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Description of the research work proposed for a PhD

Title: Observer Design for Multiple Outputs Nonlinear Systems using Nonlinear Observer Normal Forms

Keywords: Multiple Outputs Nonlinear Systems ; Observer Design; Nonlinear Observer Normal Forms.

Subject:

I. Context

I-1. Observer design

For engineers, there is always a need of knowing the states of a system in order to make important decisions, to control the system, or to predict reliably its future states. A simple and sure method for knowing the states is to measure them directly. However, in general, it is not feasible or even impossible to directly measure all of the states of a system. An alternative method for knowing the states of a system instead of measuring all of them is to develop a model for the system. If the model is perfect, the states can be accurately estimated when the inputs and the initial conditions of the system are known with good accuracy. However, the initial conditions are never known and some inputs are unknown (external disturbances for example). Hence, the estimation by a model is effective only when the model error is quite small, the effects of initial conditions are not significant and the inputs are known. In order to solve these problems, the concept of observers (called also software sensors) has been introduced to efficiently estimate the states of a system [1].

Observer design for dynamical systems has received many attentions since the pioneer works of Luenberger and Kalman [2]. It concerns the reconstruction of the states of a system based on the available measurements and the model of the system (which can be uncertain). In order to design an observer, the concept of observability is important, which concerns the ability of estimating the states using the available data of inputs and outputs of a system.

I-2. Nonlinear Observer Normal Forms

The observer design is useful to estimate the states of a system and is important in control theory. However, it is usually difficult to design an observer for a nonlinear system. In order to solve this problem, the so-called Nonlinear Observer Normal Forms (NONFs) have been introduced for nonlinear systems during the 1980s [3]. The idea is to apply geometrical

method to transform a nonlinear system into a NONF on which existing observer methods can be applied. Recently, the theory on the NONFs has been widely developed and promising results have been obtained in several areas, such as automotive, robotics, electronics, electrical engineering, and bio-medical. These normal forms include:

- the normal forms with one or more sensors (see [4]),
- the normal forms with combination of the sensor measurements (see [5]),
- the normal forms with delay (see [6]),
- the normal forms extended by adding dependent dynamic measures (see [7,8]),
- the normal forms reduced by avoiding redundancies in measurements (see [9]),
- the singular normal forms (see [10] for the linear case).

II. Work plan and expected results

The main objective of this thesis is to extend the existing results on the NONFs, which can be started by the following steps:

- characterize multi-outputs nonlinear dynamical systems that can be brought into an extended normal form (the case of a single sensor already treated in [7], see also [5] for the classical observer normal forms),
- generalize the obtained results to the multi-inputs outputs case (see [11] for the single-input-output case),
- highlight a class of nonlinear dynamical systems that can be transformed into an extended nonlinear observer form without any geometrical computation [8].

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