SYNTHESIS OF ROBUST NONLINEAR CONTROL LAW UNSTEADY DYNAMIC OBJECTS

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Abstract: An adaptive identifier for neuro-fuzzy control system nonlinear dynamic object operating in conditions of uncertainty intrinsic properties and the environment. The algorithms of structural and parametric identification in real time are a combination of an identification algorithm coefficients of linear management and methods of the theory of interactive adaptation. Adaptive neuro-fuzzy control system of nonlinear dynamic object contains an identifier and control that are based on Sugeno fuzzy model. This structure of the controller in conjunction with the optimal choice of the parameters of fuzzy controller, allows, at minimum settings, implement adaptive control systems uncertain and unsteady mechanisms regardless of their structure. To make the adaptive properties of fuzzy identifier proposed assessment rate of change of control error. Create a hybrid model based on neural networks and fuzzy models, improves the efficiency solution of the problem control of complex dynamic objects under uncertainty.

Keywords: nonlinear dynamic object, neuro-fuzzy identification, interactive adaptation, learning, fuzzy logic, neural network model.

In the development of control systems for facility operating under priori uncertainty, it is now widely used methods of adaptive, robust control, methods of fuzzy logic or neural network controller (Semichevskaja, 2006). Recently widely used methods of robust control dynamic objects, in which the desired speaker output control object is given by the explicit or implicit reference model (Gostev, 2008; Balandin and Kogan, 2007). In this case, purposeful use of non-linearity in the control law permits us to apply new mechanisms of suppression uncertainties and non-stationary control objects (Poljak, 2002).

When creating control systems of nonlinear non-stationary dynamic objects often have difficulties with priori uncertainty of the information.

The task of designing robust control systems of nonlinear non-stationary objects with different types of retarded argument that operate under priori uncertainty is relevant. The solution to this supreme prospective task of associated with the development of relatively simple control structures and effective control laws to ensure the desired quality control processes with incomplete measurement of the elements of the state vector.

Let the control object defined by a system of differential equations, written in vector-matrix form:

$$\frac{dx(t)}{dt} = \phi_1(x(t), \frac{dx(t-p)}{dt}, \xi) + \phi_2(x(t-\tau), u(t), \xi) + f_\xi(t).$$

where

$$x(t) = \phi(\tau), \tau \in [-\tau_{max}, 0], \frac{dx(p)}{dt} = \frac{dy(p)}{dt}, p \in [-p_{max}, 0],$$

$$y(t) = L^T(\xi)x(t), z(t) = g^T y(t), u(t) = u(e(t), y(t), r(t)).$$

where $x(t) \in \mathbb{R}^n$ – vector of state variables; $y(t) \in \mathbb{R}^m$ - output vector object; $z(t) \in \mathbb{R}$ – generalized output object; $g$– n-dimensional vector of the linear compensator; $u(t) \in \mathbb{R}$ – control action, the explicit form is to be determined; $\rho_{max}, \tau_{max} = const \geq 0$ – known delay; $\phi(\tau) \in C_{\tau_{max}}, \psi(\rho) \in C_{\rho_{max}}$ – vector functions; $C_{\tau_{max}}, C_{\rho_{max}}$ – space of continuous bounded functions;
\[ \Phi_1(x(t), \frac{dx(t-p)}{dt}, \xi), \Phi_2(x(t-p), u(t), \xi) \] – converting, satisfying the conditions of existence and uniqueness of the solution (1) for given initial vector functions; \( \varphi(\tau), \psi(p) \); \( f_\xi(t) \in R^n \) – vector of external disturbances or noise, which can satisfy the inequality of the form:

\[
\int_0^\infty \left\| f_\xi(t) \right\|^2 dt < \infty, \forall \xi \in Z
\] (2)

or be limited to the norm

\[
\left\| f_\xi(t) \right\| < f_0^2 = \text{const};
\]

\( \xi \in Z \) – vector of unknown parameters; \( Z \) - known set of possible values of the vector \( \xi \) or set, specifying the class of a priori uncertainty parameters object control; \( L \) - quasi-constant matrix of a given size; \( e(t) \in R^n \) – following error states of the control object and the reference model, which may be present in the system as explicitly or implicitly and explicitly, explicit-implicit; \( r(t) \in R \) – reference variable; \( n - m > 1 \) – the relative degree of the object. Object control (1) operates under a priori uncertainty of a given class \( Z \).

