Matthew D. Kvalheim

Assistant Professor of Mathematics
University of Maryland, Baltimore County
🌐 *mdkvalheim.github.io*
Citizenship: USA

Research Interests

dynamical systems, control theory, and applied topology and geometry.

Education

2013–2018	**Ph.D.**, *University of Michigan*, Electrical Engineering
2013–2017	**M.S.**, *University of Michigan*, Mathematics
2013–2017	**M.S.**, *University of Michigan*, Electrical Engineering
2009–2013	**B.S.**, *Ohio University*, Electrical Engineering, *summa cum laude*, #1 EECS graduate

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Employment

2023– **Assistant Professor**, *University of Maryland, Baltimore County*, Department of Mathematics and Statistics
Eminent Scholar Program Mentor: Eduardo D. Sontag

2022–2023 **Postdoctoral Assistant Professor**, *University of Michigan*, Department of Mathematics
Mentor: Anthony M. Bloch

2019–2022 **Postdoctoral Researcher**, *University of Pennsylvania*, Department of Electrical and Systems Engineering
Mentors: Yuliy Baryshnikov, Daniel E. Koditschek

2018–2019 **Postdoctoral Research Fellow**, *University of Michigan*, Department of Electrical Engineering and Computer Science
Mentors: Anthony M. Bloch, Shai Revzen

Selected Awards and Honors

2024–2027	**Award FA9550-24-1-0299**, *Air Force Office of Scientific Research*
2023–	**Associate Editor**, *Mathematics of Control, Signals, and Systems*
2013	**Rackham Engineering Award**, *University of Michigan*
2013	**Outstanding Senior in Electrical Engineering**, *Ohio University*
2013	**First place, EECS Division, Undergraduate Student Expo**, *Ohio University*
2012	**Undergraduate Research Award, College of Engineering**, *Ohio University*
2012	**Outstanding Junior in Electrical Engineering**, *Ohio University*
2011	**Dean's Scholarship**, *Ohio University*
2011	**Fritz & Dolores Russ Scholarship**, *Ohio University*
2009–2013	**Gateway Excellence Scholarship**, *Ohio University*

Peer-Reviewed Journal Publications

13 **Why should autoencoders work?**
Matthew D. Kvalheim and Eduardo D. Sontag
Transactions on Machine Learning Research (2024), pp. 1–24. (article, arXiv)

12 **Phase response curves and the role of coordinates**
Simon Wilshin, Matthew D. Kvalheim, and Shai Revzen
Biological Cybernetics, 118 (2024), pp. 311–330. (article, arXiv)

11 **Flux in tilted potential systems: negative resistance and persistence**
Yuliy Baryshnikov and Matthew D. Kvalheim
Communications in Mathematical Physics, 400.2 (2023), pp. 853–930 (article, arXiv)

10 **Obstructions to asymptotic stabilization**
Matthew D. Kvalheim
SIAM J. Control and Optimization, 61.2 (2023), pp. 536–542 (article, arXiv)

9 **A compositional approach to certifying the almost global asymptotic stability of cascade systems**
Jake Welde, Matthew D. Kvalheim, and Vijay Kumar
IEEE Control Systems Letters, 7 (2023), pp. 1969–1974. (article, arXiv)

8 **A generalization of the Hopf degree theorem**
Matthew D. Kvalheim
Proceedings of the American Mathematical Society, 151.1 (2023), pp. 453–454. (article, arXiv)

7 **Necessary conditions for feedback stabilization and safety**
Matthew D. Kvalheim and Daniel E. Koditschek
J. Geometric Mechanics, 14.4 (2022), pp. 659–693. (article, arXiv)

6 **Planning of obstacle-aided navigation for multi-legged robots using a sampling-based method over directed graphs**
Kaustav Chakraborty, Haodi Hu, Matthew D. Kvalheim, and Feifei Qian
IEEE Robotics and Automation Letters, 7.4 (2022), pp. 8861–8868. (article)

5 **Families of periodic orbits: closed 1-forms and global continuability**
Matthew D. Kvalheim and Anthony M. Bloch
J. Differential Equations, 285 (2021), pp. 211–257. (article, arXiv)

