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Event-triggered adaptive tracking control of a class of nonlinear systems with asymmetric time-varying output constraints

Key words: Adaptive control; Deferred asymmetric time-varying output constraints; Error-shifting function; Event-triggered control

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Motivation

1. Due to its benefits in minimizing the number of times for data transformation and conserving resources, event-triggered control (ETC) applications have found widespread use in reality.

2. Inspired by Adaldo et al. (2015), the idea of the fixed-threshold ETC (FETC) mechanism was used for nonlinear systems. Nevertheless, it is not possible to adjust the event-triggered threshold online in reaction to changes in the control input.

3. Recently, a novel approach to stabilizing uncertain nonlinear systems using finite-time control and networked control was developed. The burden of data transmission was decreased by Wang AQ et al. (2019) by using a simultaneous update approach to constructing ETC. Despite extensive research conducted on the ETC for nonlinear systems, the deferred asymmetric time-varying (DATV) output constraint problem has received less attention.

Main idea

1. An adaptive neural network (NN) tracking controller based on the event-triggered mechanism, together with an error-shifting function, is proposed for the single-link robotic arm (SLRA) system with uncertain initial values and DATV output constraints, which assures one that all the signals in the closed-loop system are semi-globally uniformly ultimately bounded (SGUUB).
2. The proposed controller combines an error-shifting function not only to attain the predetermined convergence time but also to overcome the barrier Lyapunov function (BLF)'s initial constraint condition. This enhances the practical use of the SLRA.

Main idea (Cont'd)

3. The designed ETC strategy is incorporated into the SLRA system, which not only improves the tracking performance of the SLRA but also progresses the engineering feasibility in the real world. Besides, it reduces the number of times for data transformation from the controller to the actuator and saves communication resources.

Method

1. The control aim is to design an event-triggered adaptive NN controller with the DATV output constraints such that the tracking error $e_1(t) = x_1(t) - y_d(t)$ converges to an arbitrarily small neighborhood of the origin, and the DATV output constraints are not violated after the settling time T.

Method (Cont'd)

2. To deal with the DATV output constraints, an asymmetric time-varying barrier Lyapunov function (ATBLF)

$$V_a = \frac{\underline{k}_b(t)\bar{k}_b(t)\nu_1^2(t)}{(\underline{k}_b(t)+\nu_1(t))(\bar{k}_b(t)-\nu_1(t))}$$

is first built to make the stability analysis and the controller construction simpler.

Method (Cont'd)

3. An event-triggered adaptive NN tracking controller is constructed by incorporating an error-shifting function, which ensures that the tracking error converges to an arbitrarily small neighborhood of the origin within a predetermined settling time, consequently optimizing the utilization of network resources. It is theoretically proven that all signals in the closed-loop system are SGUUB, while the initial value is outside the constraint boundary.

Major results

Case 1: States are within the constraints before a given time *T*.

Case 2: States violate the constraints before a given time *T*.

Curves of the control input under case 1 and 2

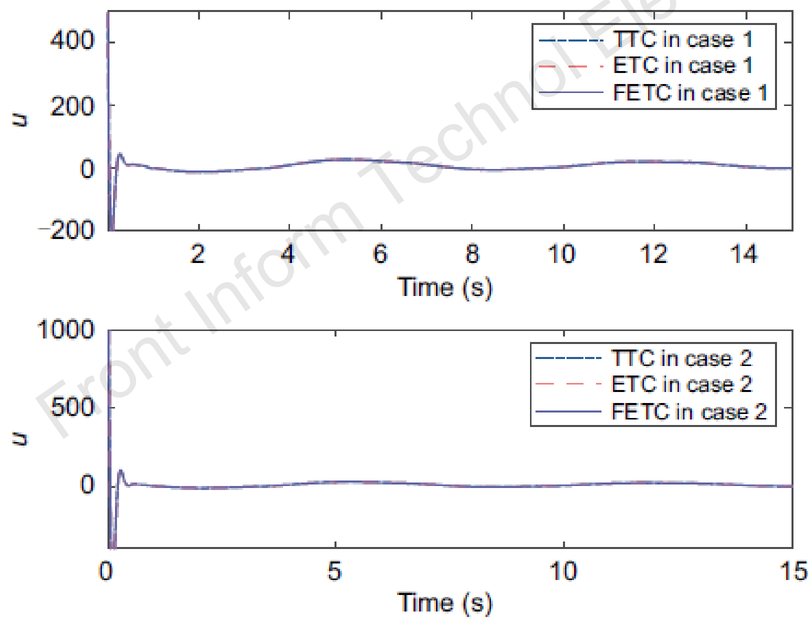

Fig. 3 Curves of the control input under cases 1 and 2 (ETC: event-triggered control; FETC: fixed-threshold ETC; TTC: time-triggered control)

