IBLFs-Based Adaptive Event-Triggered Control for a Class of Stochastic Nonlinear Systems

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***Abstract*—In this paper, an adaptive tracking control problem is addressed for nonstrict-feedback stochastic nonlinear systems subject to state constraints. Fuzzy logic systems (FLSs) are used to model unknown nonlinearities and avoid the algebraic loop arising from the system structure. Appropriate integral Barrier Lyapunov functions (IBLFs) are chosen so that time-varying full state constraints can be guaranteed directly rather than by transforming the constraint object. In the framework of backstepping technology, the relative threshold strategy is introduced to modify the adaptive control scheme so that the controller can be updated only after the trigger condition has been met, which reduces the update frequency of the controller and the loss of the actuator.**

For stochastic nonlinear systems with full state constraints, the states are considered to be limited to time-varying constraints rather than constant constraints, and the matching IBLFs are selected to ensure that state variables remain within the constraint bounds. Unlike logarithmic-BLFs and tangent-BLFs, IBLFs do not need to convert state constraints to error constraints, and the simultaneous existence of an integral and a differential can also reduce the difficulty of solving differential operators during the control design. For uncertain nonstrict-feedback nonlinear systems that combine stochastic disturbances and state constraints, the relative threshold event-triggered mechanism is introduced to decrease the execution times of control tasks under adaptive control. At the same time, FLSs are selected as a key technology, which can not only comprehensively deal with the problem of unknown functions, but also skillfully solve the problem of the algebraic loop.

Choose the stochastic nonlinear system with a nonstrict-feedback structure as

$$\begin{cases} \mathrm{d}x_i = \left(f_i(x) + x_{i+1}\right)\mathrm{d}t + g_i^T(x)\,\mathrm{d}\omega, i = 1,\cdots,n-1 \\ \mathrm{d}x_n = \left(f_n(x) + u\right)\mathrm{d}t + g_n^T(x)\,\mathrm{d}\omega \\ y = x_1, \end{cases} \tag{1}$$

where $x = \left[x_1,\cdots,x_n\right]^T \in R^n$ is the state vector, and all state variables satisfy $|x_i| < k_{c_i}(t), i = 1,\cdots,n$, $k_{c_i}(t): R^+ \to R^+$, $\forall t \geq 0$; $u \in R$ and $y \in R$ are the input and output, respectively; $f_i(x)$ and $g_i(x)$ represent unknown nonlinear smooth functions involving all state variables $x_1,\cdots,x_n$; and ω denotes the standard Wiener process.

Choose BLFs with the integral type as

$$V_j^z = \int_0^{z_j} \frac{\upsilon^3 k_{c_j}^6(t)}{k_{c_j}^6(t) - \left(\upsilon + \alpha_{j-1}\right)^6}\,\mathrm{d}\upsilon, j = 1,\cdots,n, \tag{2}$$

where the variable υ denotes the member of the integrating range $\left[0, z_j\right]$, $z_j = x_j - \alpha_{j-1}$ is the error, and the signals $\alpha_0 = y_d$, and $\alpha_1,\cdots,\alpha_{n-1}$ are continuously differentiable.

Combined with Lyapunov stability theory, it is shown that all closed-loop signals are bounded in probability, in which the states remain within the specified constraints, and there is no Zeno behavior. A series of simulation results are given to reveal the effectiveness of the constructed control scheme.

Keywords—adaptive fuzzy control, event-triggered control, integral Barrier Lyapunov functions, stochastic nonlinear systems