Observer design for a class of piecewise affine hybrid systems

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1 Introduction

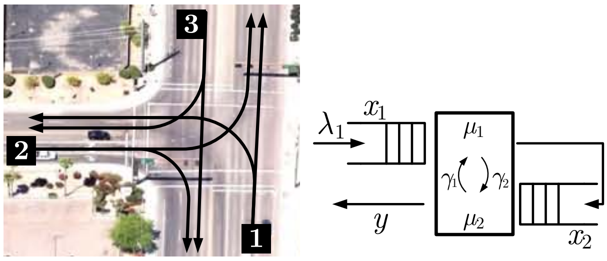
Nowadays, logic decision making and control actions are combined with continuous (physical) processes in many technological systems. Such systems are labeled *hybrid* as they have interacting continuous and discrete dynamics. Hybrid models are not only in such man-made systems important, but are also important to describe behavior of many mechanical, biological, electrical and economical systems. Therefore, in the past decades, the structural properties of hybrid systems have been investigated by many researchers. This led to various techniques for controller synthesis. However, many of these controller synthesis methods are based on the assumption that the full state variable of the hybrid system is available, which is hardly ever the case in practice. This renders the *design of observers* for hybrid systems, providing good estimates of both continuous and discrete states, of crucial importance. Despite this high practical relevance, surprisingly, results on hybrid observer design are still rather rare.

2 Hybrid system class

In this paper we are interested in designing observers for a special class of piecewise affine hybrid systems (*PWAHS*), motivated by switching servers in manufacturing systems serving multiple products consecutively, or traffic applications such as an intersection emptying lanes, e.g., see Figure 1. The considered hybrid system is autonomous with the mode dynamics consisting of constant drift and the output within a mode being constant only sometimes gives information about the active mode. In addition, during a mode transition some specific state variables might exhibit jumps. Although all subsystems are unobservable and not all events are visible, a continuous-time observer can be constructed that recovers the true state of the plant under suitable conditions.

3 Observer design

As already mentioned, for the class of PWAHS we propose a methodology for designing continuous-time observers. One of the main ideas in the construction of the continuous-time observer is sampling the system (with varying sampling periods) at so-called visible event times, i.e., times at which the output changes during a mode switch, which leads to a discrete-time linear time-varying periodic system.



(a) Signalized T-junction. (b) Two-product server.

Figure 1: Examples of switched systems.

Based on the resulting sampled system a periodic discrete-time observer is derived using standard techniques from control theory with the guarantee that the observer state converges asymptotically to the original system states.

Next, this discrete-time observer is used as a blueprint for the continuous-time observer by fixing the estimated system state at the visible event times. For the observer dynamics in between these visible event times, besides the plant dynamics, we introduce additional 'waiting' modes. The continuous-time observer switches to such a 'waiting' mode if a visible event occurs later than predicted. The drift vector in this mode is chosen such that at the occurrence of the visible event no continuous state jump is required. Occurrence of visible events before the time that the event was predicted results in a discrete state switch and an instantaneous update (jump) of the continuous states
A formal proof of the asymptotic recovery of the systems state will be provided. Via an example of a manufacturing system and a traffic intersection we demonstrate the effectiveness of the proposed observer.

4 Conclusions

This paper presented a methodology to design observers for a special class of PWAHS, being highly relevant in the context of manufacturing and traffic applications.

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