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Synthesis of the optimal fuzzy T-S controller for the mobile robot using the chaos theory

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Abstract

The automatic synthesis method of the optimal T-S controller has been proposed for nonlinear multiply dynamic object, omnidirectional mobile robot by using the chaos theory. A system of automatic adjustment of parameters of fuzzy controllers has been developed providing high-quality vector control parameters moving multiply nonlinear objects.

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Keywords: omnidirectional mobile robot; chaos theory; fuzzy T-S controller; overshoot; integral square error; damping degree

1. Introduction

There are a series of non-linear dynamic objects (or systems), which is chaotic-nonregular[1-3]. As it is well known, phenomena of this type, such as dissipative Lawrence system[3], is called "deterministic chaos", "internal stochastic" or just "chaos" in the scientific literature.

In chaos theory it is studied the dynamic regularities, generated movement of a nonlinear system, the evolution of the system in time, the determination of the current state of the system at a given prehistory. In such systems dynamic chaotic processes (irregular movement), that is the phenomenon can be characterized as "desirable" (positive) or "undesirable" (negative)[1,3].

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It is known that, if there are irregular-chaotic transients, then it is tried to deal with such phenomena in control system of nonlinear objects. In other words, in such cases it is achieved to eliminate undesirable irregular movement-chaotic controller by changing the structure and parameters of the control[2,3]. By using the chaos theory, in a dynamic system it is specifically tried to create irregular- chaotic movements in order to solve some problems, in particular, the definition of some optimum values of the parameters of control systems. Moreover, irregular-chaotic motion control system can be accomplished by introducing a special non-linear element. As examples of the application of chaos theory in order to solve fuzzy optimization problems, mathematical programming and the synthesis of the parameters of fuzzy term-set could be shown[1-4]. In particular, in[4] the synthesis problem of the automated system control regulators for the non-linear object solved with application of the elements of chaos theory. However, in the well-known works during synthesis of parameters of controller was carried out by using the "integral square error" criteria of quality.

However, there are some non-linear objects with irregular free movement, in particular, manipulators and mobile robots control system[1,4,6,11], in which the vector optimality criterion, such as the minimum of overshoot, a maximality of stability degree, speed, minimality of integral square error must be satisfied.

In the present work, it has been proposed the method of designing automatic synthesis problem of intellectual control system with using of the elements of chaos theory, i.e. tuning parameters of knowledge base T-S controller, which provides the optimal quality of the vector criterion.

2. Statement of the automatic synthesis problem of fuzzy T-S controller

Let the control object is a mobile robot that moves in all directions (omnidirectional-OD), a mathematical model, of which is described by nonlinear differential equation[6]:

$$\dot{x}(t) = A(x)\,x(t + B(x)\,\bar{u}(t),$$

$$y(t) = Cx(t) \qquad (2.1)$$

where $x(t) = [x_w, y_w(t), \varphi(t$ is state vector, i.e., velocities on the coordinate axes OX_w, OY_w and on the rotation angle of the mobile robot platform, y is output coordinates of the mobile robot on the coordinate axes and the rotation angle, $\bar{u}$- control variables generated by the corresponding wheel drives. By carrying out a series of simple transformations, a mathematical model of the omnidirectional mobile robot can be described by nonlinear differential equation:

$$\ddot{x}_w = a_1\dot{x}_w(t) - a_2\dot{\varphi}(t)\dot{y}_w(t) + u_1(t) \qquad (2.2)$$

$$\ddot{y}_w(t) = a_2\dot{\varphi}(t)\dot{x}_w(t) + a_1\dot{y}_w(t) + u_2(t)$$

$$\ddot{\varphi}_w(t) = a_3\dot{\varphi}(t) + u_3(t)$$

Nonlinear control object of the type (2.2), can be described by fuzzy model with sufficient accuracy:

$$\boldsymbol{R^i}\textbf{:}\ \boldsymbol{\dot{I}f}\ x_3(t)\ \textit{is}\ M^i\ ,\ \boldsymbol{Then}\ \ \ddot{x} = A_i x(t) + B_i u(t)\ \ \textit{and}\ \ y(t) = C_i x(t) \qquad (2.3a)$$

where