Major results (Cont'd)

Triggering instants and inter-event intervals under case 1

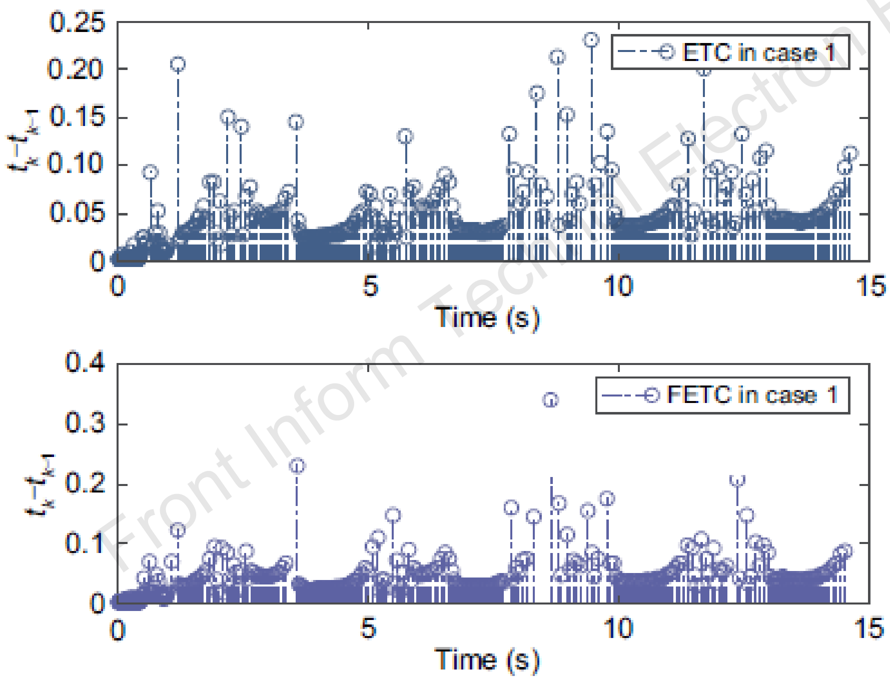

Fig. 4 Triggering instants and inter-event intervals under case 1
(ETC: event-triggered control; FETC: fixed-threshold ETC)

Major results (Cont'd)

Triggering instants and inter-event intervals under case 2

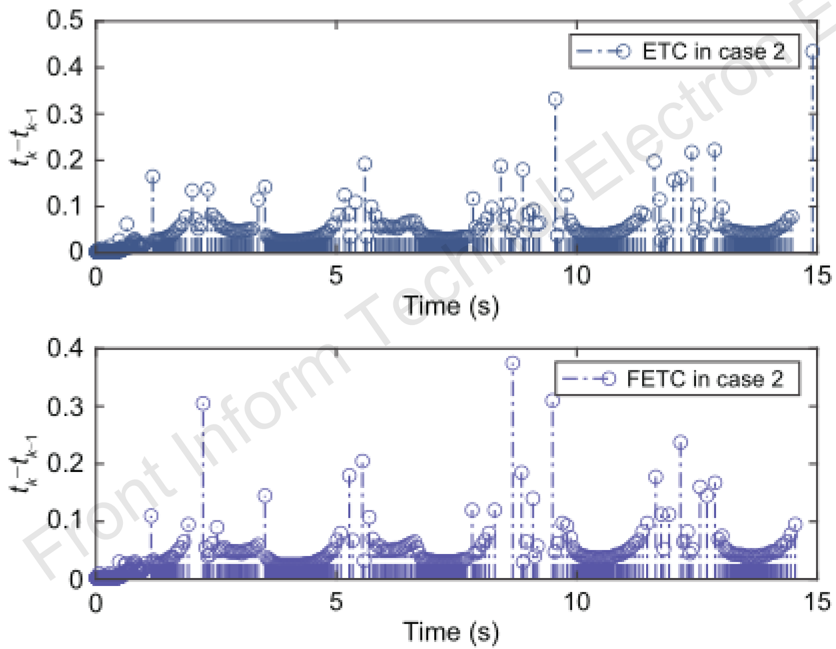

Fig. 5 Triggering instants and inter-event intervals under case 2
(ETC: event-triggered control; FETC: fixed-threshold ETC)

Conclusions

1. The problem of event-triggered adaptive NN tracking control has been solved in this study. To address the DATV output constraints, an ATBLF has first been built. In addition, an event-triggered adaptive NN tracking controller has been constructed by adding an error-shifting function to increase the usefulness of network resources.
2. It has rigorously been proved mathematically that the initial values can fall beyond the constraint boundary, and that all the signals in the closed-loop system were SGUUB.
3. The viability of the acquired control strategy has been demonstrated using an SLRA application example.