



UNIVERSITY of WASHINGTON


XU CHEN

Curriculum Vitae

Bryan T. McMinn Endowed Associate Professor

Department of Mechanical Engineering

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🌐 www.me.washington.edu/facultyfinder/xu-chen

🌐 faculty.washington.edu/chx/

👤 www.macslab.xyz

EDUCATIONAL HISTORY

University of California, Berkeley	California
Ph.D., Mechanical Engineering	12/20/2013
University of California, Berkeley	California
M.S., Mechanical Engineering	05/15/2010
Tsinghua University	Beijing, China
Bachelor's Degree, Mechanical Engineering	07/05/2008
Hong Kong University of Science and Technology	Hong Kong, China
Exchange Student, Mechanical Engineering	Fall, 2006

EMPLOYMENT HISTORY

University of Washington	Seattle, WA, USA
Bryan T. McMinn Endowed Research Professorship	(06/2021 –)
Associate Professor	(09/2021 –)
University of Washington	Seattle, WA, USA
Assistant Professor	(09/2019 – 09/2021)
University of Connecticut	Storrs, CT, USA
Assistant Professor for five years	(09/2014 – 08/2019)
University of California, Berkeley	Berkeley, CA, USA
Lecturer and assistant academic specialist for one year	(05/2013 – 07/2014)
Western Digital Corporation	Irvine and San Jose, CA, USA
Senior Research Intern	(06/2013 – 06/2013)
Research Intern	(05/2012 – 07/2012)
Research Intern	(05/2011 – 08/2011)
Research Intern	(06/2010 – 07/2010)

AWARDS AND HONORS

- **CAREER Award**, 03/15/2018, National Science Foundation
“CAREER: Adding to the Future: Thermal Modeling, Sparse Sensing, and Integrated Controls for Precise and Reliable Powder Bed Fusion”
- **Faculty Mentor, Best Student Paper on Robotics**, 10/11/2019, ASME Dynamic Systems and Control Division
Student author: Hui Xiao, “Following fast-dynamic targets with only slow and delayed visual feedback - a Kalman filter and model-based prediction approach”
- **Best Paper Award** (with Dan Wang), 07/19/2018, Japan Institute of Systems, Control, and Information Engineers (ISCIE) / ASME International Symposium on Flexible Automation
“Synthesis and analysis of multirate repetitive control for fractional-order periodic disturbance rejection in powder bed fusion”
- **Faculty Mentor, Best Student Paper on Mechatronics**, 10/03/2018, ASME Dynamic Systems and Control Division
Student author: Hui Xiao, “Multi-band beyond-Nyquist disturbance rejection on a galvanometer scanner system”
- **Teaching Excellence Recognition**, 01/26/2018, Office of the Provost, University of Connecticut
- **Best Vibrations Paper Award** (with Tianyu Jiang), 10/13/2017, ASME Dynamic Systems and Control Division
“An inverse-free disturbance observer for adaptive narrow-band disturbance rejection with application to selective laser sintering”
- **Research Excellence Program**, 2017-2018, University of Connecticut
- **University Teaching Fellow Award Nominee**, 11/22/2016, University of Connecticut
- **Breakthrough Award**, 12/06/2016, UTC Institute for Advanced Systems Engineering
- **Teaching Excellence Recognition**, 01/29/2016, Office of the Provost, University of Connecticut
- **Young Investigator Award**, 07/16/2014, ISCIE/ASME International Symposium on Flexible Automation
Citation: “Highly productive young investigator with solid publication record that offers academic and established recognition in industrial production; strong communicative competence and high productivity in collaborative research.”
- *Microsoft Surface Tech Talk*, Seattle, “**Automated Defect Inspection of Complex Metallic Parts,**” April 21, 2021
- *University of Huston* distinguished departmental seminar, Texas, “**Control Across Different Temporal Scales – A Mechatronic-System Perspective,**” November 5, 2020

- *Highlighted Project, DoD Advanced Robotics for Manufacturing Institute* membership meeting, “**Automated Defect Inspection of Complex Metallic Parts**,” October 13, 2020
- *Mechanical Engineering Byron Short Lecture, University of Texas at Austin, Austin, TX*, “**Adding to the Future: Sparse Sensing and Controls for Robust and Reliable Powder Bed Fusion**,” February 9, 2018
- *NSF US-Korea Workshop on Collaboration in Advanced Manufacturing Research, Reno, Nevada*, “**Motion Control, Precision Mechatronics, and Robotics in Advanced Manufacturing**,” August 11-12, 2014
- *Panelist, DoD Advanced Robotics for Manufacturing Institute* membership meeting, “**Achievements Using AI/ML in Fab/finishing/logistic Processes and Their Impact**,” October 14, 2020
- Top-ranked adaptive control algorithm in international benchmark on adaptive regulation [28, 33]
- Top 10% most cited papers of the year in IEEE Transactions on Control Systems Technology [30, 34]
- Top 10 most cited single-/dual-authored papers of the year IEEE Transactions on Control System Technology [31, 34] and European Journal of Controls [33]
- **Facilitating and Mentoring University Scholar** (highest undergraduate honor) Thomas Chessman, 12/20/2017, University of Connecticut
- **Facilitating and Mentoring University Scholar** (highest undergraduate honor) Dennis Schelov, 12/20/2016, University of Connecticut
- **Fostering School of Engineering Best Senior Design Team** (Paul Hanrahan, Michael Bennett, and Mark Winters), 05/15/2017, University of Connecticut

AWARDS AND HONORS TO ADVISEES

- Xiaohai Hu: UW Graduate School Research Top Scholar Fellowship 2021
- Hanah Choice: UW GO-MAP Graduate Excellence RA Award 2020-2021
- Tianyu Jiang: UW CoMotion Innovation Gap Fund 2021; Best Vibrations Paper Award, ASME Dynamic Systems and Control Division, 2017; UConn GE Graduate Fellowship for Innovation Award 2018, “Development of a Polymer Selective Laser Sintering (SLS) Testbed with Real-time Feedback Control for Part Quality Improvement,” Nov. 30th 2017
- Dan Wang: UW CoMotion Innovation Gap Fund 2021; Best Paper Award, ISCIE/ASME International Symposium on Flexible Automation 2018; Best Paper Finalist (Theory), ISCIE/ASME International Symposium on Flexible Automation 2020; UConn Outstanding Scholars Program, 2015-2018
- Hui Xiao: Best Student Paper on Mechatronics Award, ASME Dynamic Systems and Control Division, 2018; Best Student Paper on Robotics, ASME Dynamic Systems and Control Division, 2019; First place in ME Graduate Research Competition, University of Connecticut, 2019
- Thomas Chessman: UConn University Scholar, “In-Process Monitoring And Thermal Image Processing For Real-Time Feedback Control In Selective Laser Sintering,” 2018
- Paul Hanrahan, Michael Bennett, and Mark Winters: UConn School of Engineering Best Senior Design Team, “Automated Powder Bed Apparatus,” May 2017
- Dennis Schelov: UConn University Scholar, “Using a Cylindrical Coordinate System to Facilitate Multi-Material Printing,” 2017

- Kelly Cochran: Student Invited Presentation at ASME Night, Hartford, CT, “A Gesture Controlled Robot Manipulator,” Apr. 5 2016
- Gregory Bicknell: UCONN Fall Frontiers Poster Exhibition, “Intelligent Legged and Wheeled Robots with Visual Sensing and Coordination,” Storrs, Oct. 26, 2016

OTHER RECOGNITION

- Outstanding Graduate Student Instructor, 05/07/2013, UC Berkeley
- Chinese Government Award for Outstanding Self-financed Students Abroad, 03/20/2012, Ministry of Education of the People’s Republic of China
- Clyde Johnson Fellowship, 2013, UC Berkeley
- F. M. Lankershim Fellowship, 2013, UC Berkeley
- UC Berkeley Graduate Division Summer Grant Award, 2013
- Frank and Margaret Lucas Fellowship, 2011, UC Berkeley
- Distinguished College Graduate, 2008, Tsinghua University
- Distinguished Undergraduate Thesis, 2008, Tsinghua University
- Academic Excellence Scholarship, Tsinghua University, 2006
- Xu Shunshou top-honor Scholarship, 2005, Tsinghua University
- Gold Medal, Beijing College Student Physics Competition, 2005
- Jiangxi Province Distinguished Students Scholarship, 2004-2008
- Eminent award: “Ethical Leadership for the New Generation” Training Program-Case Study Competition, 01/15/2007, Hong Kong Independent Committee Against Corruption

AFFILIATIONS AND OTHER APPOINTMENTS

- Affiliate Assistant Professor, Department of Mechanical Engineering, University of Washington, Seattle, WA, 06/2019-09/2019
- Affiliate Assistant Professor, The Institute of Materials Science, University of Connecticut, Storrs, CT, 04/2015-2019
- Affiliate Assistant Professor, UTC Institute for Advanced Systems Engineering, University of Connecticut, Storrs, CT, 08/2015-2019

PUBLICATIONS

- I am interested in the broad field of dynamic interaction and controls ubiquitous in our lives. My current research involves understanding, engineering, and creating smart manufacturing that make materials and structures with extraordinary properties at low unit costs compared to conventional machining, and robots for automated inspection of complex, highly reflective parts in aerospace. My past research projects include ultra-fast nanometer precision motion control in computer disk drives and semiconductor manufacturing. These researches apply mainly the principles of mechatronics, where I aim to create both the software core and novel physical processes.
- Since 2010, I have authored and co-authored 84 papers in the above areas. Recognition of the publications includes top-ranked adaptive control algorithms in international benchmark evaluations [28, 33], top 10% most cited papers of the year [30, 34], top 10 most cited single-/dual-authored papers of the year [31, 33, 34], and four Best Paper Awards (cf Awards and Honors).
- Through my current and past researches, I have developed an expertise in controlling: the interaction between heterogeneous materials and fast moving lasers, vision-based robotic manipulation, multi-

stage actuation systems, and the fundamental limits of sensing, actuation, and controls in dynamic systems.

