Simplified Adaptation for the Dynamic Models Objects of the One Class

Alexander Verevkin
Industrial Process Automation Department
Ufa State Petroleum Technological University
Ufa, Russian Federation
apverevkin@mail.ru

Timur Murtazin
Industrial Process Automation Department
Ufa State Petroleum Technological University
Ufa, Russian Federation
tm.murtazin@mail.ru

Zukhra Pavlova
Industrial Process Automation Department
Ufa State Petroleum Technological University
Ufa, Russian Federation
e-mail: zpavlova@mail.ru

Abstract1—Its need for the construction of Advanced Process Control (APC) system as part of the automated process control system this article considers the task of modeling and adapting the dynamic characteristics of the complex control objects elements represented by cognitive maps. The models in the form of second-order difference equations are taken as the basic structure of cognitive map relations models. Models of this type allow you to simulate the dynamics of objects in controllers in real time and solve the problem of functional diagnostics of measuring instruments, data verification in the process control system. This type of model allows you to simply adapt the parameters of the difference equation to varying characteristics of the technological object and, thus, display the non-linearity, non-stationary and multi-dimensionality of the control object. It is shown that for many refining processes, the adjustment of models in the form of second-order difference equations can be carried out by periodically changing one coefficient without significant loss of accuracy. The criterion for the start of the adaptation procedure is the appearance of a stable difference between the dynamic characteristics of the object and the model. The adaptation procedure is reduced to recalculating the value of one of the difference equation coefficients based on the value of the simulation error. The proposed description of the dynamic characteristics of the technological object in the form of difference equations and the procedure of adapting the model to the changing characteristics of the object allow their algorithmic implementation within the framework of the typing controllers resources, which reduces the cost and simplifies the development of APC systems.

Keywords—advanced control, modeling, situational modeling, dynamic characteristics, adaptation, difference equation, real time.

I. Introduction

One of the main issues in the tasks developing of advanced process control systems (APC), is to obtain a dynamic model for predicting of the control object state when selecting controls. This strategy of defining controls based on predictive models is called MPC (Model Predictive Control) technology [1]. Wide application in describing the dynamic characteristics of control systems objects that are developed by means of well-known software applications, such as PACE (Platform for Advanced Control and Estimation - Yokogawa Electric Corporation), Profit®Suite (Honeywell), has differential equations (RU), transfer functions PF) and models in terms of the state space [1,2]. However, the main disadvantage of such models is their linear nature, which makes it impossible to use them in a wide range of changes in the technological parameters of nonlinear dynamic objects. This determines the need to obtain models with different parameters (or even structure) for different the technological object modes. In its meaning, such an approach is close to situational modeling [3].

In terms of managing a real nonlinear objects providing practical operability without significant costs for maintaining APC systems implies the availability of subsystems automatic (or automated) adaptation of the models on the basis of which MPC operates. In turn, a mandatory requirement for the models used for operational management, diagnostics of the state of technological objects and controls is the ability to calculate parameters and indicators in real time [4-7]. This means that model adaptation procedures should allow for the adjustment of models in less time than the parameters of the object state would change. Usually, an approach to adjusting a dynamic model is used, when parameters are adjusted periodically according to the results of a comparison predicted values with actual observations for a certain period. In this case, as a rule, the least squares method is used to minimize the residual error of the model [8-11].

To correct the result of calculating the dynamic model in real time, the model residual is added to the calculated value for a given interval, in assuming that the modeling error over n intervals in the past will be saved:

$$Y_{прогн}(t) = Y_{сим.}(t) + E(t-n),$$

where $Y_{прогн}, Y_{сим.}$ -is the predicted and calculated value of the parameter, E - . is the prediction error at

(t-n) step.

Thus, the model output is shifted by the magnitude of the error; however, the model parameters do not change.

The paper considers another approach to the adjustment of dynamic models in real time, which involves, among other things, adjusting the parameters.

