






MOLONG DUAN

Assistant Professor, Department of Mechanical and Aerospace Engineering
The Hong Kong University of Science and Technology

☎ (+852)34693024 ✉ duan@ust.hk  [molongduan](https://www.linkedin.com/in/molongduan)  [Google Scholar](https://scholar.google.com/citations?user=0000-0001-8624-0133)  [3307038](https://orcid.org/0000-0001-8624-0133)
 www.mae.hkust.edu.hk/en/people/faculty/detail/duan-molong  [0000-0001-8624-0133](https://orcid.org/0000-0001-8624-0133)

Education

Doctor of Philosophy in Mechanical Engineering

University of Michigan, Ann Arbor

- Focusing on control, manufacturing, and mechatronics (GPA: 4.00) *Jan. 2014 – Apr. 2018*
- Thesis: *Energy-Optimal Control of Over-Actuated Systems – with Application to a Hybrid Feed Drive*

Master of Science in Mechanical Engineering

University of Michigan, Ann Arbor

- Focusing on control, optimization, and mechatronics (GPA: 4.00) *Sept. 2012 – Dec. 2013*

Bachelor of Science in Theoretical and Applied Mechanics

Peking University, Beijing

- Major in mechanics and control (GPA: 3.64) *Sept. 2008 – June 2012*

Research Experiences

ASSISTANT PROFESSOR

Hong Kong University of Science and Technology

Department of Mechanical and Aerospace Engineering

July 2021 – Present

Reduced-order modeling and vibration compensation of industrial robot

- The research aims to develop reduced-order models and vibration compensation algorithms for industrial robots.
- Proposed strain-based low-order models that capture the nonlinear deformation and vibration of the robots.

Smart additive manufacturing controller

- The research aims to develop smart trajectory generation and extrusion control methods for 3D printers, which compensate for the machine dynamics and extrusion dynamics

RESEARCH FELLOW

University of Michigan, Ann Arbor

Advisors: Profs. Carlos E. S. Cesnik and Ilya V. Kolmanovskiy

Sept. 2018 – June 2021

Maneuver and gust load alleviation of flexible aircraft through control allocation

- The research aims to provide a systematic framework to alleviate the structural load of very flexible aircraft under excessive maneuver or gust.
- Proposed load alleviation methods for linear and nonlinear very flexible aircraft through dynamic control allocation.
- Verified using flexible aircraft X-HALE (developed at the University of Michigan) and flexible general transport aircraft, and Airbus transport aircraft models.

Reduced-order modeling of nonlinear structure systems – with application to very flexible aircraft

- The research aims to develop reduced-order models for model-based controller design and estimation.
- Developed a model that combines the classical rigid aircraft dynamics with aeroelastic information extracted from high-fidelity models or flight test data.
- Developed a data-driven approach in the identification and learning of the nonlinear aeroelastic responses.
- Verified against X-HALE and Airbus transport aircraft models generated by University of Michigan's Nonlinear Aeroelastic Simulation Toolbox (UM/NAST)

GRADUATE STUDENT RESEARCH ASSISTANT

University of Michigan, Ann Arbor

Advisor: Prof. Chinedum E. Okwudire

Sept. 2012 – Aug. 2018

Optimal control of over-actuated systems: with applications to a hybrid feed drive

- This research provides a set of methods to optimally allocate the redundant control efforts in over-actuated

systems, and is applied to a hybrid feed drive for machining applications to enhance the energy efficiency without sacrificing positioning performance.

- Derived the optimal control ratio/subspace for general over-actuated systems, based on which control design methodologies in maximizing the alignment are proposed.
- Proved the traditional linear quadratic control formulates one special case of the proposed optimal structure.
- Proposed proxy-based control allocation algorithms to facilitate real-time optimal control allocation without sacrificing control performance.
- Various peripheral projects around the hybrid feed drive, including nonlinearity identification and compensation, slip observer of friction drive, mode switching control, etc.

Vibration compensation for structure flexibility through trajectory optimization

- This research aims to enhance the tracking performance of motion systems with unwanted vibrations through trajectory optimization.
- Proposed a filtered basis function (FBF) method to address the non-minimum phase (NMP) behaviors, which is a major bottleneck for tracking performance in flexible structures.
- Proved and showed the advantage of the consistency of the FBF method comparing to state-of-the-art tracking control methods.
- Validated the FBF method on industrial motion stages and commercial 3D printers to significantly reduce motion-induced errors.
- Proposed algorithms for optimal corner trajectory of feed drive systems using optimal control theories.
- Collaborated with major 3D printer manufacturers to incorporate FBF as an advanced function module in the next generation of 3D printers.