- With the gained knowledge and experiences, my group also created such games as solving a Rubik's cube with two robotic arms without additional fixtures, playing chess against a collaborative robot, playing air hockey with a robot.

REFEREED ARCHIVAL JOURNAL PUBLICATIONS¹

(Total Count: 34)

- [1] A. Patel, V. Venoor, F. Yang*, X. Chen, and M. J. Sobkowicz. "Evaluating Poly (Ether Ether Ketone) Powder Recyclability for Selective Laser Sintering Applications". In: *Polymer Degradation and Stability* (2021), p. 109502. ISSN: 0141-3910. DOI: [10.1016/j.polymdegradstab.2021.109502](https://doi.org/10.1016/j.polymdegradstab.2021.109502).
- [2] D. Wang*, T. Jiang*, and X. Chen. "Control-Oriented Modeling and Repetitive Control of In-Layer and Cross-Layer Thermal Interactions in Selective Laser Sintering". In: *ASME Letters in Dynamic Systems and Control* 1.1 (Jan. 2021). DOI: [10.1115/1.4046367](https://doi.org/10.1115/1.4046367).
- [3] D. Wang*, X. Zhao, and X. Chen. "New Hammerstein Modeling and Analysis for Controlling Melt Pool Width in Powder Bed Fusion Additive Manufacturing". In: *ASME Letters in Dynamic Systems and Control* (2021). in production. DOI: [10.1115/1.4050079](https://doi.org/10.1115/1.4050079).
- [4] F. Yang* and X. Chen. "A Combined Theoretical and Experimental Approach to Model Polyamide 12 Degradation in Selective Laser Sintering Additive Manufacturing". In: *Journal of Manufacturing Processes* 70 (Oct. 2021), pp. 271–289.
- [5] F. Yang*, T. Jiang*, G. Lalier, J. Bartolone, and X. Chen. "Process Control of Surface Quality and Part Microstructure in Selective Laser Sintering Involving Highly Degraded Polyamide 12 Materials". In: *Polymer Testing* 93 (2021), p. 106920. ISSN: 0142-9418. DOI: [10.1016/j.polymertesting.2020.106920](https://doi.org/10.1016/j.polymertesting.2020.106920).
- [6] F. Yang*, A. Schnuerch, and X. Chen. "Quantitative Influences of Successive Reuse on Thermal Decomposition, Molecular Evolution and Elemental Composition of Polyamide 12 Residues in Selective Laser Sintering". In: *International Journal of Advanced Manufacturing Technology* 115.9 (2021), pp. 3121–3138. DOI: [10.1007/s00170-021-07368-w](https://doi.org/10.1007/s00170-021-07368-w).
- [7] T. Jiang*, M. Leng*, and X. Chen. "Control-oriented In-situ Imaging and Data Analytics for Coaxial Monitoring of Powder Bed Fusion Additive Manufacturing". In: *ASTM International Conference on Additive Manufacturing STP Selected Technical Papers* (2020). Accepted.
- [8] T. Jiang*, H. Xiao*, J. Tang, L. Sun, and X. Chen. "Local Loop Shaping for Rejecting Band-Limited Disturbances in Nonminimum-phase Systems with Application to Laser Beam Steering for Additive Manufacturing". In: *IEEE Transactions on Control Systems Technology* 28 (6 Nov. 2020), pp. 2249–2262. DOI: [10.1109/TCST.2019.2934941](https://doi.org/10.1109/TCST.2019.2934941).
- [9] J. Tang, X. Chen, Y. Gu, and M. Zheng. "Introduction to the Focused Section on Machine Learning, Estimation and Control for Intelligent Robotics". In: *International Journal of Intelligent Robotics and Applications* 4.4 (2020), pp. 375–377. DOI: [10.1007/s41315-020-00155-y](https://doi.org/10.1007/s41315-020-00155-y).
- [10] D. Wang* and X. Chen. "Closed-loop High-fidelity Simulation Integrating Finite Element Modeling with Feedback Controls in Additive Manufacturing". In: *ASME Journal of Dynamic Systems, Measurement, and Control* 143.2 (Oct. 2020). 021006. ISSN: 0022-0434. DOI: [10.1115/1.4048364](https://doi.org/10.1115/1.4048364).

¹*: my own graduate or visiting students.

- [11] D. Wang* and X. Chen. “H-infinity-based Selective Inversion of Nonminimum-phase Systems for Feedback Controls”. In: *IEEE/CAA Journal of Automatica Sinica* 7.3 (Mar. 2020), pp. 702–710. DOI: [10.1109/JAS.2020.1003138](https://doi.org/10.1109/JAS.2020.1003138).
- [12] H. Xiao*, Y. Bar-Shalom, and X. Chen. “A Collaborative Sensing and Model-based Realtime Recovery of Fast Temporal Flows from Sparse Measurements”. In: *IEEE Transactions on Industrial Electronics* 67.8 (Aug. 2020), pp. 6806–6814. DOI: [10.1109/TIE.2019.2934057](https://doi.org/10.1109/TIE.2019.2934057).
- [13] H. Xiao* and X. Chen. “Robotic Target Following with Slow and Delayed Visual Feedback”. In: *International Journal of Intelligent Robotics and Applications* 4.4 (2020), pp. 378–389. DOI: [10.1007/s41315-020-00151-2](https://doi.org/10.1007/s41315-020-00151-2).
- [14] F. Yang* and X. Chen. “A New Kinetic Modelling of Polyamide 12 Degradation in Selective Laser Sintering”. In: *Selected Technical Papers on ASTM International Conference on Additive Manufacturing* (2020). Accepted.
- [15] F. Yang*, T. Jiang*, G. Lalier, J. Bartolone, and X. Chen. “A Process Control and Interlayer Heating Approach to Reuse Polyamide 12 Powders and Create Parts With Improved Mechanical Properties in Selective Laser Sintering”. In: *Journal of Manufacturing Processes* 57 (2020), pp. 828–846. ISSN: 1526-6125. DOI: [10.1016/j.jmapro.2020.07.051](https://doi.org/10.1016/j.jmapro.2020.07.051).
- [16] Y. Yuan, X. Chen, and J. Tang. “Multivariable Robust Blade Pitch Control Design to Reject Periodic Loads on Wind Turbines”. In: *Renewable Energy* 146 (2020), pp. 329–341. ISSN: 0960-1481. DOI: [10.1016/j.renene.2019.06.136](https://doi.org/10.1016/j.renene.2019.06.136).
- [17] T. Jiang* and X. Chen. “Transmission of Signal Nonsmoothness and Transient Improvement in Add-On Servo Control”. In: *IEEE Transactions on Control Systems Technology* 26.2 (Mar. 2018), pp. 486–496. ISSN: 1063-6536. DOI: [10.1109/TCST.2017.2672399](https://doi.org/10.1109/TCST.2017.2672399).
- [18] W. Kim, X. Chen, Y. Lee, C. C. Chung, and M. Tomizuka. “Discrete-Time Nonlinear Damping Backstepping Control With Observers for Rejection of Low and High Frequency Disturbances”. In: *Mechanical Systems and Signal Processing* 104 (2018), pp. 436–448. ISSN: 0888-3270. DOI: [10.1016/j.ymsp.2017.11.006](https://doi.org/10.1016/j.ymsp.2017.11.006).
- [19] D. Wang* and X. Chen. “A Multirate Fractional-Order Repetitive Control for Laser-Aided Additive Manufacturing”. In: *Control Engineering Practice* 77 (2018), pp. 41–51. ISSN: 0967-0661. DOI: [10.1016/j.conengprac.2018.05.001](https://doi.org/10.1016/j.conengprac.2018.05.001).
- [20] D. Wang* and X. Chen. “A Spectral Analysis and Its Implications of Feedback Regulation beyond Nyquist Frequency”. In: *IEEE/ASME Transactions on Mechatronics* 23.2 (Apr. 2018), pp. 916–926. DOI: [10.1109/TMECH.2018.2795960](https://doi.org/10.1109/TMECH.2018.2795960).
- [21] H. Xiao*, T. Jiang*, and X. Chen. “Rejecting Fast Narrow-Band Disturbances With Slow Sensor Feedback for Quality Beam Steering in Selective Laser Sintering”. In: *Mechatronics* 56 (2018), pp. 166–174. ISSN: 0957-4158. DOI: [10.1016/j.mechatronics.2018.09.002](https://doi.org/10.1016/j.mechatronics.2018.09.002).
- [22] L. Sun*, T. Jiang*, and X. Chen. “Adaptive Loop Shaping for Wideband Disturbances Attenuation in Precision Information Storage Systems”. In: *IEEE Transactions on Magnetics* 53.5 (May 2017), pp. 1–13. ISSN: 0018-9464. DOI: [10.1109/TMAG.2017.2654200](https://doi.org/10.1109/TMAG.2017.2654200).
- [23] D. Wang* and X. Chen. “A Tutorial on Loop-shaping Control Methodologies for Precision Positioning Systems”. In: *Advances in Mechanical Engineering* 9.12 (2017), p. 1687814017742824. DOI: [10.1177/1687814017742824](https://doi.org/10.1177/1687814017742824).

