

Near Optimal Event-Triggered Control of Nonlinear Discrete-Time Systems Using Neurodynamic Programming

Avimanyu Sahoo, Hao Xu, *Member, IEEE*, and Sarangapani Jagannathan, *Senior Member, IEEE*

Abstract—This paper presents an event-triggered near optimal control of uncertain nonlinear discrete-time systems. Event-driven neurodynamic programming (NDP) is utilized to design the control policy. A neural network (NN)-based identifier, with event-based state and input vectors, is utilized to learn the system dynamics. An actor-critic framework is used to learn the cost function and the optimal control input. The NN weights of the identifier, the critic, and the actor NNs are tuned aperiodically once every triggered instant. An adaptive event-trigger condition to decide the trigger instants is derived. Thus, a suitable number of events are generated to ensure a desired accuracy of approximation. A near optimal performance is achieved without using value and/or policy iterations. A detailed analysis of nontrivial inter-event times with an explicit formula to show the reduction in computation is also derived. The Lyapunov technique is used in conjunction with the event-trigger condition to guarantee the ultimate boundedness of the closed-loop system. The simulation results are included to verify the performance of the controller. The net result is the development of event-driven NDP.

Index Terms—Event-triggered control (ETC), Hamilton-Jacobi-Bellman equation, neural networks (NNs), neurodynamic programming (NDP), optimal control.

I. INTRODUCTION

EVENT-TRIGGERED control (ETC) [1]–[6], which is evolved as an alternate control paradigm in the recent times, is found to be effective in terms of resource utilization. The ETC scheme uses events to sample the system state and execute the controller in an aperiodic manner. The aperiodic sampling and execution reduces the computational costs for the closed-loop system. In the case of a networked control system (NCS) [7], the ETC scheme saves network bandwidth due to the event-based aperiodic transmissions. The sampling and transmission instants, referred to as event-trigger instants, are decided using a state-dependent criterion. The threshold in

the criterion is designed analytically via the Lyapunov stability technique. Thus, the event-triggered paradigm saves resources, and maintains both stability and closed-loop performance.

Recently, various ETC schemes [1]–[6] have been introduced in the literature for linear [3], [4] and nonlinear systems [1], [2]. Typically, in the ETC schemes, the system dynamics are considered either completely known [1], [2], or with a small uncertainty [3].

In contrast, in [5] and [6], an attempt has been made to design the event-based controllers for systems with uncertain dynamics. In [5], the knowledge of the system dynamics is partially relaxed using an event-based neural network (NN) approximator. The NN-based design is extended to the case of completely unknown dynamics in [6]. In both the cases, the state-dependent criteria, referred to as event-trigger conditions, are made adaptive. This is in contrast with the traditional nonadaptive event-trigger conditions [1], [2]. These adaptive criteria generated a required number of events during the initial online learning phase of NN. This facilitated the event-based approximation of the unknown dynamics with aperiodic weight update. A tradeoff is observed between the accuracy of NN approximation and the reduction in computation. However, these controller designs [5], [6] render only stability without optimizing any performance index.

Inner and Basar [9] studied the optimal ETC in a constrained communication scenario using the certainty equivalence principle. Furthermore, Molin and Hirche [10] extended the linear quadratic Gaussian approach to an event-triggered context using a separation principle. However, these methods [9], [10] use backward-in-time Riccati equation-based solution with completely known system dynamics.

Traditionally, adaptive dynamic programming [11]–[14] or neurodynamic programming (NDP) [15] techniques are used to design the optimal control policy in a forward-in-time and online manner. These techniques use the policy and/or value iterations to solve the Hamilton-Jacobi-Bellman (HJB) equation online. However, a significant number of iterations within a sampling interval are needed to maintain the system stability resulting in a high computational cost. Furthermore, the knowledge of the control coefficient function is also necessary to compute the optimal control policy.

For a finite-time [16] optimal control, the solution to the HJB equation (i.e., the cost function) becomes explicitly time varying. The terminal cost constraint must also be satisfied at the same time. The event-based sampling of the state

Manuscript received January 23, 2014; revised May 15, 2015 and June 7, 2015; accepted June 19, 2015. This work was supported in part by Intelligent Systems Center, Missouri University of Science and Technology, Rolla, MO, USA, and in part by the National Science Foundation under Grant ECCS 1406533.

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Digital Object Identifier 10.1109/TNNLS.2015.2453320

Neurodynamic Programming

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