Reduced-order modeling of ball bearing and screws for electrical power-assisted steering (EPAS)

- This research aims to provide a reduced model of ball screws and bearings in EPAS while capturing the key features such as lateral deformations of the screw shaft, geometric errors, and ball-to-ball contact.
- Proposed a simplified analytical method to determine the contact conditions in ball bearings and screws considering external load, misalignment, geometric errors, and ball-to-ball contact conditions.
- Predicted and explained the friction variation in the EPAS system with the proposed model.

UNDERGRADUATE STUDENT RESEARCH ASSISTANT

Peking University, Beijing

Advisor: Profs. Ray P.S. Han, Jianjun Tao, and Cunbiao Li

Sept. 2010 – June 2012

Fabrication of fluidic antenna and wireless strain sensor

- Designed, fabricated, and verified a novel strain sensor using fluidic metal EGaIn.
- Collaborated with the University of Toronto and Siemens Shanghai.

Experiments and numerical simulation of vortex shedding from an oscillating cylinder

- Simulated the vortex patterns of an oscillating cylinder with moving mesh algorithms
- Proposed a simplified model for its shedding pattern and lifting force and verified the model by particle image velocimetry (PIV) flow visualization technique.

Awards and Honors

- Michigan Leaders and Honors Award (2021)
- Best Student Paper Award at the 2015 Dynamic Systems and Controls Conference (2015)
- Best Poster Award at 2014 International Forum on Sustainable Manufacturing (2014)
- Rackham Centennial Fellowship Award (2013)
- Outstanding Xinjiang Overseas Student Fellowship (2013)
- Kwang-Hua Scholarship (2011)
- Principal Research Fund (2010)
- Prize for Academic Excellence in Yuanpei College (2010, 2009)

Unpublished Work

- [1] **Duan, M.**, Kolmanovsky, I.V., Cesnik, C.E.S., Dematté, G. and Vetrano, F., “Low-order flexible aircraft modeling exploiting the high-fidelity model linearization,” *Journal of Aircraft* (under Airbus approval for submission).
- [2] Pereira, M.F.V., **Duan, M.**, Cesnik C.E.S., Kolmanovsky I.V. and Vetrano, F., “Model predictive control for very flexible aircraft based on linear parameter varying reduced-order models,” *AIAA SciTech 2022 Forum* (under Airbus approval for submission).

Journal Publications

- [1] Chou, C-H., **Duan, M.** and Okwudire, C.E., 2021, “A linear hybrid model for enhanced servo error pre-compensation of feed drives with unmodeled nonlinear dynamics,” *CIRP Annals - Manufacturing Technology*.
- [2] **Duan, M.**, Ramani, K.S. and Okwudire, C.E., 2020, “Energy optimal control of an over-actuated hybrid feed drive under variable-frequency disturbances - with application to machining,” *Control Engineering Practice*, 100, p.104442.
- [3] Lin, B., **Duan, M.** and Okwudire, C.E., 2019, “Analytical and low-order numerical modeling of ball-to-ball contact friction in linear ball bearings and ball screws,” *Journal of Tribology*, 141(7), p.071401.
- [4] Ramani, K.S., **Duan, M.**, Okwudire, C.E. and Ulsoy, A.G., 2019, “Optimal selection of basis functions for minimum-effort tracking control of nonminimum phase systems using filtered basis functions,” *Journal of Dynamic Systems, Measurement, and Control*, 141(11).
- [5] **Duan, M.** and Okwudire, C.E., 2019, “Connections between control allocation and linear quadratic control for weakly redundant systems,” *Automatica*, 101, pp.96-102.
- [6] **Duan, M.** and Okwudire, C.E., 2018, “Proxy-based energy optimal dynamic control allocation for dual-input, single-output over-actuated systems,” *IEEE/ASME Transaction on Mechatronics*, 23(2), pp. 895-905.
- [7] **Duan, M.**, Yoon, D. and Okwudire, C.E., 2018, “A limited-preview filtered B-spline approach to tracking control – with application to vibration-induced error compensation of a 3D printer,” *Mechatronics*, 56, pp. 287-296.
- [8] Ramani, K.S., **Duan, M.**, Okwudire, C.E. and Ulsoy, A.G., 2017, “Tracking control of linear time-invariant nonminimum phase systems using filtered basis functions,” *Journal of Dynamic System, Measurement and Control*, 139(1), pp. 11001-(1–11).
- [9] **Duan, M.** and Okwudire, C.E., 2016, “Energy-efficient controller design for a redundantly actuated hybrid feed drive with application to machining,” *IEEE/ASME Transaction on Mechatronics*, 21(4), pp. 1822–1834.
- [10] **Duan, M.** and Okwudire, C.E., 2016, “Correction to ‘Energy-efficient controller design for a redundantly-actuated hybrid feed drive with application to machining,’” *IEEE/ASME Transaction on Mechatronics*, 21(6), pp. 2999–3000.
- [11] Okwudire, C.E., Ramani, K. and **Duan, M.**, 2016, “A trajectory optimization method for improved tracking of motion commands using CNC machines that experience unwanted vibration,” *CIRP Annals - Manufacturing Technology*, 65(1), pp. 373–376.
- [12] **Duan, M.** and Okwudire, C.E., 2016, “Minimum-time cornering for CNC machines using an optimal control method with NURBS parameterization,” *International Journal of Advanced Manufacturing Technology*, 85(5–8), pp. 1405–1418.

