] the system of equations (1) with zero initial conditions can be written in the following matrix form

$$\begin{aligned} Y_N &= S_1\theta_1 + S_2\theta_2 + \sigma_1 \bar{v}_{1N}, \\ S_N &= S_1\theta_3 + S_2\theta_4 + \sigma_2 \bar{v}_{2N}, \end{aligned} \tag{2}$$

where

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 8 , August 2019

$$Y_N^T = (y_0, y_1, \ldots, y_N),\ S_N^T = (u_0 - c_0 y_0,\ u_1 - c_0 y_1, \ldots, u_T - c_0 y_N),$$

$$\bar{v}_{iN}^T = (v_{i0}, v_{i1}, \ldots, v_{iN}) \quad (i = 1, 2),$$

$$S_1 = (V_N Y_N, \ldots, V_N^k Y_N,\ V_N U_N, \ldots, V_N^I U_N),\ S_2 = (V_N^{k+1} Y_N, \ldots, V_N^p Y_N,\ V_N^{I+1} U_N, \ldots, V_N^q U_N), \tag{3}$$

$$S_3 = (V_N^{k+1} Y_N, \ldots, V_N^{\mu} Y_N,\ V_N^{I+1} U_N, \ldots, V_N^{\upsilon} U_N),\ U_N^T = (u_0, u_1, \ldots, u_N),$$

$$V_N = \left\|\delta_{i,j+1}\right\| \text{ - matrix } (N+1)\times(N+1),$$

$$K = \begin{cases} p, & p \le \mu; \\ \mu, & p > \mu; \end{cases} \quad I = \begin{cases} q, & q \le \upsilon; \\ \upsilon, & q > \upsilon; \end{cases}$$

$$\theta_1^T = (a_1, \ldots, a_k,\ b_1, \ldots, b_I),\ \theta_2^T = (a_{k+1}, \ldots, a_p,\ b_{I+1}, \ldots, b_q),$$

$$\theta_3^T = (c_1, \ldots, c_k,\ d_1, \ldots, d_I),\ \theta_4^T = (c_{k+1}, \ldots, c_{\mu},\ d_{I+1}, \ldots, d_{\upsilon}),$$

III. SOLUTION OF THE TASK

By the Gaussian assumption, the joint density of a sequence of random variables $y_N, u_N, y_{N-1}, u_{N-1}, \ldots, y_0, u_0$ will have the form

$$p(y_N, u_N, y_{N-1}, u_{N-1}, \ldots, y_0, u_0) = \frac{1}{(2\pi)^{N/2}\,|R|^{1/2}} \times$$

$$\times \exp\left\{ -\frac{1}{2} \begin{bmatrix} Y_N - S_1\theta_1 - S_2\theta_2 \\ S_N - S_1\theta_2 - S_3\theta_4 \end{bmatrix}^T R^{-1} \begin{bmatrix} Y_N - S_1\theta_1 - S_2\theta_2 \\ S_N - S_1\theta_3 - S_3\theta_4 \end{bmatrix} \right\},$$

where $R = \begin{bmatrix} \sigma_1^2 I_N & \rho\sigma_1\sigma_2 I_N \\ \rho\sigma_1\sigma_2 I_T & \sigma_2^2 I_N \end{bmatrix}, I_N$ – unit matrix $(N+1)\times(N+1)$.

Then, to evaluate the parameters of the object and the control device, you can use the following system of equations

$$S \cdot \theta = y. \tag{4}$$

where

$$S = \begin{bmatrix} \alpha_{11} S_1^T S_1 & \alpha_{11} S_1^T S_2 & \alpha_{12} S_1^T S_1 & \alpha_{12} S_1^T S_3 \\ \alpha_{11} S_2^T S_1 & \alpha_{11} S_2^T S_2 & \alpha_{12} S_2^T S_1 & \alpha_{12} S_2^T S_3 \\ \alpha_{12} S_3^T S_1 & \alpha_{12} S_3^T S_2 & \alpha_{22} S_3^T S_1 & \alpha_{22} S_3^T S_3 \\ \alpha_{12} S_1^T S_1 & \alpha_{12} S_1^T S_2 & \alpha_{22} S_1^T S_1 & \alpha_{22} S_1^T S_3 \end{bmatrix},\ \theta = \begin{bmatrix} \hat{\theta}_1 \\ \hat{\theta}_2 \\ \hat{\theta}_3 \\ \hat{\theta}_4 \end{bmatrix},\ y = \begin{bmatrix} \alpha_{11} S_1^T Y_N + \alpha_{12} S_1^T S_N \\ \alpha_{11} S_2^T Y_N + \alpha_{12} S_2^T S_N \\ \alpha_{12} S_3^T Y_N + \alpha_{22} S_3^T S_N \\ \alpha_{12} S_1^T Y_N + \alpha_{22} S_1^T S_N \end{bmatrix},$$

where $\alpha_{11} = \sigma_2^2, \alpha_{12} = -\rho\sigma_1\sigma_2,\ \alpha_{22} = \sigma_1^2$.

