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A relay-based method for servo performance improvement

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ABSTRACT

This paper proposes a relay-based performance-improving method for servo mechanism systems. The method first utilizes a relay-based feedback technique to identify the model parameters and the Coulomb friction value. Then, based on the identified results, a control algorithm, which consists of a feedforward controller, a time-delay compensator and a sliding mode controller, is designed. The feedforward controller and the time-delay compensator are used to compensate the system dynamics and the external disturbances respectively. Their parameters are decided directly according to the identified values. The sliding mode controller is to stabilize the system, two of whose parameters are one-to-one mapping to the closed-loop characteristic roots. Thus, this method avoids the complicated parameters tuning process, which is attractive in practice to the control engineers. Experimental studies on a linear-motor-driven table illustrate that the proposed method is capable of improving the servo performance greatly and canceling the external disturbances effectively.

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1. Introduction

Servo systems are widely used in many fields to drive the manipulator because of their potential to achieve accurate speed and position. These systems have two major uncertainties including the friction and inertia, which should be handled by servo controllers [1]. In the past years, a large number of researchers were dedicated to the servo controller design and until now, a great many algorithms have been proposed.

Among the existing algorithms, the feedback PID controller is the most popular for its simplicity and robustness. In order to deal with the uncertainties, PID parameters are always decided by various tuning techniques, for example, ZN method [2], R-ZN method [3], iterative feedback tuning method [4], optimal gain and phase margin method [5], constrained optimization method [6], minimizing the integral squared error (ISE) criterion method [7], and so on. It is necessary to point out that the parameters tuning requires complicated tests and relies on the engineer's experience, which is troublesome in applications. Sometimes especially when nonlinearity occurs in the systems, no matter how the parameters are tuned, PID cannot perform well. Then we need to turn to advanced control algorithms, such as adaptive control [8–11], adaptive robust control (ARC) [12,13], H_∞-based robust control [14], sliding mode control (SMC) [8,15], disturbance observer (DOB) [16,17], variable structure control (VSC) [18], composite nonlinear feedback control (CNF) [19], iterative learning control [20,21], neural networks (NNs) [22] and so on. All the advanced algorithms can improve the servo performance provided that the parameters are chosen appropriately. However, the tuning of advanced controller parameters requires much more effort than that of PID, which is the reason that advanced algorithms are seldom used in applications. In other words, the tuning techniques are necessary for advanced algorithms to be widely used.

On the controller parameters tuning, relay-based feedback technique (RFT) is a simple and effective method which has been widely studied [23,24]. The basic idea of RFT is to identify the servo model from the vibration excited by the relay modular and then tune the controller parameters based on the identified results. In the early years, RFT was mainly applied in large inertia systems such as temperature control, process control and so on, in which the nonlinear factors were lumped into the linear model. However, for servo systems which are of small inertia, the nonlinear effects always cause inaccurate or even incorrect identification. Pu et al. [25] gave a detail analysis how the nonlinearity affects the identified parameters. The experimental results verified that the friction is the major factor which leads to the varying identified results under different relay parameters. In order to gain the accurate servo system model, the effect of the friction has to be canceled in identification.

Though the friction has not been thoroughly known, various models are constructed to describe the nonlinear phenomena [26,27]. Combining the friction models, RFT can be modified to identify the parameters of both the servo system model and the friction model. In [28], the friction was modeled as a combination of Coulomb and viscous components. A dual-relay feedback structure was proposed to achieve the model parameters and the Coulomb friction. Besancon-Voda and Blaha [29] utilized a

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