The task of managing the non-stationary object (1) consists of the following: required to construct a robust control system with the control action \( u(t) \) that, for any set \( \xi \in Z \) and for any initial conditions \( x(0) \) and perturbations \( f_\xi(t) \) with the properties (2) we would have a target condition of the form:

\[
\lim_{t \to \infty} \left\| y_M(t) - y(t) \right\| \leq \delta, \quad \delta = \text{const} > 0.
\]

In this article we propose a method of synthesis of robust nonlinear control laws for different types of control systems with nonlinear time-dependent dynamic objects. The resulting new class of nonlinear robust control laws do not contain signal components (sign function \( sign \)), which can significantly simplify the implementation of robust algorithms almost with high quality operation control systems.

Consider the problem of synthesis of robust control law nonlinear time-dependent control object described by the equation:

\[
\frac{dx(t)}{dt} = A(t, \xi) \cdot x(t) + B(t, \xi) \cdot u(t) + f_\xi(t), y(t) = L^T x(t), z = g^T y_m(t),
\] (3)

functioning under a priori uncertainty

\[
A(t) = A(t, \xi), B(t) = B(t, \xi), f(t) = f_\xi(t), \xi \in Z
\]

Let the reference model in the system is given implicitly

\[
\frac{dx_M(t)}{dt} = A_M \cdot x_M(t) + B_M r(t) \equiv 0, y_M(t) = L^T x_M(t), z_M = g^T y_M(t) = \text{const}.
\] (4)
It is assumed that the following conditions are structural alignments between the object and the reference:

\[ A(t) = A_M + B_M \beta^T(t)L^T, \quad B(t) = B_M \cdot (1 + \alpha(t)) \]  

Development of robust nonlinear control law subject to a system with implicit reference model (IRM) is carried out on the basis of typical stages of synthesis of control systems of dynamic objects. Equivalent to the mathematical description of the system under study is control by joint transformation equations of the object (3) Reference (4), as well as taking into account the conditions of structural alignments (5). As a result, the following relations are obtained:

\[ \frac{de(t)}{dt} = A_M \cdot e(t) + B_M \cdot \mu(t), \quad v(t) = g^T L^T e(t), \]  

where: \( e(t) \) – the error signal between the object and the reference model; \( \mu(t) \) – modified control or input to the system; \( v(t) \) – generalizations system output generated by the choice of the values of the vector \( g \) in the case of scalar control, and the matrix \( G \) - in the case of vector control.

To ensure a positive linear stationary part of the system (6) is used to select elements of a vector \( g \) or matrix \( G \).

To perform the integral inequality considered relatively non-linear non-stationary parts of the system (6), using a modification

\[ \eta(0, t) = \sum \eta_i(0, t) = -\sum \int \mu(s) \cdot \nu(s) \cdot Q_i(s) ds \geq -\gamma_0^2, \]  

where: \( \eta_i(0, t), i = 1, 2, 3 \) – modified integral summands of the form

\[ \eta_1(0, t) = \int_0^t (r(s) + f(s)) \cdot \nu(s) \cdot |\nu(s)| ds, \]  

\[ \eta_2(0, t) = -\int_0^t \beta^T(s) \cdot \nu(s) \cdot |\nu(s)| ds, \]  

\[ \eta_3(0, t) = \int_0^t (1 + \alpha(s)) \cdot u(s) \cdot \nu(s) ds, \]

Execution of (7) with (8) - (10), takes place when a nonlinear robust control law is synthesized in the following explicit form:

\[ u(t) = \left( \gamma_1 \cdot |r(t)| + \gamma_2 \cdot f^2_0 + \gamma_3 \cdot y^T(t) \cdot y(t) \right) \cdot \nu(t), \]

where: \( \gamma_i = \text{const} > 0, i = 1, k, k = \text{const} \).

Construction of nonlinear robust control laws for the system with an explicit reference model is carried out in a similar manner, but given the fact that the reference model is included explicitly in the equations and is described
\[
\frac{dx_M(t)}{dt} = A_M x_M(t) + B_M r(t);
\]
\[
y_M(t) = L^T x_M(t), z_M = g^T y_M.
\]

Explicit reference model allows to set a desired manner the dynamics of the control object, while in the control system can be used a minimum standard of structural complexity.

Reference model order reduction is achieved by appropriately selecting components of the vector \( g \) and a reference to eigen values of the \( A_M \) matrix of the linear fixed portion of the relative order of its transfer function \( (n - m) = 1 \). This allows you to create an explicit reference model in the form of a delay element 1-st order described by the equation.

\[
\frac{dz_M(t)}{dt} = a_0 z_M(t) + b \cdot r(t)
\]

**Conclusions**

This approach is implemented for the synthesis of a nonlinear robust control algorithm multiimpellent electric. The results of simulation control system electric multiimpellent shown that the new class of robust control laws allows for a higher quality of functioning of the created system.

**References**