In (4), S linear bounded irreversible operator acting in a Hilbert space (sometimes from H1 to H2), the balance relation being complicated by the requirement, $\theta \in Q$, Q –is a closed convex set in.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 8 , August 2019

Under the above assumptions, the solution to problem (4) may be absent or unstable to small variations of the initial data. This means that when solving equation (4), regular methods should be used [14–20]. One of the classical methods for solving linear and nonlinear equations is the regularization of these equations by a small term that improves their qualitative characteristics, with the subsequent derivation of a priori estimates of the solutions and the regularization parameter tending to zero. One of the main approaches to the construction of such algorithms is the principle of iterative regularization [16, 20].

It is known [16-18] that the solution of an operator equation of type (4) can be reduced to the problem of minimizing the residual functional, that is, finding a quasisolution of the equation on Q in sense of V.K. Ivanov. As a residual, we can take a functional of the form

$$\Phi(\theta) = \|S\theta - y\|_H^{\ 2}.$$

The problem of finding the minimum of a convex functional $\Phi(\theta)$ on closed convex set $Q \subseteq H$ equivalent to the problem of solving the variational inequality [16]

$$(F(\theta), \theta - d) \le 0 \quad \forall d \in Q, \tag{5}$$

if for example, $\Phi(\theta)$ has a subdifferential $\partial\Phi = F$ at every point *Q*. In this case, in (5), as *F*, we can choose the subdifferential $\Phi(\theta)$, $\partial\Phi = F$, $D_F \supseteq Q$, or ordinary gradient in differentiable case [16-18]. Insofar as *S* – lineat operator acting in *H*, then functiona $\Phi(\theta)$ is convex and has a subdifferential.

To make an item $\theta \in Q$ was a solution to inequality (5), when *F* acts in Hilbert space *H*, necessary and sufficient to θ satisfied the equation

$$\theta = P_Q(\theta - \alpha F(\theta)) \tag{6}$$

for some $\alpha > 0$. Here P_Q – the metric projection onto *Q*. If equation (6) is satisfied for some $\alpha > 0$, then it is valid for a given θ for an $\alpha > 0$.

If $\Phi(\theta)$ is a convex functional, then $F(\theta)$ is a monotone operator [19]. The monotonicity of the operator $F(\theta)$ means that for all elements of $\theta, d \in G$ the condition

$$(F(\theta_2) - F(\theta_1), \theta_2 - \theta_1) \ge 0, \quad \forall \theta_1, \theta_2 \in Q, \tag{7}$$

where the bracket $(\ \cdot\ ,\ \cdot\ )$ on the left side of (7) means the scalar product.

Thus, it is necessary to determine those θ that satisfy the variational inequality (5), where $F(\theta)$ is the monotone operator.

Let $M(\theta)$ be an operator possessing the property of strong monotonicity $Q \subset H$, i.e.

$$(M(\theta_1) - M(\theta_2), \theta_1 - \theta_2) \ge \xi_M \|\theta_1 - \theta_2\|^2, \quad \xi_M > 0.$$

When solving equation (4), instead of the main inequality (5), it is advisable to use the family of auxiliary inequalities

$$(F_\delta(\theta) + \varepsilon M(\theta), \theta - d) \le 0, \quad \forall d \in Q, \ \varepsilon > 0. \tag{8}$$

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Issue 8 , August 2019

The variational inequalities (8) have significantly better properties, since the operator $F_\delta(\theta)+\varepsilon M(\theta)$ is strongly monotone for a fixed $\varepsilon>0$, and standard iterative methods are applicable for solving them [16-18]. On the other hand, variational inequalities (8) for $\varepsilon\to 0$ have approximating Browder – Tikhonov properties [20] for problem (5).

In this case, you can, for example, accept $M(\theta)=\theta$ and $\xi_M=1$. Inequality (8) can be called a regularized inequality. The additive is similar to the stabilizing additive of A.N. Tikhonov in the theory of incorrectly posed extremal problems.

If we assume only the existence of a solution to problem (5), then under broad assumptions about F and M [16], it can be argued that for any $\varepsilon>0$ there is θ_ε - the only solution (8) and, moreover, there exists a limit relation

$$\lim_{\varepsilon\to 0}\left\|\theta_\varepsilon-\theta^*\right\|=0, \tag{9}$$

where $\theta^*\in\Xi$ is the only solution to the variational inequality $(M(\theta),\theta-d)\le 0,\ \ \forall d\in\Xi$, Ξ is the set of solutions (4).