- [24] H. Xiao^{*}, I. D. Landau, and **X. Chen**. “A Robust Optimal Design for Strictly Positive Realness in Recursive Parameter Adaptation”. In: *International Journal of Adaptive Control and Signal Processing* 31.8 (2017), pp. 1205–1216. ISSN: 1099-1115. DOI: [10.1002/acs.2757](https://doi.org/10.1002/acs.2757).
- [25] Y. Yuan, **X. Chen**, and J. Tang. “Disturbance Observer Based Pitch Control of Wind Turbines for Enhanced Speed Regulation”. In: *ASME Journal of Dynamic Systems, Measurement, and Control* 139.7 (May 2017), p. 071006. DOI: [10.1115/1.4035741](https://doi.org/10.1115/1.4035741).
- [26] **X. Chen** and M. Tomizuka. “Discrete-time Reduced-Complexity Youla Parameterization for Dual-input Single-output Systems”. In: *IEEE Transactions on Control Systems Technology* 24.1 (2016), pp. 302–309. DOI: [10.1109/TCST.2015.2422796](https://doi.org/10.1109/TCST.2015.2422796).
- [27] **X. Chen** and H. Xiao^{*}. “Multirate Forward-model Disturbance Observer for Feedback Regulation beyond Nyquist Frequency”. In: *Systems & Control Letters* 94 (Aug. 2016), pp. 181–188. DOI: [10.1016/j.sysconle.2016.06.011](https://doi.org/10.1016/j.sysconle.2016.06.011).
- [28] A. C. Silva, I. D. Landau, L. Dugard, and **X. Chen**. “Modified Direct Adaptive Regulation Scheme Applied to a Benchmark Problem”. In: *European Journal of Control* 28 (2016), pp. 69–78. ISSN: 0947-3580. DOI: [10.1016/j.ejcon.2015.12.006](https://doi.org/10.1016/j.ejcon.2015.12.006) (cit. on pp. 3, 4).
- [29] **X. Chen**, T. Jiang^{*}, and M. Tomizuka. “Pseudo Youla-Kucera Parameterization with Control of the Waterbed Effect for Local Loop Shaping”. In: *Automatica* 62 (2015), pp. 177–183. DOI: [10.1016/j.automatica.2015.09.029](https://doi.org/10.1016/j.automatica.2015.09.029).
- [30] **X. Chen** and M. Tomizuka. “Overview and New Results in Disturbance Observer based Adaptive Vibration Rejection with Application to Advanced Manufacturing”. In: *International Journal of Adaptive Control and Signal Processing* 29 (2015), pp. 1459–1474. ISSN: 1099-1115. DOI: [10.1002/acs.2546](https://doi.org/10.1002/acs.2546) (cit. on pp. 3, 4).
- [31] **X. Chen** and M. Tomizuka. “New Repetitive Control with Improved Steady-State Performance and Accelerated Transient”. In: *IEEE Transactions on Control Systems Technology* 22.2 (Mar. 2014), pp. 664–675. ISSN: 1063-6536. DOI: [10.1109/TCST.2013.2253102](https://doi.org/10.1109/TCST.2013.2253102) (cit. on pp. 3, 4).
- [32] **X. Chen** and M. Tomizuka. “Optimal Decoupled Disturbance Observers for Dual-Input Single-Output Systems”. In: *ASME Journal of Dynamic Systems, Measurement, and Control* 136.5 (2014), p. 051018. DOI: [10.1115/1.4027282](https://doi.org/10.1115/1.4027282).
- [33] **X. Chen** and M. Tomizuka. “Selective Model Inversion and Adaptive Disturbance Observer for Time-Varying Vibration Rejection on an Active-Suspension Benchmark”. In: *European Journal of Control* 19.4 (2013), pp. 300–312. ISSN: 0947-3580. DOI: [10.1016/j.ejcon.2013.04.002](https://doi.org/10.1016/j.ejcon.2013.04.002) (cit. on pp. 3, 4).
- [34] **X. Chen** and M. Tomizuka. “A Minimum Parameter Adaptive Approach for Rejecting Multiple Narrow-Band Disturbances with Application to Hard Disk Drives”. In: *IEEE Transactions on Control Systems Technology* 20.2 (Mar. 2012), pp. 408–415. ISSN: 1063-6536. DOI: [10.1109/TCST.2011.2178025](https://doi.org/10.1109/TCST.2011.2178025) (cit. on pp. 3, 4).

CONFERENCE PROCEEDINGS AND OTHER NON-JOURNAL ARTICLES

Fully Refereed Publications

(Total Count: 50)

- [1] T. Jiang^{*}, M. Leng, and X. Chen. “Control-oriented Mechatronic Design and Data Analytics for Quality-assured Powder Bed Fusion Additive Manufacturing”. In: *IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)*. 2021.
- [2] F. Yang^{*}, T. Jiang^{*}, X. Chen, G. Lalier, and J. Bartolone. “A Control of Surface Quality in Selective Laser Sintering Additive Manufacturing With Reclaimed Polyamide Materials”. In: *Proceedings of Annual International Solid Freeform Fabrication Symposium*. Nov. 2021.
- [3] D. Wang^{*} and X. Chen. “Closed-loop Simulation Integrating Finite Element Modeling with Feedback Controls in Powder Bed Fusion Additive Manufacturing”. In: *Proceedings of ASME/ISCIE International Symposium on Flexible Automation*. July 2020. DOI: [10.1115/ISFA2020-9611](https://doi.org/10.1115/ISFA2020-9611).
- [4] D. Wang^{*}, X. Zhao, and X. Chen. “New Hammerstein Modeling and Analysis for Controlling Melt Pool Width in Powder Bed Fusion Additive Manufacturing”. In: *Proceedings of ASME Dynamic Systems and Control Conference*. Oct. 2020.
- [5] F. Yang^{*}, T. Jiang^{*}, G. Lalier, J. Bartolone, and X. Chen. “Active Interlayer Heating for Sustainable Selective Laser Sintering With Reclaimed Polyamide 12 Powders”. In: *Proceedings of ASME/ISCIE International Symposium on Flexible Automation*. July 2020. DOI: [10.1115/ISFA2020-9654](https://doi.org/10.1115/ISFA2020-9654).
- [6] N. Zobeiry, C. Seaton, M. Salviato, X. Chen, A. Banerjee, S. Devasia, J. Yang, A. Blom-Schieber, J. Buttrick, and S. Pedigo. “A Factory-Centric Workforce Development Approach for Aerospace Industry”. In: *SAMPE Conference Proceedings, Society for the Advancement of Material and Process Engineering - North America*. May 2020.
- [7] D. Wang^{*}, T. Jiang^{*}, and X. Chen. “Control-Oriented Modeling and Repetitive Control of In-Layer and Cross-Layer Thermal Interactions in Selective Laser Sintering”. In: *Proceedings of ASME Dynamic Systems and Control Conference*. 2019, V002T27A001.
- [8] H. Xiao^{*} and X. Chen. “A Dynamic Target Tracking Under Slow and Delayed Vision Feedback”. In: *Joint 12th IFAC Conference on Control Applications in Marine Systems, Robotics, and Vehicles 1st IFAC Workshop on Robot Control*. 2019.
- [9] H. Xiao^{*} and X. Chen. “Following Fast-Dynamic Targets With Only Slow and Delayed Visual Feedback - a Kalman Filter and Model-Based Prediction Approach”. In: *Proceedings of ASME Dynamic Systems and Control Conference*. 2019, V003T19A004.
- [10] X. Chen, T. Jiang^{*}, D. Wang^{*}, and H. Xiao^{*}. “Realtime Control-Oriented Modeling and Disturbance Parameterization for Smart and Reliable Powder Bed Fusion Additive Manufacturing”. In: *Proceedings of Annual International Solid Freeform Fabrication Symposium*. 2018, pp. 2335–2348.
- [11] T. Jiang^{*}, J. Tang, and X. Chen. “Wide-band Loop Shaping for Modulation of Energy Transmission in Nonminimum-phase Systems”. In: *Proceedings of ASME Dynamic Systems and Control Conference*. Oct. 2018, V002T18A001. DOI: [10.1115/DSCC2018-9089](https://doi.org/10.1115/DSCC2018-9089).
- [12] D. Wang^{*} and X. Chen. “A Multirate Repetitive Control for Fractional-Order Servos in Laser-Based Additive Manufacturing”. In: *Proceedings of IEEE American Control Conference*. June 2018, pp. 4831–4826.