II. Modeling the dynamic characteristics of the control object by difference equations (DE)

In accordance with the well-known rule A. Yu. Ishlinsky, most of the dynamic characteristics of an object in a wide range of variation of process variables can be approximated by a DE or transfer functions (TF) of the second and third order.

The advantage of DE is that their structure can be justified on the basis for the accuracy of the dynamic characteristics approximation, and the coefficients of DE can be obtained by known methods of regression analysis. In addition, DE allows you to simply simulate nonlinear objects and ensure the adequacy of models with large changes in technological regimes. The disadvantage is that the accuracy of the transient characteristics predictive by DE is determined by the quantization step of the function, which can be different for different transmission channels. The same sampling step for different channels leads to the known problems of choosing a quantization period, which are similar to the problems of numerical integration of differential equations systems. Models in terms of state space are easily parameterized, but difficulties arise with the presence of delays in the object.

The structure of the DE can be obtained from the second-order TF for a small (relatively characteristic time constant of the object) quantization step as

$$y = c_1 * x + c_2 * y(l-1) + c_3 * y(l-2), \qquad (1)$$

where c_1, c_2, c_3 - coefficients DE, $y(l-1)$, $y(l-2)$ – the value (state) of the i – th output parameter at the calculation step $(l-1)$, $(l-2)$ respectively.

The coefficients can be obtained, for example, by the least squares method by processing time series for a given observation interval.

Representing a second order differential equation in the form:

$$T^2 \frac{d^2y}{dt^2} + 2\zeta T \frac{dy}{dt} + y = kx, \qquad (2)$$

you can get the expression for the calculation of the coefficients DE (1):

$$c_1 = \frac{k}{T^2/\theta^2 + 2\zeta T/\theta + 1}, \quad c_2 = \frac{2T^2/\theta^2 + 2\zeta T/\theta}{T^2/\theta^2 + 2\zeta T/\theta + 1}, \qquad (3)$$

$$c_3 = \frac{T^2/\theta^2}{T^2/\theta^2 + 2\zeta T/\theta + 1}$$

where T – object time constant, ς – damping factor, k – object gain, θ – discretization step of a continuous function.

Analysis (3) leads to the following conclusions:

1. Real objects are usually stable and are described by DE with coefficients in limited ranges: $c_3 \in (-1,0)$, $c_2 \in (1,2)$, $c_2 < 1 - c_3$;
2. For large values $T/\theta >> 1$ coefficient sensitivity c_1, c_2, c_3 to change T dramatically reduced;
3. The coefficient c_1 is weakly dependent on T/θ and ζ but to a large extent determined by the gain k .

Considering that the transition from model in the TF form to a model in the DE form with a relatively small time discretization step, is well known when modeling technological objects in real time as the main one, it is proposed to adopt the DE for describing the dynamic characteristics of the control object.

III. Adjustment of difference equations based on the results of observations at a real control object

In [12], it was shown that for many refining processes, the adjustment static model of a type $B = a_0 + a \cdot P$ (where B is the vector of calculated values of the model, a_0, a_1 are vectors of free and associated coefficients of the model, P is the vector of defining process parameters, when the characteristics of an object change) for changing characteristics of an object is possible by changing free member a_0 without significant loss of calculation accuracy B.

This allows us to simplify the procedure for adapting a static model. Consider the possibilities of a similar adaptation method for dynamic models in the form of DE.

When describing the object's dynamic between the input parameters of the model and the output using sufficiently weak constraints on the left hand side coefficients of the differential equations (2) (which are almost always performed for real objects), we can suggest adapting the dynamic model to the changing characteristics of the object by adjusting only the static gain coefficient in the DE.

Taking into account the above, we can suggest a method for adjusting the switchgear when simulating transient modes of a technological object in real time:

1. The calculation the parameters of the object state on the model and the magnitude of the deviation as

$$E = |Y - D|, \qquad (4)$$

where Y, E, D – vector of model output values, discrepancies and observable values of simulated variables.

