



Review Article

Sampled-data control systems with non-uniform sampling: A survey of methods and trends^aXian-Ming Zhang^a, Qing-Long Han^{a,*}, Xiaohua Ge^b, Boda Ning^b, Bao-Lin Zhang^c^a School of Science, Computing, and Engineering Technology, Swinburne University of Technology, Melbourne, VIC 3122, Australia^b Centre for Smart Infrastructure and Digital Construction, Swinburne University of Technology, Melbourne, VIC 3122, Australia^c College of Automation and Electronic Engineering, Qingdao University of Science & Technology, Qingdao, Shandong 266061, China

ARTICLE INFO

Keywords:

Sampled-data control systems
Non-uniform sampling
Event-triggered sampling
Automated vehicles
Planning
Islanded microgrid
Frequency control

ABSTRACT

The convergence of sensing, computing, communication and control elements drives the traditional point-to-point control systems towards networked control systems. Sampled-data control systems, which focus on the significant interplay between sampling and control, play a critical role in modern networked control systems, including intelligent transportation systems, smart grids, and advanced manufacturing systems. This paper presents a survey of methods and trends in non-uniform sampled-data control systems, where sampling and control actions are performed in an aperiodic manner. First, some fundamental issues of both continuous- and discrete-time sampled-data control systems are discussed. Next, main methods in both continuous-time and discrete-time domains are elaborated, respectively. Then, event-triggered sampling, under which sampling is executed only when the system needs attention, is examined. Typical triggering mechanisms in the existing literature are reviewed and classified into four types according to different threshold functions. Furthermore, two applications in terms of automated vehicle platoons and islanded microgrids are provided to demonstrate that sampled-data control methods are capable to support relevant practical application scenarios. Finally, several challenging issues are envisioned to direct future research.

1. Introduction

Sampled-data systems have been studied for over seven decades (Clarke, 1951). When sampling is periodic, there has been the mature theory for stability analysis and control design of sampled-data systems; see, e.g., Apkarian and Adams (1998), Chen and Francis (1995), Nevic and Teel (2001), Oishi (2001) and Yamamoto (2019). Undoubtedly, the mature theory has laid a solid foundation for networked control systems (NCSs). However, in practical scenarios, the sampling intervals between two consecutive sampling instants in an NCS are usually time-varying rather than constant (Gupta & Chow, 2010; Hespanha, 2014; Hu, Ren, Deng, & Li, 2022; Lu, Wen, Lu, Wang, & Zhang, 2022; Mahmood & Hamdan, 2018). For example, when an NCS is subject to packet dropouts or denial-of-service (DoS) attacks, it can be modelled as a sampled-data system with non-uniform sampling (Hoemela, Teel, van de Wouw, & Nevic, 2010; Hespanha, Naghshbani, & Xu, 2007; Liu, Shtyrov, & Fridman, 2019; Pang, Bai, Liu, Han, & Zhang, 2021; Zhang, Han, Ge, & Ding, 2020; Zhang, Han, Ge, et al., 2020), sometimes also known as aperiodic sampling and variable sampling.

The frequency of sampling actions for a sensor or sampler device should be proactively reduced due to the constrained resource budget. For example, real-world sensor and sampler devices are often battery-operated. Persistent or periodic sampling of the continuous-time signal of interest that has little fluctuation since the last sampling time inevitably causes unnecessary power consumption. In this case, event-triggered sampling is regarded as a promising sampling mechanism to reduce the potential resource consumption (Borgers & Hoemela, 2014; Hoemela, Sanden, & Van Den Bosch, 2008; Tabuada, 2007; Tiberi, Fischione, Johansson, & Benedetto, 2013). On the other hand, the core of NCSs is the communication network that enables data transmissions between networked sensors and controllers. However, communication resources such as bandwidth are often limited (Hespanha et al., 2007; Zhang, Han, & Ge, 2022). In this sense, the event-triggered sampling is prevalently employed to reduce the transmission frequency only when ‘needed’, e.g., when the current signal of interest suffers from a significant change from the last sampling and transmitting instant. The promising benefit of saving precious resources represents the primary

^a This paper was not presented at any IFAC meeting.

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Received 2 October 2022; Received in revised form 6 March 2023; Accepted 6 March 2023

Available online 18 March 2023

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Theory Of Sample Data Control Systems

D K Anand



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Theory of Sampled Data Control Systems David P. Lindorff, 1965

Introduction to Control Systems D K Anand, 2013-10-22 This book is written for use as a text in an introductory course in control systems The classical as well as the state space approach is included and integrated as much as possible The first part of the book deals with analysis in the time domain All the graphical techniques are presented in one chapter and the latter part of the book deals with some advanced material It is intended that the student should already be familiar with Laplace transformations and have had an introductory course in circuit analysis or vibration theory To provide the student with an understanding of correlation concepts in control theory a new chapter dealing with stochastic inputs has been added Also Appendix A has been significantly expanded to cover the theory of Laplace transforms and z transforms The book includes worked examples and problems for solution and an extensive bibliography as a guide for further reading

Applied Mechanics Reviews, 1966

Scientific and Technical Aerospace Reports, 1965

Theory and Applications of Automatic Controls B C Nakra, 2005 Theory And Applications Of Automatic Controls Is Written In A Simple Style As A Text Book Based On The Author S Experience Of Teaching The Subject To Undergraduate And Postgraduate Students In Mechanical Engineering It Would Be Useful To The Students Of Various Disciplines Including Mechanical Electrical Chemical Aerospace Production Textile Engineering Etc And Also For Practicing Engineers From Industry Salient Features Chapter 10 Has Been Expanded To Cover Topics On Design Of Digital Controllers Process Delays And Digital Controller For Dead Beat Response A Detailed Treatment Is Given For Ladder Diagrams Hydraulic And Pneumatic Actuation Systems Programmable Logic Controller And Its Ladder Diagram And Programming Have Been Covered A Number Of Examples And Exercise Problems Have Been Added Omissions And Corrections Have Been Taken Care Of

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