- [13] D. Wang* and X. Chen. “Synthesis and Analysis of Multirate Repetitive Control for Fractional-order Periodic Disturbance Rejection in Powder Bed Fusion”. In: *Proceedings of ASME/ISCIE International Symposium on Flexible Automation*. July 2018, pp. 30–38. doi: [10.11509/isfa.2018.30](https://doi.org/10.11509/isfa.2018.30).
- [14] H. Xiao*, Y. Bar-Shalom, and X. Chen. “Model-based Sparse Information Recovery by Collaborative Sensor Management”. In: *Proceedings of ASME Dynamic Systems and Control Conference*. Oct. 2018. doi: [10.1115/DSCC2018-9088](https://doi.org/10.1115/DSCC2018-9088).
- [15] Y. Yuan, X. Chen, and J. Tang. “Periodic Wind Disturbance Rejection using Robust Individual Pitch Control”. In: *Proceedings of SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring*. Vol. 10601. Mar. 2018, p. 10601.
- [16] T. Jiang*, H. Xiao*, and X. Chen. “An Inverse-Free Disturbance Observer for Adaptive Narrow-Band Disturbance Rejection With Application to Selective Laser Sintering”. In: *Proceedings of ASME Dynamic Systems and Control Conference*. 2017.
- [17] H. Xiao* and X. Chen. “Multi-band beyond-Nyquist Disturbance Rejection on a Galvanometer Scanner System”. In: *Proceedings of IEEE International Conference on Advanced Intelligent Mechatronics, July 3-7 2017, Munich, Germany*. 2017, pp. 1700–1705. doi: [10.1109/AIM.2017.8014263](https://doi.org/10.1109/AIM.2017.8014263).
- [18] S. Zhou, X. Chen, M. Zheng, and M. Tomizuka. “Control of Dual-stage HDDs with Enhanced Repetitive Disturbance Rejection”. In: *Proceedings of ASME Information Storage and Processing Systems Conference, San Francisco, CA*. Aug. 2017, V001T03A002. doi: [10.1115/ISPS2017-5432](https://doi.org/10.1115/ISPS2017-5432).
- [19] X. Chen and H. Xiao*. “Multirate Forward-model Disturbance Observer for Feedback Regulation beyond Nyquist Frequency”. In: *Proceedings of IEEE American Control Conference*. July 2016, pp. 839–844. doi: [10.1109/ACC.2016.7525018](https://doi.org/10.1109/ACC.2016.7525018).
- [20] T. Jiang*, P. Hanrahan*, and X. Chen. “Input-to-output Discontinuity and Transient Improvement in Add-on Control Design”. In: *Proceedings of IEEE American Control Conference*. July 2016, pp. 1717–1722. doi: [10.1109/ACC.2016.7525164](https://doi.org/10.1109/ACC.2016.7525164).
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- [22] L. Sun, X. Chen, and M. Tomizuka. “Enhanced Wide-Spectrum Vibration Suppression Based on Adaptive Loop Shaping”. In: *Proceedings of IEEE American Control Conference*. July 2016, pp. 6189–6194. doi: [10.1109/acc.2016.7526642](https://doi.org/10.1109/acc.2016.7526642).
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- [37] **X. Chen** and M. Tomizuka. “Control Methodologies for Precision Positioning Systems”. In: *Proceedings of IEEE American Control Conference*. June 2013, pp. 3710–3717. DOI: [10.1109/ACC.2013.6580403](https://doi.org/10.1109/ACC.2013.6580403).

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Refereed by Abstract Only

- [1] T. Jiang* and **X. Chen**. “An In-situ Imaging and Data Analytics for Selective Laser Sintering in Presence of System Degradation”. In: *ASTM International Conference on Additive Manufacturing*. Orlando, FL, Nov. 2020.
- [2] F. Yang* and **X. Chen**. “A New Kinetic Modelling of Polyamide 12 Degradation in Selective Laser Sintering”. In: *ASTM International Conference on Additive Manufacturing*. Orlando, FL, Nov. 2020.

JOURNAL ISSUES EDITED

- [1] J. Tang, **X. Chen**, Y. Gu, and M. Zheng. *Focused Section on Machine Learning, Estimation and Control for Intelligent Robotics*. International Journal of Intelligent Robotics and Applications. Dec. 2020.

PATENTS SUBMITTED AND/OR AWARDED

- [1] M. Gerges* and **X. Chen**. *Adaptive Illuminance Control of Uniform and Uneven Topographies*. U.S. Patent Application 63/180,631. Apr. 2021.
- [2] T. Jiang*, **X. Chen**, and M. Leng*. *System and Method for Defect Detection in Laser Powder Bed Fusion Additive Manufacturing*. U.S. Patent Application 63/176,737. Apr. 2021.
- [3] D. Wang* and **X. Chen**. *Closed-loop Feedback For Additive Manufacturing Simulation*. International PCT patent application PCT/US2020/060465. Nov. 2020.
- [4] D. Wang* and **X. Chen**. *Closed-loop High-fidelity Simulation Integrating Finite Element Modeling with Feedback Controls in Additive Manufacturing*. U.S. Patent Application 62/935,213. Nov. 2019.
- [5] J. Wang, J. Steppan, B. Nair, and **X. Chen**. *Selective Area Forging (SAF) for Additive Manufacturing*. US Patent filed. Dec. 2018.
- [6] M. Zheng, M. Tomizuka, **X. Chen**, W. Xi, and G. Guo. *Data Storage Devices and Methods with Frequency-Shaped Sliding Mode Control*. US Patent 9542966B1. Jan. 2017.
- [7] M. Zheng, **X. Chen**, H. Wang, Y.-H. Kim, W. Xi, and K.-Y. Tu. *Data Storage Device Comprising Slew Rate Anti-Windup Compensation for Microactuator*. US Patent 9,007,714. Apr. 2015.
- [8] **X. Chen**, W. Xi, Y.-H. Kim, and K.-Y. Tu. *Methods for Closed-loop Compensation of Ultra-high Frequency Disturbances in Hard Disk Drives and Hard Disk Drives Utilizing Same*. US Patent 8,630,059. Jan. 2014.
- [9] **X. Chen**, J. Zhou, W. Xi, K.-Y. Tu, and G. Guo. *Disk Drive Filtering Disturbance Signal and Error Signal for Adaptive Feed-Forward Compensation*. US Patent 8,922,938. Dec. 2014.

PAPERS SUBMITTED

- [1] J. Shim* and X. Chen. “Control-oriented Modeling and Learning of Fast 3-Dimensional Laser-material Interaction from 2-Dimensional Images”. Submitted for publication. 2022.
- [2] H. Xiao* and X. Chen. “Target Tracking Under Delayed and Irregularly-Sampled Visual Feedback for a Robotic Air-Hockey System”. Submitted for publication. 2022.
- [3] J. Xie*, T. Jiang, and X. Chen. “Image Processing and Machine Learning for Melt Pool Segmentation in Coaxial Laser Power Bed Fusion Monitoring”. Submitted for publication. 2022.
- [4] M. Gerges* and X. Chen. “Adaptive Lighting for Uneven and Non-Uniform Topographies in Opto-Mechanical Inspection Systems”. Submitted for publication. 2021.
- [5] F. Yang* and X. Chen. “A Review of Aging, Degradation, and Reusability of Polyamide 12 Powders In Selective Laser Sintering Additive Manufacturing”. Submitted for publication. 2021.

ABSTRACTS, LETTERS, NON-REFEREED PAPERS, TECHNICAL REPORTS

- [1] T. Jiang* and X. Chen. *An Open-source Selective Laser Sintering Additive Manufacturing System*. Poster, International Conference on Complex Systems Engineering. Nov. 2015.

OTHER SIGNIFICANT RESEARCH DISSEMINATION

- PI, Designer and maintainer of [Advanced Robotics for Manufacturing Assets in American Northwest](#). I lead this multidisciplinary project to create a first-of-its-kind [resource map of robotics training for manufacturing](#) in American Northwest. As part of a major project by ARM, a federally-funded Manufacturing U.S.A. Institute, the University of Washington is leading a canvassing effort to identify all of the potential training resources in advanced robotics for manufacturing across five states: Washington, Oregon, Montana, Idaho and Alaska.
- Publicity Chair, designer and maintainer of IEEE/ASME International Conference on Advanced Intelligent Mechatronics 2020 website: <https://depts.washington.edu/aim20>. As a flagship conference focusing on mechatronics and intelligent systems, AIM 2020 brought together an international community of experts to discuss the state-of-the-art, new research results, perspectives of future developments, and innovative applications relevant to mechatronics, robotics, automation, industrial electronics, and related areas. 2020 marked the first virtual AIM in the history of the conference.
- Scientific Committee Member, UW [Boeing Advanced Research Center \(BARC\)](#): helping to transform fundamental research into practice, and feedback successful technologies into workforce education and training.
- Scientific Committee Member, UW [Advanced Composites Center \(ACC\)](#): helping to build a robust innovation ecosystem for industry and academia to advance the field of data-driven methods for composites manufacturing.
- Major participant of the 2012-2013 [International Benchmark on Adaptive Regulation](#) with pioneers of system identification including Ioan D. Landau. The benchmark provided state-of-the-art evaluation and dissemination of adaptation methods for active vibration control and noise control.

