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PASSIVITY ANALYSIS AND SYNTHESIS OF DISCRETE-TIME DELAY SYSTEMS

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Abstract. This paper considers a class of linear uncertain discrete-time systems with state-delays. The uncertainties are time-varying norm-bounded and the delay factor is unknown constant within a prescribed interval. Both delay-independent and delay-dependent stability criteria are developed and all the results are cast into the form of algebraic matrix inequalities. In each case, the problem of passivity analysis is considered and conditions for passivity are established. With focus on delay-independent analysis, it has been proved that strong robust passivity of the uncertain system can be ascertained from the strong stability with strict passivity of a linear discrete-time system without uncertainties and having a scaling parameter. For the passivity synthesis, both state- and output-feedback designs are considered and it is proved in both cases that the controller gains can be determined from the solution of linear matrix inequalities. A design example of multivriable digital feedback control for regulating vapor compression cycles in two-phase flow heat exchangers with recycling is presented along with a computational algorithm to illustarte the theoretical developments and its implementation.

Keywords: Passivity Analysis, Time-Delay Systems, Passivity Synthesis, Norm-Bounded Uncertainties, Discrete-Time Systems.

1 Introduction

State-space modeling of industrial systems frequently involve delayed information either in the state varaibles, input variables or both. Time delays arise in connection with system measurements, due to physical properties of flow or occur in the transmission of information between different parts of dynamical systems including chemical processing systems, communication systems, hydraulic systems, rolling mills and power systems . Considerable research has been done for more than three decades, on various aspects of dynamical systems with delay factors in the state variables and/or control inputs [5,15]. In recent years, output-feedback control schemes have been developed for the stabilization of a wide-class of time-delay systems; see [8,9,11] and the references cited therein. On another front of systems research, the concepts of passivity and small gain play important roles in stability analysis, robust stabilization and robust performance. During the past two-decades, there has been a lot of advancement in H_∞ and robust control where small gain property has been widely used; see [3,17] and their references. On the other hand, passivity has been applied to develop results in adaptive and nonlinear control [2,7,16,20].

The primary motivation for studying the passivity control problem is due to its simplicity and effectiveness in dealing with robust and nonlinear systems. More precisely, passivity of a certain system block in a feedback interconnected system will ensure the overall stability