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State observers for a class of multi-output nonlinear dynamic systems

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ABSTRACT

This note considers the problem of observer design for a class of multi-output nonlinear systems. A new state observer design methodology for linear time-varying multi-output systems is presented. Furthermore, we show that the same methodology can be extended to a class of multi-output nonlinear systems. Some sufficient conditions for the existence of the proposed observer are obtained, which guarantee that the error of state estimation converges asymptotically to zero. An example is given to demonstrate the effectiveness of the proposed methodology.

1. Introduction

The problem of observer design for nonlinear systems has got great attention in the recent literature [1–15]. The nonlinear observer has been a topic of interest in control theory. For linear system, it has been extensively studied, and has been proven extremely useful, especially for control applications. Whereas for nonlinear systems, the theory of observer is not nearly as complete nor successful as it is for the linear case. The first contributions to the nonlinear observer design were made by [1,2]. In [1], Bestle and Zeitz introduced a nonlinear observer canonical form in which system nonlinearities depend only on the input and output of the original system. In [2], Krener and Isidori proposed the Lie-algebraic conditions under which nonlinear observers with linearizable error dynamics can be designed. Some observers were designed for a restricted class of nonlinear systems such as bilinear systems [3,4]. In [5], a novel sliding mode observer for current-based sensor less speed control of induction motors is presented. In [6], two observers are provided for nonlinear systems given in Brunovski form. The first observer is a high-gain observer with a classical output injection form, while the second one is a high-gain observer with a q-integral path. Based on generalized input–output injection, state transformation procedures and exterior numerical differentiation, Mishkov [7], reduced the generalized observer canonical form. Because most available techniques usually deal with special forms of nonlinearities, the observer design technique for Lipschitz nonlinear systems is discussed in [8]. In [9], an observer is given for a class of nonlinear systems which are not necessarily control affine. However, the gain of the proposed observer is not easily computable. The nonlinear observer design technique by dynamic observer error linearization is presented in [10]. In [11], the state observation problem for autonomous nonlinear systems is considered. An observation mapping is introduced, which is defined by applying a linear integral operator to the output of the system. The observer is established by showing that observability and finite complexity of the system are sufficient conditions for the observer to exist, and by giving an explicit expression for its nonlinearity. In [12], the problem of equivalence under coordinate changes and output transformations to observer canonical forms is addressed in discrete time for multi-output systems. Necessary and sufficient conditions are given for local equivalence to this form which yields a straightforward observer design with linear error dynamics.

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