Conference Publications

- [1] Chou, C-H., **Duan, M.** and Okwudire, C.E., 2021, “A hybrid filtered basis functions approach for tracking control of linear systems with unmodeled nonlinear dynamics,” *IEEE International Conference on Automation Science and Engineering (CASE)*.
- [2] **Duan, M.**, Kolmanovsky, I.V. and Cesnik, C.E.S., 2021, “Maneuver load alleviation of very flexible aircraft via nonlinear decoupling control,” *AIAA SciTech 2021 Forum*.
- [3] **Duan, M.**, Kolmanovsky, I.V., Cesnik, C.E.S. and Vetrano, F., 2021, “Nonlinear low-order modeling for very flexible aircraft,” *AIAA SciTech 2021 Forum*.
- [4] Hansen, J., **Duan, M.**, Kolmanovsky, I.V. and Cesnik, C.E.S., “Control allocation for maneuver and gust load alleviation of flexible aircraft,” *AIAA SciTech 2020 Forum*, Orlando, GA, USA.

- [5] **Duan, M.**, Hansen, J., Kolmanovsky, I.V. and Cesnik, C.E.S., 2019, "Maneuver alleviation of flexible aircraft through control allocation: a case study using X-HALE," *International Forum on Aeroelasticity and Structural Dynamics*, Savannah, GA, USA.
- [6] Ramani, K.S., **Duan, M.**, Okwudire, C.E. and Ulsoy, A.G., 2018, "A lifted domain-based metric for performance evaluation of LTI and LTV discrete-time tracking controllers," *International Symposium on Flexible Automation*, Kanazawa, Japan.
- [7] Lin, B., **Duan, M.**, Okwudire, C.E. and Wou, J.S., 2018, "An improved analytical model of friction and ball motion in linear ball bearings – with application to ball-to-ball contact prediction," *ASME International Mechanical Engineering Congress and Exposition*, Pittsburgh, PA, USA.
- [8] **Duan, M.** and Okwudire, C.E., 2017, "Proxy-based energy optimal dynamic control allocation for multi-input, multi-output over-actuated systems," *ASME Dynamic Systems and Control Conference*, Tyson, VA, USA.
- [9] Yoon, D., **Duan, M.** and Okwudire, C.E., 2017, "Software-based compensation of vibration-induced errors of a commercial desktop 3D printer," *6th International Conference on Virtual Machining Process Technology*, Montréal, Canada.
- [10] Lin, B., **Duan, M.**, Okwudire, C.E. and Wou, J.S., 2017, "A simplified analytical model of rolling/sliding behavior and friction in four-point-contact ball bearings and screws," *ASME International Mechanical Engineering Congress and Exposition*, Tampa, FL, USA.
- [11] **Duan, M.** and Okwudire, C.E., 2016, "Modeling and observer-based compensation of slip in a friction drive for servo positioning," *International Symposium on Flexible Automation*, Cleveland, OH, USA.
- [12] **Duan, M.** and Okwudire, C.E., 2016, "Near energy optimal control allocation for dual-input over-actuated systems," *ASME Dynamic Systems and Control Conference*, Minneapolis, MN, USA.
- [13] **Duan, M.**, Ramani, K.S., and Okwudire, C.E., 2015, "Tracking control of non-minimum phase systems using filtered basis functions: a NURBS-based approach," *ASME Dynamic Systems and Control Conference*, Columbus, OH, USA. (**Best Student Paper Awarded**)
- [14] **Duan, M.** and Okwudire, C.E., 2015, "Energy efficiency and performance optimized control of a hybrid feed drive," *ASME International Manufacturing Science and Engineering Conference*, Charlotte, NC, USA.
- [15] **Duan, M.** and Okwudire, C.E., 2014, "Minimum-time cornering for manufacturing machines using optimal control," *ASME Dynamic Systems and Control Conference*, San Antonio, TX, USA.