4 **Existence and uniqueness of global Koopman eigenfunctions for stable fixed points and periodic orbits**
Matthew D. Kvalheim and Shai Revzen
Physica D, 425 (2021), pp. 132959. (article, arXiv)

3 **Conley's fundamental theorem for a class of hybrid systems**
Matthew D. Kvalheim, Paul Gustafson, and Daniel E. Koditschek
SIAM J. Applied Dynamical Systems, 20.2 (2021), pp. 784–825. (article, arXiv)

2 **Gait modeling and optimization for the perturbed Stokes regime**
Matthew D. Kvalheim, Brian Bittner, and Shai Revzen
Nonlinear Dynamics, 97.4 (2019), pp. 2249–2270. (article, arXiv)

1 **Global linearization and fiber bundle structure of invariant manifolds**
Jaap Eldering, Matthew D. Kvalheim, and Shai Revzen
Nonlinearity, 31.9 (2018), pp. 4202–4245. (article, arXiv)

Peer-Reviewed Conference Publications

3 **The role of symmetry in constructing geometric flat outputs for free-flying robotic systems**
Jake Welde, Matthew D. Kvalheim, and Vijay Kumar
2023 IEEE International Conference on Robotics and Automation (2023), pp. 12247-12253. (article, arXiv)

2 **Generic properties of Koopman eigenfunctions for stable fixed points and periodic orbits**
Matthew D. Kvalheim, David A. Hong, and Shai Revzen
IFAC-PapersOnline, 54.9 (2021), pp. 267–272. (article, arXiv)

1 **Data-driven models of legged locomotion**
Shai Revzen and Matthew D. Kvalheim
Micro-and Nanotechnology Sensors, Systems, and Applications VII, 9467 (2015). (article)

Book Chapters

2 **Bioinspired legged locomotion, chapter 3.2: Templates and anchors**
Matthew D. Kvalheim and Shai Revzen
Butterworth-Heinemann, Elsevier, Oxford (2017)

1 **Bioinspired legged locomotion, chapter 3.5: Locomotion as an oscillator**
Shai Revzen and Matthew D. Kvalheim
Butterworth-Heinemann, Elsevier, Oxford (2017)

Preprints

8 **Global linearization without hyperbolicity**
Matthew D. Kvalheim and Eduardo D. Sontag
(2025). (arXiv)

7 **Relationships between necessary conditions for feedback stabilizability**
Matthew D. Kvalheim
(2023). (arXiv)

6 **Linearizability of flows by embeddings**
Matthew D. Kvalheim and Philip Arathoon
(2023). (arXiv)

5 **Koopman embedding and super-linearization counterexamples with isolated equilibria**
Philip Arathoon and Matthew D. Kvalheim
(2023). (arXiv)

4 **Estimating phase from observed trajectories using the temporal 1-form**
Simon Wilshin, Matthew D. Kvalheim, Clayton Scott, and Shai Revzen
(2022). (arXiv)

3 **A pasting lemma for Lipschitz functions**
Matthew D. Kvalheim, Paul Gustafson, and Samuel A. Burden
(2021). (arXiv)

2 **Poincaré-Hopf theorem for hybrid systems**
Matthew D. Kvalheim
(2021). (arXiv)

1 **Reverse-engineering invariant manifolds with asymptotic phase**
Matthew D. Kvalheim and Shai Revzen
(2016). (arXiv)

Invited Talks

2025 **On the capabilities and limitations of autoencoders**, *Joint Mathematics Meetings*, Seattle, WA, USA
with Eduardo D. Sontag
Special session: Control theory and artificial intelligence

2024 **Obstructions to feedback stabilization**, *Basic Research Innovation Collaboration Center*, Arlington, VA, USA
2024 AFOSR Dynamical Systems and Control Theory Review

2024 **Identifying engineering (im)possibilities with geometry and topology**, *University of Delaware*, Newark, DE, USA
Electrical and Computer Engineering Spring Seminar Series

2024 **Linearizability of dynamical systems by embeddings**, *Joint Mathematics Meetings*, San Francisco, CA, USA
Minisymposium: Geometry and Symmetry in Differential Equations, Control, and Applications

