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POSITIONING CONTROL OF A 2-MASS-SPRING SYSTEM WITH STATIC AND KINETIC FRICTION USING HYBRID CONTROLLER

Yasuo Konishi, Nozomu Araki, Kenji Tadokoro and Hiroyuki Ishigaki

Graduate School of Engineering
University of Hyogo
2167 Shosha, Himeji-shi, Hyogo, 671-2201, Japan
konishi@eng.u-hyogo.ac.jp

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Abstract. *This paper proposes a new hybrid controller for a 2-mass-spring system with stick-slip motion. The system is considered as a hybrid system with two modes: a static friction mode and a kinetic friction mode. In the controller design, the system is described as a piecewise affine (PWA) system, which is a modeling framework of hybrid systems. It is known that the model predictive control (MPC) method is applicable to PWA systems. The controller's effectiveness has been evaluated through computer simulations.*
Keywords: Piecewise affine system, Hybrid system, Positioning control, Stick-slip

1. **Introduction.** Recently, a lot of research has been conducted with a view to improve the accuracy of position control. One reason for degrading position control accuracy is quantization error or noise in the sensor data. For example, Oguro et al. proposed an analog clamp controller for evaluating the control condition on a sliding mode plane in order to solve the quantization error problem of a pulse encoder [1]. Moreover, to attain continuous precise positioning, an integer ambiguity estimation and validation method for carrier phase differential GPS/GNSS positioning has been proposed by Kubo et al. [2].

Friction is also an impediment to high accuracy positioning in mechanical systems. It is always a factor in the motion of bodies in contact. This problem is principally caused by the so-called stick-slip phenomenon, which arises due to friction mode switching, that is, static and kinetic friction mode [4]. To avoid this phenomenon, Canudas de Wit et al. proposed a new friction model called the LuGre model, and a friction compensation controller using this model [3]. However, accurate positioning is difficult with such a controller because of the strong nonlinear dynamics of the stick-slip phenomenon. Consequently, many actual mechanical systems have employed a PID controller or a controller derived from linear control theory as a positioning control method.

To solve this problem, this paper proposes a hybrid controller for a machine with the stick-slip phenomenon. Here, we consider positioning control of a 2-mass-spring system with static and kinetic friction as an example of mechanical system control. Because the stick-slip phenomenon is caused by friction mode switching, it can be considered as a discrete phenomenon with mode change. In our proposed method, we deal with this discrete phenomenon as a hybrid system. Several modeling frameworks for hybrid systems have been proposed in recent years. In this study, we applied piecewise affine (PWA) systems [6] to modeling of a 2-mass-spring system. It is known that the model predictive control (MPC) [9] method is applicable to PWA systems [10, 11]. Consequently, we described a 2-mass spring system with static and kinetic friction as a PWA system, and derived the control input using the MPC method. The effectiveness of our proposed approach has been evaluated through computer simulations.