

Piecewise continuous hybrid systems based observer design for linear systems with variable sampling periods and delay output



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ABSTRACT

The present paper deals with a new continuous undelayed state observer design approach by using only the sampled and delayed measurements where the sampling period and delayed value are variable and unknown. This proposed piecewise continuous observer (PCO), which is derived by using the theory of a particular hybrid systems called piecewise continuous hybrid systems (PCHS), has a very simple structure and can be easily implemented to the networked visual serving systems. This type PCO observer can be also adapted easily according to other kind feedbacks, such as sampled output, delayed output, sampled and delayed state, sampled state, or delayed state whose sampling periods and delayed values are unknown. The proposed PCO observer stability is also analyzed and demonstrated. Moreover, to show the proposed PCO observer performance, a comparison with a Lyapunov–Krasovskii technique and descriptor representation based observer is conducted via a numerical example.

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1. Introduction

This work is devoted to observer design for a class of linear systems with variable sampled and delayed measurements. In the last few decades with recent advances in communications and computing technologies, networked visual servoing systems (NVSS) have received a considerable amount and increasing attentions, especially motivated by more flexible contactless wiring, improved signal/noise ratio and common communication network connection [1]. Its have been widely implemented in industrial production, building automation, remote video communicating networks, education, and aerospace exporting.

Compared with traditional point-to-point control systems, the advantages of NVSS are great particularly when a system becomes more and more communicable, intelligent and flexible by requiring more sensors, more actuators and more complicate controllers. However despite their numerous advantages and wide applications, the communication networks (Ethernet/Internet) and vision based systems in the control loops makes the control design more complicated. The main concern is the signal processing, coding, decoding and the networks across transmission induced delay which degrade inevitably the systems performance and possible cause systems instability. Therefore, the design of continuous undelayed state observer for NVSS is an very important issue.

In NVSS, there are two types of delays which are generally from two parts: the time delay T_{sc} between the sensor and the controller and the event based delay T_{ca} between the controller and actuator. Many methods have

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been reported to compensate the T_{ca} , such as through a Lyapunov–Krasovskii functional derived observer in [2,3], a discrete Lyapunov functional method based full dimension state observer in [4], a feedback control method based on forecast for state compensation [5], a Grey theory based prediction compensation method [6], and a dual dynamics based periodic observer [7], etc.

In present paper, we focus on the compensation of the variable and unknown delay T_{sc} which is introduced by sensor sampling effect and information coding, decoding, processing and networks communication induced delay. This compensation is particularly important for NVSS [8,9,1,10] because of their limited communication ability and image shoot speed where the application of the classical sampled-data control runs into serious difficulties due to important sampling periods. In the literature, there exist four main approaches dealing with this problem:

- The first one is referred as continuous approach means to based on the continuous-time system to design its continuous-time observer (its sampling effects in the original controlled systems have been ignored), and then discretized the derived continuous-time observer for applications; the problem is that the resulting discretized observer works only under the sampling period which is small enough to meet the closed-loop systems stability [11–13].
- The second is referred as discrete approach, a discrete observer is designed on the discretized plant model. The main advantages of this approach are that the resulting conditions are tight and less conservative than other methods [14]. However, it suffers from the inaccuracy of the discretized model comparing to its continuous-time model, the complexity of the conditions and the difficulty to include uncertainties in the original system [15].
- The third is generally referred as the input delay approach which is introduced firstly in [16,17]. This method allows for using the continuous-time Lyapunov–Krasovskii framework in order to take into account the sampling as a particular type of delay. The main advantages of the method are the possibility to take into account time varying uncertainties both in the sampling period and in the system parameters. However the resulting conditions are generally more conservative than the previous method, and necessary to solve complex linear matrix inequalities which are not always existing and easy.
- And the last one is the most recent developed methods referred as hybrid systems based approach [18,1,19–21]: such as in [18], the introduction of an impulsive system approach which refines the previous input delay method; and in [19,20], the introduction of a particular type of piecewise continuous observer (PCO) which is developed on a piecewise continuous hybrid systems (PCHS) and used to reconstruct the visual servoing control systems continuous un-delayed state.

Recalling that the referred proposed PCO observer which is derived by using PCHS, has a very simple structure and can be implemented easily for real-time

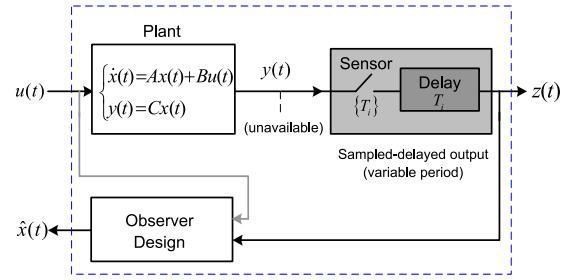


Fig. 1. Sampled-data delayed system to be controlled.

applications. The used PCHS, which is firstly proposed in [22] and then developed in [19,23,20], is a hybrid system characterized by autonomous switchings and controlled impulses. Further on, to show the proposed observer performances, a comparison with the most effective and widely accepted input delay approach of Lyapunov–Krasovskii observer (LKO) [16,17] is effectuated.

The following paper is organized as follows: Section 2 presents the problem formulation of NVSS. Section 3 introduces the observer design preliminaries of PCHS and NVSS time diagrams. In Section 4, a PCO observer which is based on the PCHS theory and the sampled and delayed measurements whose sampling periods and delayed values are variable and unknown is designed and analyzed. For comparison sake, in Section 5 a LKO observer and their corresponding numerical results are illustrated. Finally, some conclusion remarks are followed in Section 6.

2. Problem statement

From the analysis of NVSS, we study the case when the only available plant information is delivered from the plant output via a numerical camera sensor introducing a delay with variable value $T_{sc} = T_i$, $i = 0, 1, 2, \dots$ which corresponds to the time needed to sample, code, decode, process and communicate the information (see Fig. 1). Further on, we consider that the camera sampling period is also T_i to prevent out of memory in micro-processor or network congestion problem.

Their dynamics can be described as follows:

$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) \\ y(t) = Cx(t) \\ z(t) = y^*(t - T_i) \end{cases} \quad (1)$$

where $A \in \mathbb{R}^{n \times n}$, $B \in \mathbb{R}^{n \times r}$ and $C \in \mathbb{R}^{m \times n}$ are constant matrices and $*$ represents sampling operation with variable period T_i . For simplified notation, $z(t)$ in (1) can be denoted as $y(t_{i-1})$ or more simply as y_{i-1} .

Assume that (A, C) is observable, the main issue in this paper is to reconstitute the system continuous undelayed state $x(t)$ from the sampled delayed output measurements y_{i-1} whose sampling periods and delayed values are variable and unknown.

Reminding that, from the other kind feedbacks such as sampled output y_i , delayed output y_{t-T_i} , sampled and delayed state x_{i-1} , sampled state x_i or delayed state x_{t-T_i} , the developed observer can be also adapted easily

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