

# **2020 ASPE Spring Topical Meeting**

**Design and Control of Precision  
Mechatronic Systems**

**Online  
6 - 8 May 2020**

ISBN: 978-1-7138-3926-2

**Printed from e-media with permission by:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571



**Some format issues inherent in the e-media version may also appear in this print version.**

Copyright© (2020) by American Society for Precision Engineering (ASPE)  
All rights reserved.

Printed with permission by Curran Associates, Inc. (2021)

For permission requests, please contact American Society for Precision Engineering (ASPE)  
at the address below.

American Society for Precision Engineering (ASPE)  
230 Washington Ave. Ext., Suite 101  
Albany, NY  
12203

Phone: (518) 463-8687  
Fax: (518) 463-8656

[www.aspe.net](http://www.aspe.net)

**Additional copies of this publication are available from:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571 USA  
Phone: 845-758-0400  
Fax: 845-758-2633  
Email: [curran@proceedings.com](mailto:curran@proceedings.com)  
Web: [www.proceedings.com](http://www.proceedings.com)

# **ASPE 6<sup>th</sup> Design and Control of Precision Mechatronic Systems**

## **Topical Meeting Oral Sessions**

### Session Chairs:

David L. Trumper (Massachusetts Institute of Technology),  
Chinedum Okwudire (University of Michigan),  
Dick Laro (MI-Partners),  
Wouter B.J. Hakvoort (University of Twente)

### **Session 1 - Industry 4.0 and Learning Control**

**Thursday, May 7, 2020, 9:30 AM - 11:00 AM**

1. How Learning Control Supports Industry 4.0 in Semiconductor Manufacturing  
Van der Veen, G.; Stokkermans, J. (Equipment & Automation Technologies Nexpria); Mooren, N.; Oomen T. (Eindhoven University of Technology) .....1
2. Advanced Feedforward Control as a Service from the Cloud  
Okwudire, C. E. (University of Michigan).....6
3. Procedure Control of Nano Materials Design via Reinforcement Learning Control  
Wang, Y.; Cao, Z. (Department of Mechanical Engineering); Farimani, A. B. (Department of Mechanical Engineering; Carnegie Mellon University) .....12
4. Long-range Piezo-stepper Actuators: Towards Nanoscale Accuracy Through Commutation-angle Iterative Learning  
Aarnoudse, L.; Strijbosch, N. (Eindhoven University of Technology); Verschueren, E. (Thermo Fisher Scientific); Oomen T. (Eindhoven University of Technology) .....16

## **Session 2 - Advances in Motors**

**Thursday, May 7, 2020, 11:30 AM - 12:45 PM**

1. Harness the Lag: Precision Positioning with Hysteresis Motors  
Zhou, L. (Mitsubishi Electric Research Laboratories); Trumper, D. L. (Massachusetts Institute of Technology) ..... 21
2. Design and Measurement of a 6-Phase Combined Winding Bearingless Synchronous Reluctance Slice Motor  
Gruber, W.; Enengl, P. (Institute of Electrical Drives and Power Electronics Johannes Kepler University Linz); Sokolov, M. (Aalto University School of Electrical Engineering) ..... 27
3. Decoupled, Closed-loop, Multi-DoF Suspension of a Spherical Permanent Magnetic Dipole Actuator  
Hamer, T. T. (Massachusetts Institute of Technology); Chabot, J. (MIT Lincoln Laboratory); Trumper, D. L. (Massachusetts Institute of Technology) ..... 31
4. A Novel Position Sensing System for Bearingless Motors  
Weinreb, B. S. (Massachusetts Institute of Technology; The Charles Stark Draper Laboratory, Inc.); Fyler, D. (The Charles Stark Draper Laboratory, Inc.); Trumper, D. L. (Massachusetts Institute of Technology) ..... 37

## **Session 3 - Advances in Autotuning and Feedforward Control**

**Thursday, May 7, 2020, 1:30 PM - 3:00 PM**

1. Auto-Tuning of Precision Servo Controllers Suffering from Large Mass Ratio Induced Vibrations  
Dumanli, A. (Oregon State University); Lowe, J.; Badrawy, S. (Moore Nanotechnology Systems); Sencer, B. (Oregon State University) ..... 43
2. Combined Feedforward Tracking Control and Feedrate Optimization - with Application to a Precision XY Stage  
Kim, H.; Okwudire, C. E. (University of Michigan) ..... 49
3. Feedforward Spectral Tuning and Using Iterative Learning Control for Automated Parameter Fitting  
Jabben, L.; Luijten, F. (MI-Partners) ..... 54
4. Adaptive Feedforward Control of a Flexure Based Hexapod  
Spanjer, S. T.; Hakvoort, W. B. J. (University of Twente) ..... 58