2023 **Discovering engineering (im)possibilities with geometry and topology**, *Johns Hopkins University Applied Physics Laboratory*, Baltimore, MD, USA

2023 **Discovering engineering (im)possibilities with geometry and topology**, *University of Pennsylvania*, Philadelphia, PA, USA
GRASP SFI Seminar ([link](#))

2023 **Asymptotic stabilizability**, *Banff Internation Research Station*, Banff, AB, Canada
Workshop: Geometry, Topology and Control System Design ([link](#))

2022 **Existence and uniqueness of Koopman eigenfunctions near stable equilibria and limit cycles**, *International Symposium on Nonlinear Theory and Its Applications*, online

2022 **Negative resistance in small-noise dynamics via persistent homology**, *Indian Institute of Technology Bombay*, online
SysConTalks

2022 **Nonlinear systems**, *University of Michigan*, Ann Arbor, MI

2022 **Large deviations, persistent homology, and Brownian conductors with negative resistance**, *Cornell University*, online
Probability Seminar

2022 **When can hybrid systems operate safely?**, *University of Michigan*, online
Control Seminar

2022 **Flux in small noise dynamics: persistence and negative resistance**, *Brown University, Division of Applied Mathematics*, online

2021 **Flux in small noise dynamics: negative resistance and persistence**, *University of Illinois Urbana-Champaign*, online
Mathematical Biology Seminar

2021 **When and how are hybrid dynamical systems conjugate to their classical quotients?**, *SIAM Conference on Control and its Applications*, online
with Samuel A. Burden
Minisymposium: Physically grounded semantics for programming hybrid dynamical systems

2021 **Toward a physically grounded type theory for robot task composition**, *IEEE International Conference on Robotics and Automation*, online
with Daniel E. Koditschek and Paul Gustafson
Workshop: Compositional robotics: mathematics and tools

2021 **Toward a physically grounded type theory for robot task composition**, *IEEE International Conference on Robotics and Automation*, online
with Daniel E. Koditschek and Paul Gustafson
Workshop: Compositional robotics: mathematics and tools

2021 **Small noise dynamics, persistence, and negative resistance**, *SIAM Conference on Applications of Dynamical Systems*, online
with Yuliy Baryshnikov
Minisymposium: Stochastic oscillators

2021 **Flux in tilted potential systems: negative resistance and persistence**, *Army Research Office SLICE MURI W911NF-18-1-032 Group Meeting*, online

2021 **Towards a Conley theory for hybrid dynamical systems**, *Rutgers University*, online
TRIPODS/DATA-INSPIRE Workshop: Dynamics, Topology, and Robotic Control

2021 **Hierarchical composition via collapse of dimension in dynamical systems**, *ETH Zürich*, online
Series: Autonomy Talks

2021 **Existence and uniqueness of global linearizing coordinates**, *Army Research Lab*, online
Representing the MURI group funded by Army Research Office MURI 911NF-17-1-0306

2021 **Safety and stabilization: necessary conditions**, *Army Research Office SLICE MURI W911NF-18-1-032 Group Meeting*, online

2021 **Necessary conditions for feedback stabilization and safety**, *University of Pennsylvania*, online
Kod*Lab Research Seminar

2020 **Proving periodic orbits exist: global continuation and Lyapunov 1-forms**, *Invited Talk, University of Pennsylvania*, online
Graduate Research Seminar in Applied Topology

2020 **Proving periodic orbits exist: Lyapunov 1-forms and global continuation**, *University of Pennsylvania*, online
Kod*Lab Research Seminar

2020 **Geometry and dynamics of circulant systems**, *AMS sectional meeting*, online
with Anthony M. Bloch (speaker)
Special session: Geometric dynamics

2020 **Conley's fundamental theorem for a class of hybrid systems**, *Army Research Office SLICE MURI W911NF-18-1-032 Group Meeting*, online

2020 **Conley's fundamental theorem for a class of hybrid systems**, *University of Pennsylvania*, online
Kod*Lab Research Seminar

2020 **Toward a task planning theory for robot hybrid dynamics**, *Casa Matemática Oaxaca*, online
Workshop: Topological complexity and motion planning