OTHER SCHOLARLY ACTIVITY

INVITED LECTURES AND SEMINARS

1. *Microsoft Surface Tech Talk*, Seattle, “**Automated Defect Inspection of Complex Metallic Parts**,” April 21, 2021
2. *University of Huston* distinguished departmental seminar, Texas, “**Control Across Different Temporal Scales – A Mechatronic-System Perspective**,” November 5, 2020
3. *DoD Advanced Robotics for Manufacturing Institute* membership meeting, “**Automated Defect Inspection of Complex Metallic Parts**,” October 13, 2020
4. *Texas Tech University*, Texas, “**From Nanometer Precision Control to Quality Additive Manufacturing and Robotic Inspection Under Limited Sensing**,” February 3rd, 2020
5. *University of Minnesota Twin Cities*, Minnesota, “**Fast Online Control under Sparse Sensing**,” March 4, 2019
6. *Case Western Reserve University*, Cleveland, “**From Precision Systems to Quality Additive Manufacturing: A Mechatronic System Approach**,” March 19, 2019
7. *University of Texas, Austin*, “**From Precision Systems to Quality Additive Manufacturing: A Mechatronic System Approach**,” February 20, 2019
8. *AFRL visiting UConn*, “**Instrumentation, Sensing, and Process Controls for Quality Metal Additive Manufacturing**,” (Xu Chen, Jason Hancock, and Rainer Hebert) February 9, 2019
9. *School of Engineering, University of Connecticut*, “**Preparing a successful CAREER proposal: Recent SoE CAREER Recipients Discuss their Experiences**,” January 15, 2019
10. *University of Rhode Island*, “**From Precision Mechatronics to Quality Additive Manufacturing**” November 16, 2018
11. *Rutgers University*, “**Adding to the Future: A System-Theoretical Modeling and Controls Framework for Precise and Reliable Additive Manufacturing**,” November 14, 2018
12. *Tsinghua University*, Beijing, China, “**From Precision Systems to Quality Additive Manufacturing: A Mechatronic System Approach**,” July 05, 2018
13. *Zhejiang University*, Zhejiang, China, “**From Precision Systems to Quality Additive Manufacturing: A Mechatronic System Approach**” July 10, 2018
14. *Aerospace Component Manufacturers (ACM) Team Meeting and Seminar*, Windsor Locks, CT, “**The Current Trends in Additive Manufacturing: Yesterday, Today and Tomorrow**,” May 24, 2018
15. *Mechanical Engineering Byron Short Lecture, University of Texas at Austin*, Austin, TX, “**Adding to the Future: Sparse Sensing and Controls for Robust and Reliable Powder Bed Fusion**,” February 9, 2018
16. *Unilever*, Trumbull, CT, “**Fast Prototyping Opportunities**,” December 18, 2017

17. *IPG Photonics*, Oxford, MA, Discussion on Metal Additive Manufacturing Instrumentation, April 25, 2016
18. *GE Power*, Windsor, CT, “**Mechatronics and Adaptive Local Loop Shaping for Advanced Manufacturing and Beyond**,” April 28, 2016
19. *Institute of Materials Science Industrial Affiliates Program*, Storrs, CT, “**From Additive Manufacturing to Precision and Adaptive Control**,” May 25, 2016
20. *University of Connecticut*, Storrs, CT, “**Adaptive Local Loop Shaping for Advanced Manufacturing and Precision Mechatronics**,” March 03, 2014
21. *University of California, San Diego*, “**A Loop-Shaping Approach for Precision Control and Adaptive Disturbance Rejection**,” August 26, 2013
22. *MIT & American Society for Precision Engineering Spring Topical Meeting*, MIT Campus, Cambridge, Massachusetts, “**Add-on Loop Shaping via Youla Parameterization for Precision Motion Control**,” April 21, 2013
23. *Western Digital Co.*, Irvine, CA, “**Anti-windup Design for Saturation Protection**,” Jun. 2013
24. *Western Digital Co.*, San Jose, CA, “**Unknown Multiple Narrow-band Disturbance Rejection – An Overview**,” June 2010

Media, Interviews, and Invited Panelists

25. *IEEE Spectrum* Video Friday, “**How an industrial robot manipulator learns to play chess (6th video in the list)**,” August 27, 2021
26. *DoD Advanced Robotics for Manufacturing Institute* membership meeting, “**Achievements Using AI/ML in Fab/finishing/logistic Processes and Their Impact**,” October 14, 2020
27. *Society of Manufacturing Engineering*, “**ARM Counts Wire-harness Installation, Pop-up Boot Camp Among Its Successes**,” September 24, 2020
28. *NSF US-Korea Workshop on Collaboration in Advanced Manufacturing Research*, Reno, Nevada, “**Motion Control, Precision Mechatronics, and Robotics in Advanced Manufacturing**,” August 11-12, 2014

Other Invited Seminars, Talks, and Participation

29. *UW ME Frontpage*, “**A vision for robotics - The UW MACS Lab Builds Robots that Play Games, Perform Tasks and Advance Research**,” August 24, 2021
30. *UW Today* Cover Article, “**A vision for robotics - The UW MACS Lab Builds Robots that Play Games, Perform Tasks and Advance Research**,” August 27, 2021
31. *NSF Workshop for Industry-Academia Collaboration in Advanced Manufacturing*, Virtual Event, May 19 - May 21, 2021
32. *Paul G. Allen School of Computer Science & Engineering*, University of Washington, “**ME Themed Robotics Overview**,” October 30, 2020
33. *Xerox*, “**Additive and Advanced Manufacturing Opportunities**,” June 23, 2020

34. *HP/Dyndrite*, “**Adaptive and Intelligent Machines**,” January 31, 2020
35. *Mechanical Engineering External Advisory Board Meeting*, University of Washington, “**Adaptive Machines and Manufacturing Autonomy**,” November 15th, 2019
36. *Farsoon America*, Austin, TX, Opening Workshop, December 20, 2017
37. *Abaqus, Dassault Systems*, Johnston, RI, Additive Manufacturing Process Simulations Workshop, February 13, 2017
38. *Joule Fellows Program, University of Connecticut*, CT, “**From Additive Manufacturing to Precision Mechatronics**,” July 18, 2016
39. *United Technologies Research Center*, East Hartford, CT, *Road Mapping Workshop*, April 22, 2016
40. *Texas A&M University*, “**Adaptive Local Loop Shaping and Inverse-based Youla-Kucera Parameterization with Application to Precision Control**,” (Masayoshi Tomizuka and Xu Chen) October 9, 2013
41. *Stony Brook University*, “**Add-on Loop Shaping via Youla Parameterization for Precision Motion Control**,” (Masayoshi Tomizuka and Xu Chen), March 8, 2013
42. 2nd Workshop on Dynamics and Control of Micro Nanoscale Systems, Newcastle, Australia, “**Handling Narrow-Band Disturbances in Precision Motion Control Systems**,” (Xu Chen and Masayoshi Tomizuka), February 23, 2012
43. *Mechanical Engineering External Advisory Board Meeting*, UC Berkeley, “**Vibration Rejection in Precision Systems – An Adaptive Band-limited Loop-shaping Control Approach**,” December 08, 2011

PROFESSIONAL SOCIETY MEMBERSHIPS

- IEEE (Institute of Electrical and Electronics Engineers) member, 2009-Present
- ASME (American Society of Mechanical Engineers) member, 2010-Present
- SME (Society of Manufacturing Engineers) member, 2015-Present
- SIAM (Society for Industrial and Applied Mathematics) member, 2016-Present
- ASTM International (formerly known as American Society for Testing and Materials) member, 2020-Present

GRADUATE STUDENTS

CHAired DOCTORAL DEGREES

- Dan Wang (2015-2020). Dissertation: “Control-oriented Modeling and Multirate Feedback Control in Laser Powder Bed Fusion Additive Manufacturing”; defense date: December 2, 2020. Other committee members: Santosh Devasia, Ramulu Mamidala, Behçet Açıkmeşe. Now at UW as Research Scientist.
- Hui Xiao (2015-2021): sparse sensing and robotics. Other committee members: Santosh Devasia, Sawyer Fuller, Jeff Lipton, Byron Boots. Now with Medtronic, Carlsbad, CA.

- Tianyu Jiang (2015-2021): manufacturing systems and non-contact sensing in 3D printing. Other committee members: Ramulu Mamidala, Santosh Devasia, Jennifer Mankoff (CSE). Now with Western Digital, CA.

CURRENT DOCTORAL STUDENTS

- Feifei Yang (2018-present): sustainable additive manufacturing; passed UW qualifying exam on June 08, 2020. Other committee members: Ramulu Mamidala, Mark Ganter, Ashis Banerjee.
- Xiaohai Hu (starting 09/2021). Other committee members: TBD.
- Thomas Chu (starting 09/2021). Other committee members: TBD.

CHAired MASTERS DEGREES

- Mingyu Wang (June 2020 - June, 2021). Thesis: “Vision-Based Robotic Chess Player”. Other committee members: Santosh Devasia, Sawyer Fuller.
- Mark Ghali Georges (Jan 2020 - June 2021, now with Tesla). Thesis: “Provision of Controlled and Consistent Light Distribution Over an Uneven Topography to Maximize Efficacy of Machine-Vision based Defect Identification”. Other committee members: Santosh Devasia, Jae-Hyun Chung.
- Abhishek A. Kulkarni (2019-2021, now with Third Wave Robotics, a startup in California). Thesis: “Motion Planning and Image Capturing for Robotic Inspection of a Curved Surface subject to Imaging Constraints”; defense date: December 4, 2020. Other committee members: Santosh Devasia, Sawyer Fuller.
- Michael Gagnier (October - December 15, 2020). Project: robotic inspection.
- Hongkuan Lin (2019-2021, now with Apple, Shanghai, China). Project: bi-stable mechanisms for additive manufacturing.
- Mengying Leng (2019-2021, now with startup on portfolio AI). Project: image processing for additive manufacturing.
- Guowei Hua (2019-2021, now in Electronics Industry, Chengdu, China). Project: robotic inspection.
- Ruiwei Sui (2020 - 2021, now applying for graduate school). Project: mobile robot.
- Samantha Brown (2017-05/2018, now with Pratt & Whitney). Thesis: “Communication and Control of Multiple Sensors for Selective Laser Sintering”. Other committee members: Jiong Tang, Vito Moreno, UConn.
- Kelly Cochran (2016-2017, now with Pratt & Whitney). Thesis: “Hand Gesture Control of Robots”. Other committee members: Jiong Tang, Vito Moreno, UConn.