Patent

- [1] **Duan, M.**, Okwudire, C.E. and Ramani, K.S., "Use of filtered basis splines to compensate servo-induced motion errors," U.S. Patent 10585414, issued Mar. 2020.

Magazine Articles

- [1] Ramani, K.S., **Duan, M.**, Yoon, D., Okwudire, C.E. and Ulsoy, A.G., 2018, "Boosting speed and accuracy in precision motion control," *Mechanical Engineering Magazine Select Articles*, 140(09), pp. S17-S23.

Teaching Experience

INSTRUCTOR

The Hong Kong University of Science and Technology

ME40000: Introduction to Additive Manufacturing and Rapid Prototyping

Fall 2020

- Developed this new undergraduate course covering different additive manufacturing technologies.
- Lab sessions with continuous carbon fiber 3D printer structure design and mechanical testing.

GUEST LECTURER

Davis Aerospace Technical High School

Aerospace Structure and Manufacturing (High School)

Fall 2020

- Developed the lectures to introduce manufacturing technologies for aerostructures.

INSTRUCTOR

University of Michigan, Ann Arbor

AE 543: Structural Dynamics (Graduate)

Winter 2019

- Covered beam theory, finite element methods, vibration analysis, stability theory, etc.

GUEST LECTURER

University of Michigan, Ann Arbor

AE 470: Dynamics and Control in Aerospace Applications (Undergraduate)

Winter, Fall 2019

- Developed and delivered PID controller design sessions and experiment sessions.
- Co-developed this new undergraduate control course with Profs. Kolmanovsky and Girard.

GRADUATE STUDENT INSTRUCTOR

University of Michigan, Ann Arbor

ME 584: Advanced Mechatronics for Manufacturing (Graduate)

Winter 2017

- Covered machining fundamentals, trajectory generation, mechatronics system modeling, system identification, and basic control design of feed drives.

Student Mentoring Experiences

John Hansen (*Ph.D. Candidate*)

University of Michigan, Ann Arbor

Ph.D. student mentoring

Sept. 2018 – Present

- Research: control allocation based load alleviation of flexible and very flexible aircraft

Cheng-Hao Chou, Xiaozhu Fang (*Graduate*)

University of Michigan, Ann Arbor

Master students mentoring

Sept. 2019 – July 2020

- Research: data-driven identification and trajectory optimization of 3D printers

Chandler Harris (*Undergraduate*)

University of Michigan, Ann Arbor

Mentoring via Undergraduate Research Opportunity Program (UROP)

June – Sept. 2017

- Research: redesign and manufacturing of the roh'lix in the hybrid feed drive

Yifan Ding (*Undergraduate*)

University of Michigan, Ann Arbor

Mentoring via Undergraduate Research Opportunity Program (UROP)

June – Sept. 2016

- Research: segment-based tracking control using filtered basis function method

Calvin Wang (*Undergraduate*)

University of Michigan, Ann Arbor

Mentoring via Research, Innovation, Service and Entrepreneurship (RISE) program

June 2014 – May 2015

- Research: mode switching and friction drive investigation on a hybrid feed drive

Invited Talks

Department of Mechanical Engineering

Michigan State University, Lansing

“Embracing redundancy and flexibility for Industry 4.0”

Apr. 2020

Department of Mechanical Engineering

The University of British Columbia, Vancouver

“Towards Industry 4.0: enhancing manufacturing performance via mechatronics, control, and data”

