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# HAAR WAVELET FAT-BASED ADAPTIVE CONTROLLER WITH SELF-TUNING FUZZY COMPENSATION FOR A PIEZOELECTRIC-ACTUATED SYSTEM CONTROL

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Abstract. *An adaptive sliding controller is proposed in this paper for controlling a piezoelectric-actuated X-Y table system. Due to hysteretical behaviors observed in the piezoelectric actuator (PA), the X-Y table can be viewed as a nonlinear time-varying system. Therefore, reliable and universal hysteresis model is difficult to achieve in order to implement model-based controller design. To cope with this problem, nonlinear hysteresis and the system's uncertainties are firstly lumped into an unknown time-varying function. The variation bound of this function is assumed to be unavailable. Then, the function approximation technique (FAT) levering on Haar wavelets is employed to represent the unknown function. In addition, a fuzzy scheme with online learning ability is augmented to compensate for the finite approximation error and facilitate the controller design. Finally, the Lyapunov direct method is applied to find adaptive laws for updating coefficients in the approximating series and tuning parameter in the fuzzy compensator. The closed-loop stability is also guaranteed. To validate the proposed scheme, control results obtained by using the proposed FAT sliding method augmented with fuzzy compensator are compared with those obtained by using solely the FAT approach.*
**Keywords:** Piezoelectric-actuated system, Function approximation technique (FAT), Fuzzy compensation

1. **Introduction.** Recently, micro-positioning table has become an important component in achieving high-resolution requirement of precision industry. As such, applications can be seen in the semiconductor manufacturing process, biotechnology process and opto-electronics system. Since piezoelectric actuator (PA) has many advantages, such as high stiffness, good precision and quick response, it has been widely used as actuators for micro-positioning tables. PA can be electrically controlled to move within the order of nanometer. Nevertheless, PA also exhibits undesired hysteretic behaviors which limit the performance of the piezoelectric-actuated system.

In order to overcome the nonlinear hysteresis associated with the PA, different control methods have been proposed. For instance, Chang and Sun [1] attempted to control a two degree-of-freedom monolithic piezoelectric actuator. Choi et al. [2] designed a sliding-mode controller for fine motion tracking control of the objective lens in vertical direction. Lin and Yang [3] employed a PI feedback control incorporated with feedforward compensation levering on a hysteresis observer to compensate for the nonlinearity of the PA. Jayawardhana et al. [4] tried to use the PID control for set point regulation and disturbance rejection in a context of second-order systems with hysteretic components. Bashash and Jalili [5] proposed a modeling and control methodology for real-time compensation of nonlinearities and precise trajectory control of piezoelectric actuators in