Data-driven Event-triggered Control for Discrete-time Systems with Exogenous Inputs

Vijayanand Digge†, Ramkrishna Pasumarthy,†† and Gianluca Bianchin†
† ICTEAM institute, UCLouvain, firstName.lastName@uclouvain.be
†† Department of Electrical Engineering, IIT Madras, ramkrishna@ee.iitm.ac.in

1 Introduction

This work develops generalized data-driven event-triggered control techniques for systems with exogenous inputs. Many real-world systems incorporate exogenous inputs as a fundamental part of the system that cannot be manipulated, and affect the system's performance. It is crucial that the data acquisition phase and the closed-loop operations remain unaffected by the presence of these exogenous inputs. In this context, we present a data-driven approach for systems whose explicit state-space model is unknown. The methodology relies on input-state data collected from an open-loop experiment and involves two stages: finding a state feedback controller that ensures stability and meets pre-defined performance criteria. Followed by designing an event-triggering policy design to determine control update instances. Event-triggered control involves the continuous or periodic evaluation of a condition known as the triggering condition. A popular policy in event-triggered control literature is relative thresholding, where the norm of error between the actual state and the last-known state is always maintained small relative to the norm of the current state [1].

Willems et al.'s fundamental lemma [2] shows that a single, sufficiently long exciting trajectory of the LTI system can be used to characterize all trajectories that the system can produce. The consequences of this lemma have been widely used in the data-driven literature, which involves a method for computing the response of a system to a given persistently excited input and initial conditions directly from a trajectory of the system [3].

2 Methodology

Firstly, a data-driven representation of the closed-loop system, accounting for state measurement errors caused by the event-triggered condition, is derived. Subsequently, a controller is designed to satisfy the desired closed-loop performance criteria. Followed by the estimation of the maximum relative thresholding rate of the event-triggered policy using the S-procedure, which simplifies the problem to solving a set of LMIs. We validate the results practically on an experimental setup of a web-server system as shown in Fig. 1 without a readily available state-space model. The implementation results are shown Fig. 2. To test the performance of the controller we have implemented the control law in two different frameworks: time-triggered implementation and event-triggered implementation. In time-triggered implementation, the control law is updated at each sample time. We observed that the event-triggered implementation closely matches time-triggered implementation and also ensures that the control law does not change frequently. Hence, saving communication channel bandwidth.

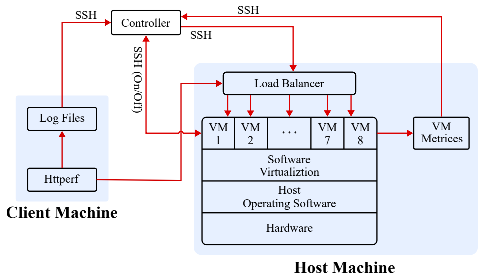

Figure 1: Experimental testbed of web-server system.

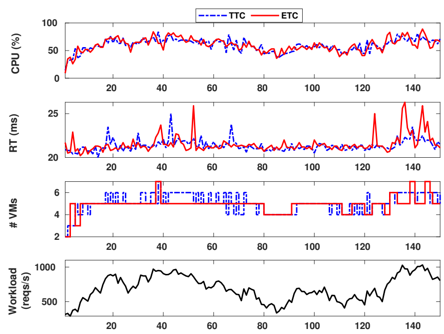

Figure 2: Performance of data-driven controller.

References

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[3] C. De Persis and P. Tesi, "Formulas for data-driven control: Stabilization, optimality, and robustness," *IEEE Transactions on Automatic Control*, vol. 65, 2019.