Jan. 2020

UM-JITRI Symposium on Smart Manufacturing

JITRI, Nanjing

“Novel machine design and control for additive and smart manufacturing”

Mar. 2019

Department of Mechanical Engineering

Xi'an Jiaotong University, Xi'an

“Enhancing manufacturing via mechatronics: managing redundant actuation and structural flexibility”

July 2018

Control Engineering Group

Cymer, San Diego

“Enhancing manufacturing through control algorithms”

May 2018

Department of Mechanical Engineering

Purdue University, West Lafayette

Department of Environmental and Ecological Engineering

Mar. 2018

“Towards smart and sustainable manufacturing: managing redundant actuation and structural flexibility”

Selected Media Coverage

- [1] Wetzel, R. (2017, Nov. 3). Software algorithm developed at University of Michigan speeds up 3d printing. Retrieved from <https://3dprint.com/193133/algorithm-speeds-3d-printing/>

- [2] Yusuf, B. (2017, Nov. 3). New algorithm cuts 3d printing times by half. Retrieved from <https://all3dp.com/algorithm-3d-printing-time-michigan/>
- [3] Lynch, J. (2017, Nov. 2). 3-D printing gets a turbo boost from U-M technology. Retrieved from <http://additivemanufacturing.com/2017/11/02/3-d-printing-gets-a-turbo-boost-from-u-m-technology>
- [4] Jackson, B. (2017, Oct. 23). How to cut FFF 3D print times in half by the University of Michigan. Retrieved from <https://3dprintingindustry.com/news/cut-fff-3d-print-times-half-university-michigan-123158/>
- [5] Benedict. (2017, Oct. 20). University of Michigan professor doubles 3D printing speeds using vibration-mitigating algorithm. Retrieved from <https://www.3ders.org/articles/20171020-university-of-michigan-professor-doubles-3d-printing-speeds-using-vibration-mitigating-algorithm.html>

Services

REVIEWER (verified on Publons profile [3307038](#))

- IEEE/ASME Transaction on Mechatronics (13)
- Precision Engineering (6)
- IEEE Transactions on Industrial Electronics (4)
- Journal of Guidance, Control, and Dynamics (2)
- IEEE Control Systems Letters (1)
- International Journal of Machine Tools and Manufacture (1)
- Journal of Manufacturing Science and Engineering, Transactions of the ASME (1)
- Journal of Dynamic Systems, Measurement and Control (1)
- Journal of Mechanical Engineering Science (1)
- Applied Science (1)
- Machines (1)
- North American Manufacturing Research Conference (NAMRC) (2)
- American Control Conference (ACC) (2)
- IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM) (1)
- International Symposium on Flexible Automation (ISFA) (1)

VOLUNTEER

- Judge of Engineering Graduate Symposium (EGS) on control, manufacturing, and automation University of Michigan, Ann Arbor
Oct. 2018
- Student judge of Research, Innovation, Service, and Entrepreneurship (RISE) program University of Michigan, Ann Arbor
Dec. 2017
- Student judge of Mechanical Engineering Undergraduate Symposium (MEUS) University of Michigan, Ann Arbor
Apr. 2016, Apr. 2017
- Support team member of ASME International Manufacturing Manufacturing Science and Engineering Conference (MSEC) Detroit
June 2014

Entrepreneur Training and Events

Celebrate Invention

- Presented the FBF method in 3D printing among 8 annually selected technologies by the Office of Technology Transfer. University of Michigan, Ann Arbor
Oct. 2017

NSF Innovation Corps (I-Corps)

- Investigated the commercialization potential of the over-actuated motion platform in the semiconductor industry. National Science Foundation
Mar. – May 2015
- Established business models for the technology based on industry surveys and interviews of more than 50 experts in the semiconductor industry.

iPodia Program **Peking University, National Taiwan University, University of Southern California**

- Formulated a green-campus program based on product design methodologies and market analysis, in a collaborating global team of USC, PKU, and NTU students. *Jan. – June 2011*

Skills

Engineering Software

- NI Certified Labview Associate Developer
- Advanced user of dSPACE, MATLAB, Simulink, Mathematica
- Competent with SolidWorks, Gambit, Fluent, C, C++, FORTRAN, Python

Language

English, Chinese