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FAULT DIAGNOSIS IN NONLINEAR DIFFERENTIAL-ALGEBRAIC SYSTEMS VIA AN ITERATIVE LEARNING OBSERVER

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Abstract. The problem of fault detection and estimation in a class of nonlinear differential-algebraic systems (NDAS), using an Iterative Learning Observer (ILO), is investigated in this paper. An NDAS is in a semi-explicit form with the differential variables coupled with the algebraic variables. In order to estimate the algebraic variables directly, an algorithm is developed to reconstruct the algebraic variables by converting a singular distribution matrix to a nonsingular one, using a series of elementary matrix operations followed by differentiation. An ILO is designed based on the reconstructed algebraic variables such that the estimated states, including both the differential and algebraic variables, converge to the actual values. The stability of the proposed observer is established and an illustrative example is provided to show the effectiveness of this new scheme.
Keywords. Nonlinear Differential-Algebraic Systems, Algebraic Variable Conversion, Iterative Learning Observer, Faults, Fault Estimation.

1 Introduction

A large class of engineering systems are described by both differential equations and algebraic equations, such as robotic systems with kinematic constraints [14, 20], power systems and electric circuits [10, 23]. In chemical processes, for example, the differential equations are stemmed from dynamic conservation relations, while the algebraic equations commonly arise from thermodynamic equilibrium relations, empirical correlations, and pseudo-steady-state assumptions. The majority of research on NDAS has been focused on the solvability and numerical solutions [1, 2]. The issue in feedback controller synthesis has been addressed only for a class of NDAS that often arise from mechanical systems [13, 19]. A framework for the study of Lyapunov stability of equilibria in NDAS is presented in [10]. Reference [16] addresses the output feedback control problem for a class of nonlinear multivariable high-index NDAS in semi-explicit form. A local disturbance decoupling issue has been considered in [18] where an algorithm is first developed such that the system can be expressed in a simple form. A feedback control law is then constructed to ensure that the closed-loop system has a unique solution without impulses and the output is not affected by disturbances.