CURRENT MASTERS STUDENTS

- Harshil Shah. Other committee members: TBD.

RESEARCH ACTIVITIES

CURRENT FUNDED RESEARCH

Most of my research have led to or been supported by part of a \$10.4 million total funding (\$6.4M as PI or project PI) that includes my share of \$3.9 million. Grants over \$19,999 are listed below.

Source	Title	Role	Amount	Dates	Notes
DOD: Advanced Robotics for Manufacturing Institute	Uniform Work Robotic Sanding with Intrastage Inspection	Subcontract PI (Lead: M. Philo (GKN Aerospace))	\$1,339,942; my share: \$150,000	1/3/2022 - 1/2/2023	total cash and in-kind cost share: \$839942
NSF	I/UCRC Planning Grant: University of Washington: Center for Data-driven High-rate Composites Manufacturing (DH-COM)	Co-PI (PI: J. Wang)	\$20,000; my share: \$4,000	07/01/2022 - 06/30/2023	pending
Boeing	Autonomous Data Flagging during Fiber Placement	Co-PI (PI A. Banerjee; Co-PI K. Manohar)	\$100,000; my share: \$33,333	1/3/2022 - 1/2/2023	pending
Boeing	Stringer Handling And Forming Tool (SHAFT) Development	PI (Co-PI S. Devasia)	\$300,000	09/16/2021 - 09/15/2022	-
Boeing	ARCAM Powder Bed Additive Manufacturing Phase II	Co-PI (PI Ramulu M.; Co-PI D. Arola)	\$473,438; my share: \$8,775	12/16/2019 - 11/30/2021	-
UW and Washington Research Foundation	Software for Quality Assurance in 3D Printing	PI	\$20,000	01/15/2021 - 01/14/2022	-
The Joint Center for Aerospace Technology Innovation (JCATI)	Developing a Portable and Multifaceted Inspection Method for Evaluation of Tool Surface Condition and Release Coating and Tool Cleaning Strategies in Composites Processing	Co-PI (PI N. Zobeiry)	\$110,362; my share: \$55,181	09/15/2021 - 09/14/2022	-
UW and Washington Research Foundation	Online Defect Detection and Quality Evaluation for 3D printing	PI	\$50,000	06/01/2021 - 05/31/2022	-

(continued)

Source	Title	Role	Amount	Dates	Notes
National Science Foundation	CAREER: Adding to the Future: Thermal Modeling Sparse Sensing and Integrated Controls for Precise and Reliable Powder Bed Fusion	PI	\$550,000	09/01/2018 - 08/31/2023	-

PAST FUNDED RESEARCH

Source	Title	Role	Amount	Dates	Notes
DOD: Advanced Robotics for Manufacturing Institute	Automated Defect Inspection of Complex Metallic Parts	PI (UW co-PI S. Devasia; Subcontracts: J. Tang and S. Gupta @UConn; GKN Aerospace)	\$1,264,346	12/1/2019 - 2/28/2021	cash and in-kind cost shares: \$236426 (GKN Aerospace); \$196268 (UConn); \$355204 (UW)
DOD: Advanced Robotics for Manufacturing Institute	Advanced Robotics for Manufacturing Assets in the Northwest	PI (co-PI S. Devasia)	\$250,000	3/15/2020 - 9/31/2020	subcontracts: Oregon and Montana Mfg Extension Partnerships
Xerox	Toward a Sustainable Additive Manufacturing of Polymeric Materials	PI	\$20,000	01/15/2020 - 06/30/2020	-
Wichita State University	Large Metallic Sanding and Finishing	Subcontract PI	\$1,501,889; my share: \$91,995	04/2019 - 07/2020	cost shares \$612750 (WSU); \$156024 (UConn and UW); \$158626 (GKN Aerospace)

(continued)

Source	Title	Role	Amount	Dates	Notes
U.S. Air Force	Instrumentation Sensing and Process Controls to Enable Adaptive and Uncertainty-Resilient Additive Manufacturing	Project PI (Co-PI: R. Hebert)	\$600,000	08/16/2019 - 08/15/2022	selected and ready for execution; dropped after institutional move
CT Innovations: UConn Quiet Corner Innovation Center	Two-in-One Position and Velocity Transducers	Project PI	\$21,508	02/01/2019 - 05/31/2019	-
NSF: I/UCRC: Center for Science of Heterogeneous Additive Printing of 3D Materials	Characterization and Process Monitoring of Selective Laser Sintering for Reclaimed High-Temperature-Resistant Polymers	PI (Co-I: M. SobkowiczKline @UMass Lowell)	\$50,000	01/01/2019 - 12/31/2019	-
CT Innovations: CTNext Higher Education	Inspiring Industry 4.0 Innovation through University-Industry Collaboration	Co-PI (PI: J. Tang @UConn)	\$400,000; my share: \$80,000	01/01/2019 - 12/31/2019	-
CT Innovations: UConn Quiet Corner Innovation Center	Work-flow Analysis Optimization and Process Automation for Complex Product Assembly	Co-PI (PI: L. Zhang @UConn)	\$64,508; my share: \$21,502	10/01/2018 - 05/31/2019	-
Unilever Corp.	Quality Remake: Toward a Quality-assured Sustainable Additive Manufacturing of PA12 Materials	PI	\$54,800	10/02/2018 - 10/01/2019	-
DOE: Clean Energy Smart Manufacturing Innovation Institute	Energy Management Systems for Subtractive and Additive Precision Manufacturing	Co-PI (PI: G. Bollas @UConn)	\$2,064,837; my share: \$78,008	06/01/2019 - 05/31/2021	cost share: \$1199298; dropped after institutional move

(continued)

Source	Title	Role	Amount	Dates	Notes
DOE SBIR: Hifunda Inc.	Fabrication of Extreme Environment Materials for Large Parts Using Additive Manufacturing Methods	Co-PI (PI: R. Hebert @UConn)	\$150,000; my share: \$25,000	06/12/2017 - 04/30/2018	subcontract award
UConn Research Excellence Program	Mechatronics and Modeling of an Open-Protocol Powder Bed Fusion Additive Manufacturing System	PI (Co-PI: R. Hebert @UConn)	\$49,999	06/01/2017 - 6/30/2018	-
UTC Institute for Advanced Systems Engineering	Modeling and Learning in Powder Bed Fusion Additive Manufacturing	PI	\$50,000	01/01/2017 - 12/15/2017	-
Next-Gen CT	Design of an Open-source Powder Bed Fusion Additive Manufacturing System	PI (Co-PI: R. Hebert and A. Ma @UConn)	\$461,457	07/01/2015 - 07/01/2018	-
Next-Gen CT and UConn Tech Park Initiative	Acquisition of a Metal Powder Bed Fusion Additive Manufacturing System	PI (Co-PI: R. Hebert @UConn)	\$288,475	05/01/2017 - 05/01/2018	+\$34700 industry equipment share

OTHER FUNDING EXPERIENCE

- Proposal drafter: “Advanced Control Design for Hard Disk Drives,” Computer Mechanics Lab at UC Berkeley (funded jointly by HGST, a Western Digital Company, SAE Magnetics, Seagate Technology, Western Digital Corporation, and Hysitron Technologies), ~\$160,000 (\$35,000~\$50,000 / year, 2010, 2012, 2013, and 2014). PI: M. Tomizuka.
- Proposal drafter: “Servo Design for Modern and Future Hard Disk Drives,” sponsored by Western Digital Corporation, ~\$200,000 (\$40,000~\$50,000 per year, 2011, 2012, 2013, and 2014). PI: M. Tomizuka.

DOCUMENTATION OF TEACHING EFFECTIVENESS

Teaching website: <https://faculty.washington.edu/chx/learningtree>, with over 1000 pages of LaTeX-typeset course notes and slides on controls, data sciences, manufacturing, and engineering mathematics; video lectures and open-learning materials at <https://www.youtube.com/channel/UCMmCrJo9sScOKPYINz-nleg>.

COURSES TAUGHT & STUDENT EVALUATIONS AT UW

Course	Title	Quarter	Credit Hrs	Enrollment	Evaluation Response	Evaluation: Raw / Adjusted			
						Item 1 (course)	Item 3 (instructor)	Item 4 (effective)	Overall
ME 599E	Robotics Vision and Mechatronics for Mfg.	Sp 21	4	22	18/22	4.2/4.0	4.4/4.2	4.1/3.9	4.2/4.0
ME 599H-K*	Linear Syst. Theory	Wtr 21	4	37	23/37	3.7/3.8	3.9/4.0	3.2/3.3	3.8/3.8
ME 599N/E	Control Factorization	Sp 20	3	8	8/8	4.7/4.2	4.9/4.5	4.8/4.3	4.9/4.4
ME 547	Linear Syst. Theory	Wtr 20	4	67	47/67	4.0/4.0	4.4/4.4	4.1/4.1	4.1/4.1

Note:

0: lowest; 5: highest

*: during the COVID 19 pandemic, ME 547 was offered as ME 599 H-K without prerequisites.