Following [20], it can be shown that under the conditions considered above, the iterative sequence $\hat\theta_r$ can be written in the following form:

$$\hat\theta_{r+1}=P_Q(\hat\theta_r-\alpha_r(F_\delta(\hat\theta_r)+\varepsilon_r M(\hat\theta_r))),\ r=0,1,\ldots, \tag{10}$$

where P_Q is the metric projector; $\alpha_r>0,\ \varepsilon_r>0$ - regularization parameters, r – iteration number,

$$\lim_{r\to\infty}\frac{\alpha_r}{\varepsilon_r}=0,\ \lim_{r\to\infty}\varepsilon_r=0,\ \sum_{n=1}^{\infty}\alpha_r\varepsilon_r=\infty,\ \lim_{r\to\infty}\frac{|\varepsilon_r-\varepsilon_{r+1}|}{\alpha_r\varepsilon_r^2}=0.$$

$$\alpha_r=(1+r)^{-1/2},\ \varepsilon_r=(1+r)^{-p},\ \ 0<p<1/2.$$

The iterative process under consideration can be stopped on the basis of relations of the form [16]:

$$\lim_{\delta\to 0}\delta/\varepsilon_{r(\delta)}=0,\ \lim_{\delta\to 0}\delta^{1/2}/\varepsilon_{r(\delta)}^2=0.$$

The parameter δ characterizes the error level of the job F and is assumed to be known, with $\rho(F_\delta-F)\le\delta,\ \delta\ge 0,\ F_\delta\in\mathscr{F}$, where $\mathscr{F}$ is a class of approximate operators.

IV. CONCLUSION

The developed regular algorithms for identifying the parameters of an object and a regulator in a closed-loop control system based on the principle of iterative regularization using the method of variational inequalities ensure the convergence of the desired estimates of the parameters of the object and the regulator almost surely to true values.

REFERENCES

1. Zybin E.Yu. On the identifiability of linear dynamic systems in a closed loop in the normal operation mode. Izvestiya SFedU. Technical science. №4(165), 2015. -PP. 160-170.
2. Vorchik B.G., Fetisov V.N., Shteinberg Sh.E. Identification of a stochastic closed system // Automation and Remote Control, 1973, № 7. –PP.41-52.
3. Vorchik B.G. Identification of an object in a stochastic closed system // Automation and Remote Control, 1975, №4. –PP.32-48.

4. 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.
5. Bunich A.L., Bakhtadze N.N. Synthesis and application of discrete control systems with identifier / V.A. Lototsky. Moscow: Science, 2003. - 232 p.
6. Korovin S.K., Fomichev V.V. State observers for linear systems with uncertainty. Moscow: Science, 2007. - 224 p.
7. Myshlyaev L.P., Ageev D.A. Synthesis of identifiers in the form of closed dynamical systems // university news. Ferrous metallurgy. 2010. №12. PP. 60-62.
8. Shardt Y., Huang B. Closed-loop identification condition for ARMAX models using routine operating data, Automatica, 2011, Vol. 47, №7. -P. 1534-1537.
9. Ljung L. Prediction error estimation methods, Circuits, systems, and signal processing, 2002, Vol. 21, №1. -P. 11-21.
10. Van der Veen G., van Wingerden J.-W., Bergamasco M., Lovera M., Verhaegen M. Closed-loop subspace identification methods: an overview, IET Control Theory & Applications, 2013, Vol.7, №10. -P. 1339-1358.
11. Igamberdiyev, H.Z., Yusupbekov, A.N., Zaripov, O.O. Regular methods of estimation and control of dynamic objects in the conditions of uncertainty. Tashkent: Tashkent State Technical University. 2012. – 320 p.
12. Igamberdiev H.Z., Sevinov J.U., Zaripov O.O. Regular methods and algorithms for the synthesis of adaptive control systems with customizable models. - T.: Tashkent State Technical University, 2014. - 160 p.
13. Steinberg Sh.E. Identification in control systems. Moscow: Energoatomizdat. 1987.
14. Tikhonov A.N., Goncharsky A.V., Stepanov V.V., Yagola A.G. Numerical methods for solving ill-posed problems. Moscow: Science. 1990.
15. Lavrentiev M.M., Savelyev L.Ya. Linear operators and ill-posed problems, Moscow: Science, 1991.
16. Bakushinskij A.B., Goncharsky A.V. Iterative approach of ill-conditioner problems solution. Moscow: Science. 1989. – 128 p.
17. Vajnikko G.M, Veretennikov A.U. Iterative procedure in incorrect problems. Moscow: Science. 1986.
18. Alifanov O.M., Artyukhin E.A., Rumyantsev S.V. Extreme methods for solving ill-posed problems, Moscow: Science, 1988.
19. Ill-conceived problems of natural science / Edited by A.N. Tikhonov, A.V. Goncharsky. Moscow: Publishing house of Moscow University, 1987. - 299 p.
20. Bakushinsky A.B., Goncharsky A.V. Incorrect tasks. Numerical methods and applications. Moscow: Moscow Publishing House. University, 1989. -199 c.