

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

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A dissertation submitted in partial fulfillment of  
the requirements for the degree of

Doctor of Philosophy

University of Washington

2004

Program Authorized to Offer Degree: Mechanical Engineering



University of Washington  
Graduate School

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Abstract

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

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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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## ACKNOWLEDGMENTS

First, I express my sincere gratitude and appreciation to my advisor, Santosh Devasia, for his expert guidance and mentorship, for his words of encouragement over countless cups of coffee, and for his unflagging support at all levels.

Next, I gratefully acknowledge the research support of Grants NAG 2-1450, NSF-CMS 0196214, and 0301787. Also, I am grateful for the generous financial assistance and teaching experiences I gained from the National Science Foundation and University of Washington GK-12 Fellowship awards (2001-2004).

Finally, this project would have never been completed without the encouragement and devotion of my family and friends. In particular, I thank my parents, Chiv and Ngor, for their constant love, patience and understanding. I also thank my siblings, Pat, Cindy and Dee, for their unwavering faith in me. And to my friends, many thanks for the support, the laughs and, of course, the unforgettable times spent together in the mountains.

## DEDICATION

In loving memory of my mother, Ngor Lay Leang,  
May 10, 1949 – August 15, 2004.