TEACHING AWARDS, NOMINATIONS FOR TEACHING AWARDS

- *Nominee of University Teaching Fellow Award*,² 11/22/2016, University of Connecticut
- *Teaching Excellence Recognition by Office of the Provost*, 01/26/2018, University of Connecticut
- *Teaching Excellence Recognition by Office of the Provost*, 01/29/2016, University of Connecticut

COURSES TAUGHT & STUDENT EVALUATIONS AT THE UNIVERSITY OF CONNECTICUT

Semester & Year	Course Section No. & Title	Credit Hrs	Response / Enrollment	Chen / Dept / School	
				Course	Instructor
Sp 2019	ME 3220 – Mechanical Vibrations	4	17/30	3.0/3.1/3.7	4.0/3.4/3.9
Sp 2019	ME 6340 – Graduate Seminar	1	11/35	4.0/4.0/4.2	4.5/4.3/4.5
Fa 2018	ME 5160 – Theory and Design of Automatic Control Systems	4	8/13	4.0/3.1/3.8	4.0/3.4/4.0
Fa 2017	ME 3295/5895 3 – Special Topics in Mechanical Engineering	3	4/6	5.0/3.6/3.9	5.0/3.9/4.1
Sp 2017	ME 3220 2 – Mechanical Vibrations	4	52/70	3.0/3.2/3.7	3.0/3.4/3.9
Fa 2016	ME 3295/MSE 4095 – Introduction to 3D Printing: Learn by Building	4	12/34	4.0/3.3/3.5	4.0/3.5/3.6
Sp 2016	ME 3220 002 – Mechanical Vibrations	4	44/67	3.0/3.3/3.3	3.0/3.6/3.6

²University Teaching Fellow is the highest teaching honor at UConn.

(continued)

Semester & Year	Course Section No. & Title	Credit Response /		Course	Instructor
		Hrs	Enrollment		
Fa 2015	ME 5895 001 – Special Topics: System Identification and Adaptive Control	3	7/10	5.0/3.5/3.9	5.0/3.5/4.0
Fa 2014	ME 5507 001 – Engineering Analysis I	4	19/31	3.0/3.5/4.0	4.0/3.6/4.1

COURSES TAUGHT & STUDENT EVALUATIONS AT UC BERKELEY

Semester & Year	Course Section No. & Title	Credit Hrs	Response / Enrollment	Chen / Dept. Avg	
				Course Worth	Teaching Effectiveness
Sp 2014	ME 233 – Advanced Control Systems II	4	21/23	6.4/5.9	6.2/5.8
Fa 2013	ME 132 – Dynamic Systems and Feedback	4	62/100	5.9/5.4	5.4/5.1

Note:

0: lowest; 7: highest

Teaching Assistant Positions & Student Evaluations at UC Berkeley

Responsibilities: lead weekly discussions sessions; hold office hours; grading homework and exams.

Semester & Year	Course Section No. & Title	Credit Hrs	Response / Enrollment	Effectiveness	
				Avg	Median
Sp 2013	ME 233 – Advanced Control Systems II	4	30/30	4.60	5
Fa 2012	ME 232 – Advanced Control Systems I	4	29/36	4.45	5

Note:

No relative comparison provided to TA evaluations.

UC Berkeley Outstanding Graduate Student Instructor Award.

TAUGHT COURSES: DYNAMIC SYSTEMS, ROBOTICS, AND CONTROLS

Linear Systems (UW ME547, graduate controls core course)

- ME547 is a first-year graduate course on modern control systems focusing on: state-space description of dynamic systems, linear algebra for controls, solutions of state-space systems, discrete-time models, stability, controllability and observability, state-feedback control, observers, observer state feedback controls, and linear quadratic optimal controls. ME547 is a prerequisite to most advanced graduate control courses in the UW ME department.
- *Course website:* <https://faculty.washington.edu/chx/teaching/me547/>
- *Youtube List:* https://www.youtube.com/playlist?list=PLujcneWPG6EB0KrqW_dEVZVmsFtxYEzek

Robotics, Vision, and Mechatronics for Manufacturing (UW ME 599E, graduate elective)

- This course provides a hands-on demonstration of tools at the intersection of robotics and mechatronics for manufacturing. We walk through the fundamentals of robotic manipulation and computer vision, in tandem with focused discussions on vision-based planning and controls in a 3-dimensional space. Along the way, the course provides insights into how complex problems can be decomposed and solved using powerful numerical tools and effective software. Project-based assignments and demonstration enhance in-class learning. And occasional, student-lead presentations foster a mindset of predictive planning and technical communication.
- *Course website:* <https://faculty.washington.edu/chx/teaching/robotics/>

Advanced Control Systems II (UC Berkeley ME233, graduate required)

- ME233 discusses advanced control methodologies and their applications in engineering systems. Methodologies include but are not limited to: Linear Quadratic Optimal Control, Kalman Filter, Stochastic Control, System Identification and Adaptive Control.
- *Course website:* <https://faculty.washington.edu/chx/teaching/ucb-me233/>
- *Open learning initiative:* YouTube, iTunes-U, taught cross-campus to students at UC Davis.

Control Parameterization and Graphical Control Synthesis (UW 599, graduate elective)

- Experience-based learning in the design of feedback controllers for linear systems, frequency-domain control synthesis, principles of feedback controls, limits of performance, approximation theory, and parameterization of stabilizing controllers (Youla-Kucera parameterization).
- *Course website:* <https://faculty.washington.edu/chx/teaching/loopshaping/>

System Identification and Adaptive Control (UCONN ME5895-001, graduate elective)

- Input-output data-based system identification, model-based adaptive control.
- *Course website:* <https://faculty.washington.edu/chx/teaching/ykidac/>

Adaptive and Optimal Controls (UCONN ME5895/ME3295, graduate/undergrad elective)

- Advanced control methodologies and their applications to engineering systems such as motion control, additive manufacturing. Topics include: State-Space Modeling, Observer Design, Linear Quadratic Optimal Control, Optimal Estimation, Linear Quadratic Gaussian Problem, Data-Driven Modeling, Adaptive Identification and Estimation, Introduction to H infinity Control, Introduction to Sampled-Data Systems.

Theory and Design of Automatic Control Systems (UCONN ME5160, graduate core)

- Graduate level introductory control course covering system modeling, time- and frequency-domain system analysis and designs.

Dynamical Systems and Feedback (UC Berkeley ME132, undergraduate required)

- ME132 is the first undergraduate course on dynamic systems and control in the ME department. It introduces the general concepts and fundamental theories of systems and controls.

TAUGHT COURSES: MATH**Engineering Analysis I (UCONN ME5507, graduate required)**

- ME5507 is a first-year graduate course covering topics in mathematics that are central for solving practical engineering problems. Topics include but are not limited to: differential equations, linear

algebra, and optimization. It is a prerequisite to other advanced graduate courses in the UCONN ME department.

- *Course website:* <https://faculty.washington.edu/chx/teaching/enganalysis/>

TAUGHT COURSES: MANUFACTURING

Robotics, Vision, and Mechatronics for Manufacturing (UW ME 599E, graduate elective)

- cf *Taught Courses: Dynamic Systems, Robotics, and Controls*
- *Course website:* <https://faculty.washington.edu/chx/teaching/robotics/>

3D Printing: Learn by Building (UCONN ME3295/MSE4095, undergraduate elective)

- “3D Printing: Learn by Building” 2016 is a flended (flipped+blended) course that introduces the exciting engineering in 3D printing to junior/senior undergraduate students. It offers a hybrid learning experience that focuses on the mechatronics, design, and systematic integration of 3D printing machines. Students will build 3D printers from a series of inexpensive open-source parts, together with receiving in-class and online lectures on the fundamental theory and applications of additive manufacturing (AM). With the flipped and blended learning, the course fosters cognitive skills including collaboration, communication, critical thinking, creativity, persistence, and learning from failure.

TAUGHT COURSES: ENGINEERING

Mechanical Vibrations (UCONN ME3220-6339, undergraduate required)

- ME3220-6339 is an undergraduate required class that discusses: free and forced vibrations, with damping, of linear systems with one and two degrees of freedom; transient vibrations; vibration isolation; rigid rotor balancing; and elements of Laplace transforms.

Mechanical Engineering Seminar (UCONN ME6340, graduate core)

- Seminar coordination between department and speakers; announcement to and evaluation of students.

SERVICE

COLLEGE SERVICE

1. *Robotics and Manufacturing:* Starting 2021, I am serving in CoE robotics and manufacturing groups to engage with such industry leaders as Microsoft and Blue Origin, to foster tighter UW-industry partnerships in robotics and manufacturing. I participated in three virtual group discussions and hosted two in-person visits at UW that were attended by over 12 engineers and managers from Microsoft. Microsoft expressed interests in collaborating on manufacturing inspection, robotics, cloud computing. I also initiated collaboration opportunities with the Advanced Robotics for Manufacturing Institute, GKN Aerospace, and Xerox, to have secured two letters of support for the ongoing building of an NSF Industry-University Cooperative Research Centers (IUCRC).
2. *Scientific Committee Member, Boeing Advanced Research Center (BARC) and Advanced Composites Center (ACC):* I participate in biweekly meetings with the committee to develop collaborative proposals (two funded to date, cf. RESEARCH ACTIVITIES) and along the way, to foster tighter UW-Boeing and UW-industry partnerships.

