Iterative Learning Control of Hysteresis in Piezo-based Nano-positioners: Theory and Application in Atomic Force Microscopes

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This is to certify that I have examined this copy of a doctoral dissertation by

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and have found that it is complete and satisfactory in all respects,

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Abstract

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Atomic force microscopy (AFM)-based systems are the key enabling tools in emerging nanotechnologies, such as high-density data storage devices, semiconductor lithography, and nanosurgery. By using piezo-based positioners (actuators), the AFM-probe tip can be moved relative to the sample surface for observing, manipulating, and fabricating objects at nanometer scale. However, a critical problem in AFM is nano-precision control of the piezo positioner. In particular, hysteresis (as well as creep and vibration) in piezos makes precise positioning a challenge and the relatively large tracking error due to hysteresis, which is substantially larger than 100 nm, is not sufficient for emerging nanoscale applications. This thesis solves an iterative learning control (ILC) problem for hysteretic systems to achieve nano-precision positioning. Specifically, an ILC algorithm is proposed and applied to compensate for hysteresis-caused positioning error in piezo-based systems, such as AFMs, and a proof of convergence, based on the Preisach hysteresis model, is presented. Moreover, the required number of iterations to achieve a desired tracking precision is quantified, and the method is experimentally evaluated on a commercial AFM system. Results show that the proposed ILC algorithm reduces the tracking error to the noise level of the sensor measurement.

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DEDICATION

In loving memory of my mother, Ngor Lay Leang,

May 10, 1949 – August 15, 2004.