



Decentralized event-based control

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1 Introduction

The aim of event-based control is to reduce the feedback communication within a control loop by closing the loop only at time instants for which an event indicates a significant control error. In [4] a state-feedback approach to event-based control has been presented that introduced a novel structure of the event-based control loop, Fig. 1. Between consecutive events the control input generator produces the control signal $\mathbf{u}(t)$ using a linear model of the plant. The event generator measures the plant state $\mathbf{x}(t)$ continuously and generates an event when the plant state $\mathbf{x}(t)$ and the state $\mathbf{x}_s(t)$ of the same model deviate eminently, caused by an unknown disturbance $\mathbf{d}(t)$. As indicated by the dashed arrow, the event generator sends at event time t_k the current plant state $\mathbf{x}(t_k)$ to the control input generator, which uses the received information to reinitialize its model and, hence, to update the generation of the control input $\mathbf{u}(t)$.

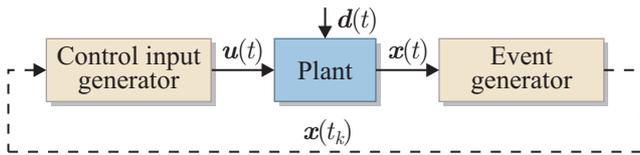


Figure 1: Event-based control loop

The main control objective is disturbance rejection expressed by the requirement of ultimate boundedness of the plant state

$$\mathbf{x}(t) \in \Omega_d, \quad \forall t \geq 0 \quad (1)$$

with Ω_d being a compact set that contains the origin under the constraint to minimize the feedback of information.

2 Project aims

The above scheme to event-based control needs the plant to have a central sensor unit that provides all state measurements and a central actuator unit over which all actuators can be steered simultaneously. Since this requirement is not met by large-scale systems, as industrial process plants, this project aims at the extension of the concept to decentralized event-based control of interconnected sys-

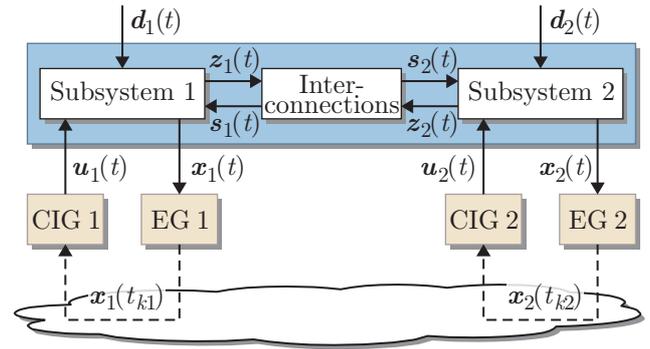


Figure 2: Decentralized event-based control

tems, that are described by the linear state-space model

$$\begin{aligned} \dot{\mathbf{x}}_i(t) &= \mathbf{A}_i \mathbf{x}_i(t) + \mathbf{B}_i \mathbf{u}_i(t) + \mathbf{E}_i \mathbf{d}_i(t) + \mathbf{F}_i \mathbf{s}_i(t), \\ \mathbf{x}_i(0) &= \mathbf{x}_{i0}, \\ \mathbf{z}_i(t) &= \mathbf{C}_{zi} \mathbf{x}_i(t). \end{aligned}$$

The subsystems are coupled according to the equation

$$\mathbf{s}_i(t) = \sum_{j=1}^N \mathbf{L}_{ij} \mathbf{z}_j(t)$$

where N is the number of subsystems and the matrix \mathbf{L}_{ij} determines how the subsystem j directly affects the subsystem i . The scheme of the decentralized event-based control of two physically coupled subsystems is illustrated by Fig. 2. According to (1) the control objective is to keep each subsystem state \mathbf{x}_i in a bounded surrounding Ω_{di} of the origin:

$$\mathbf{x}_i(t) \in \Omega_{di} \quad \forall t \geq 0 \text{ and } i = 1, \dots, N. \quad (2)$$

The main challenge to the design and analysis of the event-based control system that results from the decentralized control structure is that the event generation and, hence, the reinitialization of the control loops takes place asynchronously.