## **Session 4 - Advances in Mechatronic Design I**

**Thursday, May 7, 2020, 3:00 PM - 4:00 PM**

1. Vacuum Compatible Contactless Active Magnetic Linear Bearings for High Cleanliness Robotic Applications Baade, R. (Eindhoven University of Technology); Peijnenburg, T. (VDL Enabling Technology Group); Steinbuch, M. (Eindhoven University of Technology) .....	63
2. Variable Resolution Fused Filament Fabrication (FFF) Printing Using a Variable Orifice Extruder System Habbal, O.; Pannier, C (University of Michigan-Dearborn) .....	69
3. Design and Control of a Thermal Actuation System Fan, C.; Hastings, D. J.; Smith, S. T. (The University of North Carolina at Charlotte) .....	73

## **Session 5 - Advances in Sensing and Feedback Control I**

**Friday, May 8, 2020, 9:30 AM - 11:00 AM**

1. Low-cost, High Dynamic Range Position Sensing Enabled by Oversampling and Averaging Bhushan, B. M.; Trumper, D. L. (Massachusetts Institute of Technology) .....	77
2. Improved Current Control of Inverter Fed Two-phase Bipolar Stepper Motors Using Repetitive Control Kramer, B. (ACS Motion Control) .....	82
3. Dynamics and Control of the PTB Nanometer Comparator Köchert, P.; König, R.; Weichert, C.; Flügge, J. (Physikalisch-Technische Bundesanstalt); Manske, E. (Ilmenau University of Technology) .....	87
4. Heuristically Optimized H-Infinity Synthesis for the Real-time Positioning of a Tip-based Measurement Device Connolly, L. G.; Dibua, O. G.; Cullinan, M. (The University of Texas at Austin) ....	.93

## **Session 6 - Advances in Sensing and Feedback Control II**

**Friday, May 8, 2020, 11:30 AM - 12:45 PM**

1. Model and Controller Design for High-speed Atomic Force Microscope Imaging and Autotuning Fangzhou, X.; Yang, C.; Wang, Y.; Youcef-Toumi, K. (Massachusetts Institute of Technology) .....	99
2. Implementation of Length Control of an Optical Cavity Using Second-order Transverse Modes Fernández-Galiana, A. (Massachusetts Institute of Technology); Arnbak, J. (The Technical University of Denmark); Evans, M.; Mavalvala, N. (Massachusetts Institute of Technology) .....	105
3. Active Optical Mode Matching for Quantum Squeezing Cavities and Upcoming LIGO Upgrades Noh, M. (LIGO Laboratory, Massachusetts Institute of Technology) (The British University of Technology); Cao, T. C.; Ng, S. (The University of Adelaide); Srivastava, V. (Syracuse University); Jia, W.; Mansell, G. (LIGO Laboratory, Massachusetts Institute of Technology); Griffith, D.; Torrie, C.; Abbott, R.; Brooks, A. (LIGO Laboratory); Ballmer, S. (Syracuse University); Veitch, P. (The University of Adelaide); Fritschel, P. (LIGO Laboratory, Massachusetts Institute of Technology); Matichard, F. (LIGO Laboratory, Massachusetts Institute of Technology) .....	110

## **Session 7 - Modeling and Control of Precision Machines**

**Friday, May 8, 2020, 1:30 PM - 3:00 PM**

1. Reduced Thermo-mechanical Model of a Rotary Table of a 5-axis Precision Machine Tool Hernández-Becerro, P. (Inspire AG Technoparkstrasse; Institute of Machine Tools and Manufacturing); Mayr, J. (Inspire AG Technoparkstrasse); Wegener, K. (Institute of Machine Tools and Manufacturing) .....	113
2. Loop-shaping Controller Design in the Development of the High-Dynamic Double-Crystal Monochromator for Sirius Light Source Caliari, R. M. (Brazilian Synchrotron Light Laboratory); Geraldes, R. R. (Brazilian Synchrotron Light Laboratory; Eindhoven University of Technology); Moraes, M. A. L. (Brazilian Synchrotron Light Laboratory); Witvoet, G. (Eindhoven University) .....	119
3. Dynamic Error Budgeting in the Development of the High-Dynamic Double-Crystal Monochromator for Sirius Light Source Geraldes, R. R. (Brazilian Synchrotron Light Laboratory; Eindhoven University of Technology); Moraes, M. A. L. (Brazilian Synchrotron Light Laboratory); Caliari, R. M. (Brazilian Synchrotron Light Laboratory); Witvoet, G. (Eindhoven University) ...	125

4. The FPGA Control Implementation of the High-Dynamic Double-Crystal Monochromator at Sirius Light Source  
Moraes, M. A. L.; Caliari, R. M. (Brazilian Synchrotron Light Laboratory); Geraldes, R. R. (Brazilian Synchrotron Light Laboratory; Eindhoven University of Technology) ..... 131
- 

## Session 8 - Advances in Mechatronic Design II

Friday, May 8, 2020, 3:00 PM - 3:45 PM

1. Delta Robot Combining Millimetre Travel with Nanometre Performance  
Kelly, J. H. (Harwell Science Campus) ..... 137
2. Thermally-stable Precision Motion and Positioning Mechanism  
Chun, H. (Texas A&M University); Kim, H. Y. (Korea Institute of Industrial Technology); Lee, C. (Texas A&M University) ..... 141