2. Adjustment the parameters C_1 DE (1) when a stable difference appears between the dynamic characteristics of the object D and the model by more than the specified value of the model error $E^{зад.}$ through the ratio $C_1^* = F(K, C_2, C_3)$ or $C_1^* = F(K, T, \theta)$.

Gain factors K are determined by the steady-state value of the observed variable D.

After the adjustment, an object model is obtained with new parameters:

$$Y = C_1^* \cdot X + C_2 \cdot Y(k-1) + C_3 \cdot Y(k-2).$$

Thus, descriptions the dynamic characteristics of a technological object in the form DE allow you to adapt the model in accordance with the observed (measured) parameters of the object by adjusting the one coefficient, which greatly simplifies the task of setting the dynamic model object used by MPC technology.

IV. Application of the proposed methods for adjusting the DE

To illustrate the proposed approach of adapting the model, we consider some control object.

Let the model M_1be obtained for calculating the parameter p_1

$$p_1(k) = 0.154 \cdot x(k) + 1.453 \cdot p_1(k-1) - 0.546 \cdot p_1(k-2)$$

Figure1shows that there is an increase in the error in calculating the parameter p_1, starting from the 40th discrete step, and due to the change in the characteristics of the object along the considered channel of transmission of exposure.

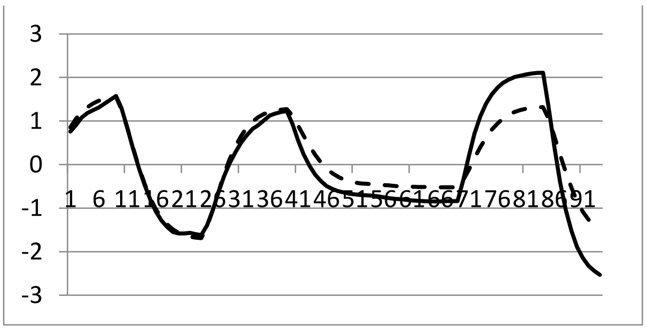

Figure 1- The result of the simulation parameter p_1
((solid line) - change the parameter of the control object,
(dashed line) - the calculated value of the parameter for the model M_1).

After the adjustment according to the proposed procedure, after the 40-th step, the model M_1^{cor} takes the form:

$$p_1(k) = 0.248 \cdot x(k) + 1.453 \cdot p_1(k-1) - 0.546 \cdot p_1(k-2)$$

Figure 2 shows the result of the parameter simulation using the adjusted model $M_1^{cor.}$.

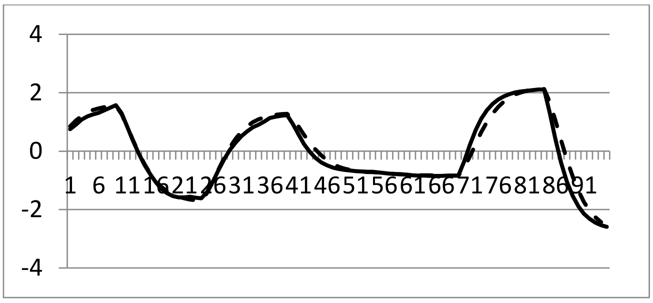

Figure 2. - The result of the calculation of the parameter p_1, taking into account the adjustment of the model M_1
((solid line) - change the parameter of the control object,
-(dashed line) - calculated value of the parameter by the model M_1^{cor}.

V. Conclusions

Based on the considered example, we can draw the following conclusions.

1. The proposed method the adapting model in form DE to changing object characteristics makes it possible to quite simply obtain dynamic models for the purposes of operational control in real time.
2. On the basis of the proposed adaptation method models in form DE it is possible to propose the development of a situational dynamic model of an object with a mechanism for identifying the situation based on finite-automatic models for analyzing the situation [13].
3. The proposed procedure for adapting the model allows for its algorithmization and implementation within the framework on the resources of serial controllers, which reduces the cost and simplifies the development of APC systems.

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