3 Decentralized event-based control

3.1 Controller design

In order to account for the couplings $\mathbf{s}_i(t)$ that affect the i -th subsystem among the disturbance $\mathbf{d}_i(t)$, the subsys-

tem is considered together with a coarse model [1] that approximates the dynamics of the remaining control loops, as illustrated by Fig. 3. The controller is then designed for the *extended subsystems*, which consists of the i -th subsystem and its coarse model. In this way the impact of the other control loops is diminished.

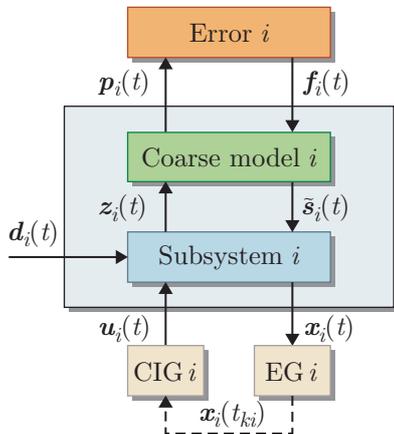


Figure 3: Extended subsystem

The central question to be answered by the analysis of the i -th controlled subsystem is: How accurate does the coarse model have to be to let the error signal $f_i(t)$ be small enough, such that the control aim (2) is satisfied? This also leads to investigations of the robustness of the event-based control scheme, since in this situation the model of the i -th subsystem is not exactly known any more.

3.2 Analysis of the event-based control system

Due to the asynchrony of the event generation and reinitialization of the several event-based control loops, the analysis of the overall system behavior between consecutive event times as done in single-loop event-based control is impossible. Based on the knowledge that the decentralized event-based control system behaves like hybrid dynamical system, the idea of a common Lyapunov function (cf. [3]) shall be adapted to analyze the stability of the system. At this point the main objective is to determine conditions under which such a function exists that not only decreases between, but also at the event times.

3.3 Delayed information exchange

As shown in Fig. 2 the several event-based control loops share a common communication network. Hence, collisions of data packets occur if two event generators send information at the same time which in turn leads to delayed information exchange between the event generator and the respective control input generator. The effect of a delay in the feedback of an event-based control loop has been investigated in [2] and these results shall be extended to the case of decentralized event-based control.

4 Application

The event-based control strategy shall be applied to the thermofluid process depicted in Fig. 4. The process consists of two cylindrical batch reactors TB and TS in which the level and temperature of the fluid is to be held constant. In both tanks the level is controlled over the inflow from the spherical tank T1 or T4, respectively. While in tank TB the fluid is warmed by the use of the heating rods, in tank TS it is cooled down via the cooling jacket. By means of an additional water supply from Tank T2 into the reactor TB the control of the level as well as of the temperature is disturbed. Likewise the heating rods in the reactor TS are used to realize desired disturbance characteristics.

The interconnections between the two subsystems are implemented by means of a flow from tank TB to tank TS and vice versa. The flow rate represents the strength of the couplings which is adjustable by setting the valve angle of the respective valve.

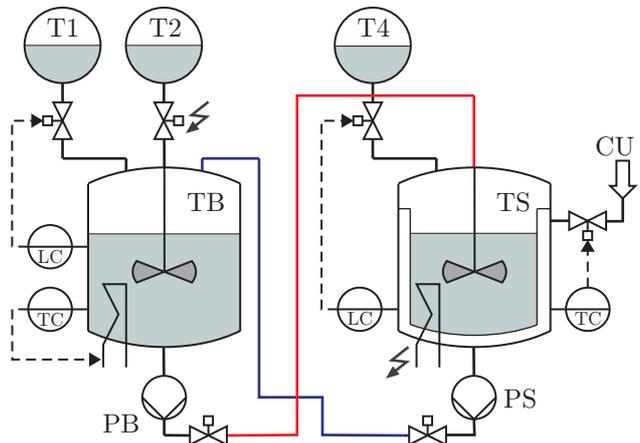


Figure 4: Thermofluid process

5 Cooperation

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