3. *UW Industrial Outreach and Manufacturing Leadership in American Northwest*: I am leading a multidisciplinary project to create a first-of-its-kind [resource map of robotics training for manufacturing](#) in American Northwest. The project brings UW together with regional manufacturing extension partnerships at Oregon and Montana, positioning UW as the Northwestern lead in the [DOD Advanced Robotics for Manufacturing Institute](#).
4. *UW-Kawasaki Robotics engagement*: Extending from the ARM industrial outreach, I co-developed UW's engagement with Kawasaki Robotics, in activities ranging from hardware incentives to education development.
5. *UW-DENSO engagement*: I worked as a project PI with Erin Schwartz, Director of Corporate & Foundation Relationships at COE, to develop a proposal on photonic sintering with DENSO, and to foster a pathway towards long-term partnership between UW and DENSO's newly established Seattle office.
6. *UW-HP engagement*: I participated in fostering the college's engagement with HP in 2020 including the initial full-day on-campus visit, follow-up email communications, and accommodating HP's second virtual visit in the form of an ME department seminar. HP invited follow-up discussions. Collaboration is ongoing.
7. *Cluster hire proposal committee*, UW COE "advanced metal alloys", 2020: I participated in developing the proposal as an ME representative.
8. *Cluster hire proposal committee*, UW COE "data-driven solutions for resilient communities", 2020: I participated in developing the proposal as an ME representative.
9. *Undergraduate Commencement Faculty on Stage*, UConn, 2019.
10. *Faculty advisor, UConn SoE Open House*, 2015 fall, 2016 spring, 2016 fall, 2017 spring: I served as the ME representative to answer questions to prospective students and parents of the School of Engineering.
11. *SoE industrial open house presentation*, 2014 fall: poster presentation to industrial visitors.

UNIVERSITY SERVICE

1. *Scientific Committee Member*: Advanced Composites Center, UW
2. *Faculty advisor of two UConn University Scholars* (Dennis Scheglov, Thomas Chessman) 2017-2019
3. *Faculty advisor of one UConn IDEA grantee* 2018-2019
4. *UConn Graduate Faculty*, 2014-2019
5. *Invited panelist for UConn Innovation Connection: Additive Manufacturing – 3D Printing*, 05/08/2017
6. Invited faculty reviewer (two proposals): UConn IDEA Grant, 2015
7. "Manufacture Automation and Control Systems," poster at UCONN Industry Open House, November 5, 2014

PROFESSIONAL SOCIETY AND OTHER SERVICE

Editorship and Editorial Board

- *Journal Guest Editor*, "[Focused Section on Machine Learning, Estimation and Control for Intelligent Robotics](#)," International Journal of Intelligent Robotics and Applications, 2020
- *Editor*, ASME Dynamic Systems and Control Division (DSCD) Newsletter, Spring 2017-December 2018
- *Associate Editor*, ASME DSCD Newsletter, 2015-2016

Conference Organization

- *Program Chair*, ISCIE/ASME International Symposium on Flexible Automation (ISFA), 2024
- *Operation Committee*, IEEE/ASME Intl. Conf. on Advanced Intelligent Mechatronics, 2024
- *Local Arrangements Chair*, IEEE/ASME Intl. Conf. on Advanced Intelligent Mechatronics, 2023
- *Program Co-Chair*, ISCIE/ASME International Symposium on Flexible Automation (ISFA), 2022
- *Program Chair*, ASME Dynamic Systems and Control Conference, 2022
- *Scientific Committee Member*, SME North American Manufacturing Research Conference (NAMRC) 50, 2022
- *Program Committee Co-Chair*, 10th International Conference on Nano and Materials Science (ICNMS), January 22-24, 2022
- *Exhibits Chair and Associate Editor at Large*, IEEE American Control Conference, 2021
- *Steering Committee Member*, American Automatic Control Council (AACC) Modeling, Estimation, and Control Conference, 2021
- *Scientific Committee Member*, SME North American Manufacturing Research Conference (NAMRC) 49, 2021
- *Program Committee Chair*, 4th International Conference on Manufacturing Technologies, 2020
- *Student Best Paper Award Committee*, ASME Dynamic Systems and Control Conference (DSCC), 2020
- *Student Best Paper Award Committee*, Modeling, Estimation and Control Conference, 2022
- *Publicity Chair*, IEEE/ASME International Conference on Advanced Intelligent Mechatronics, 2020
- *Organizing Committee Member*, ISCIE/ASME International Symposium on Flexible Automation (ISFA), 2020
- *Students and Young Members Chair*, ASME Dynamic Systems and Control Conference, 2016, 2020

Committee Leadership

- *Awards Chair*, Vibration Technical Committee, ASME DSCD, 2020
- *Chair*, Vibration Technical Committee, ASME DSCD, October 2018-2020
- *Vice Chair*, Vibration Technical Committee, ASME DSCD, October 2017-October 2018
- *Secretary*, Vibration Technical Committee, ASME DSCD, October 2015-October 2017
- *Working Group Member*, ASTM New Standard Additive Manufacturing – Data Registration, 2020-
- *Scientific Committee Member*, Society of Manufacturing Engineering [North American Manufacturing Research Conference](#), 2020-
- *Science Committee Member*, Smart Manufacturing Track, Society of Manufacturing Engineers, 2019-
- *Technical Committee member*: Clean Energy Smart Manufacturing Innovation Institute, Northeast Region, 2016-2018

Organized Special Sessions

- Special student session: *Navigating a Post-Graduate Career Path in a Challenging Time*, ASME Dynamic Systems and Control Conference (DSCC) 2020: the session brings together five industry leaders from Boeing, Toyota Research Institute, Western Digital, National Instruments, and Quanser to focused panel discussions on career development under a global pandemic.
- Special session: *Federal Funding Opportunities for Junior Investigators in System Science and Control Engineering*, ASME Dynamic Systems and Control Conference (DSCC) 2016: the session brings together four program officers from three federal agencies (NSF, AFOSR, DOE) in a focused panel on funding opportunities for junior investigators in the field of dynamic systems and controls.

- *Invited Session*: “Control of Additive Manufacturing Processes,” American Control Conference, 2022
- *Invited Session*: “Advanced Mechatronics and Vibrations of Smart Systems I,” American Control Conference, 2020
- *Invited Session*: “Advanced Mechatronics and Vibrations of Smart Systems II,” American Control Conference, 2020
- *Invited Session*: “Vibrations: Modeling, Analysis, and Control I,” ASME Dynamic Systems and Control Conference, 2019
- *Invited Session*: “Vibrations: Modeling, Analysis, and Control II,” ASME Dynamic Systems and Control Conference, 2019
- *Invited Session*: “Modeling and Control of Additive Manufacturing,” IEEE American Control Conference, 2018
- *Invited Session Organizer*: “Modeling and Control of Advanced Manufacturing Processes,” IEEE American Control Conference, 2018
- *Invited Session Organizer*: “Vibrations: Modeling, Analysis, and Control I,” ASME Dynamic Systems and Control Conference, 2018
- *Invited Session Organizer*: “Vibrations: Modeling, Analysis, and Control II,” ASME Dynamic Systems and Control Conference, 2018
- *Invited Session Organizer*: “Vibrations,” ASME Dynamic Systems and Control Conference, 2017
- *Session Organizer*: “Control Systems,” IEEE International Midwest Symposium on Circuits and Systems, 2017
- *Invited Session Organizer*: “Motion and Vibration Control Applications,” ASME Dynamic Systems and Control Conference, 2016
- *Invited Session Organizer*: “Mechatronics & Controls in Advanced Manufacturing,” ASME Dynamic Systems and Control Conference, 2016
- *Session Organizer*: “Mechatronics & Precision Manufacturing,” ISCIE International Symposium of Flexible Automation, 2016
- *Session Organizer*: “Control of Mechatronic Systems,” ASME Dynamic Systems and Control Conference, 2015
- *Session Organizer*: “Estimation and Tracking,” ASME Dynamic Systems and Control Conference, 2015
- *Session Organizer*: “Drilling Automation,” ASME Dynamic Systems and Control Conference, 2015
- *Session Organizer*: “Physical Human-Robot Interactions,” ASME Dynamic Systems and Control Conference, 2014

Conference Editorial Board / Associate Editorship

- *IEEE American Control Conference*, 2015-2017, 2019-2021
- *17th International Conference on Ubiquitous Robots (UR)*, Kyoto, Japan, 2020
- *IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, 2016, 2018-2020
- *International Conference on Control, Automation, Robotics and Vision (ICARCV)*, 2018
- *ISCIE/ASME International Symposium on Flexible Automation*, 2016, 2018
- *IEEE International Midwest Symposium on Circuits and Systems (MWSCAS)*, 2017
- *ASME Dynamic Systems and Control Conference*, 2014, 2016, 2017
- *International Conference on Complex Systems Engineering*, 2015

International, National or Governmental Service

- Proposal Review Panelist, *National Science Foundation*, 2015, 2017, 2018, 2019, 2020 (7+ times)
- Ad-hoc Proposal Reviewer, *National Science Foundation*, 2017, 2018, 2019 (4+ times)
- Ad-hoc Proposal Reviewer, *US Department of Defense (DOD)*, 2017 (1 time)
- Proposal Reviewer, *Advanced Robotics for Manufacturing Institute*, 2019-2020 (2 times)
- Ad-hoc Proposal Reviewer, *Kentucky Science and Engineering Foundation*, 2014 (1 time)
- Ad-hoc Proposal Reviewer, *Netherlands Organisation for Scientific Research*, 2016 (1 time)
- Ad-hoc Proposal Reviewer, *Flanders Innovation & Entrepreneurship*,³ 2018

³Flanders Innovation & Entrepreneurship (<http://www.vlaio.be/english>) is a government agency, charged with implementing the economic and enterprise policy in Flanders, the Dutch speaking northern part of Belgium. Acting for the Hermes Fund the agency is charged with selecting funding applications for research & development by and for enterprises. The agency is the merger of Enterprise Flanders (AO) with IWT.