2020 **Isochrons from short, noisy data**, *Dynamics Days Europe*, online
with Simon Wilshin, Clayton Scott, and Shai Revzen
Minisymposium: Stochastic oscillators

2019 **Invariant manifolds, locomotion, and the Koopman operator**, *Invited Talk, University of Pennsylvania*, Philadelphia, PA
Chaudhari Research Group Seminar

2019 **Templates, anchors, and normally hyperbolic invariant manifolds**, *Invited Talk, University of Pennsylvania*, Philadelphia, PA
DAIR Lab Research Seminar

2019 **Templates, anchors, and normally hyperbolic invariant manifolds**, *Invited Talk, University of Pennsylvania*, Philadelphia, PA
ScalAR Lab Research Seminar

2019 **Existence and uniqueness of linearizing semiconjugacies for stable fixed points and periodic orbits**, *California Institute of Technology*, Pasadena, CA
Army Research Office MURI 911NF-17-1-0306 Group Meeting

2019 **Dynamics of circulant systems of ODEs**, *SIAM Conference on Applications of Dynamical Systems*, Snowbird, UT
with Anthony M. Bloch (speaker)

2019 **Reduced-order models for locomotion in the perturbed Stokes regime**, *SIAM Conference on Applications of Dynamical Systems*, Snowbird, UT
with Shai Revzen

2019 **Hybrid oscillators: phase and amplitude in a class of non-smooth systems**, *SIAM Conference on Applications of Dynamical Systems*, Snowbird, UT
with Shai Revzen

2018 **Aspects of invariant manifold theory and applications**, *University of California Santa Barbara*, Santa Barbara, CA
Army Research Office MURI 911NF-17-1-0306 Group Meeting

2018 **Oscillators, asymptotic phase, and reduction of dynamical systems**, *University of Michigan*, Ann Arbor, MI
Applied and Interdisciplinary Mathematics Student Seminar

2018 **Invariant manifolds, asymptotic phase, and data-driven algorithms**, *University of Pennsylvania*, Philadelphia, PA
Kod*Lab Research Seminar

2016 **A recipe for embedding templates in anchors**, *University of Michigan*, Ann Arbor, MI
Legged Robotics Seminar

2015 **Introduction to homology: towards topological data analysis, pt. II**, *University of Michigan*, Ann Arbor, MI
Signal Processing Student Seminar

2015 **Introduction to homology: towards topological data analysis, pt. I/II**, *University of Michigan*, Ann Arbor, MI
Signal Processing Student Seminar

Other Talks

2023 **A compositional approach to certifying the almost global asymptotic stability of cascade systems**, *IEEE International Conference on Robotics and Automation*, London, UK
with Jake Welde (speaker) and Vijay Kumar
Workshop: Compositional robotics: mathematics and tools

2023 **A principal bundle perspective on differential flatness in complex robotic and biological systems**, *Americal Physical Society March Meeting*, Las Vegas, Nevada, USA
with Jake Welde (speaker) and Vijay Kumar

2019 **Is legged locomotion almost smooth?**, *Dynamic Walking*, Calgary, AB, Canada
with Shai Revzen (speaker) and George Council

2018 **Testing an extended 'Posture Principle'**, *Annual meeting of the Society for Integrative and Comparative Biology*, San Francisco, CA
with Shai Revzen

2015 **Phase-based models of rhythmic systems**, *Dynamic Walking*, Columbus, OH
with Shai Revzen

2015 **Better models of rhythmic systems: predicting locomotion from phase alone**, *Annual meeting of the Society for Integrative and Comparative Biology*, West Palm Beach, FL
with Shai Revzen

2014 **Why the trot?**, *Annual meeting of the Society for Integrative and Comparative Biology*, Austin, TX
with Shai Revzen and Sam Burden (speakers)

Posters

2023 **The role of symmetry in constructing geometric flat outputs for free-flying robotic systems**, *IEEE International Conference on Robotics and Automation*, London, UK
with Jake Welde (presenter) and Vijay Kumar

2020 **A mode map representation to predict steady states and attraction basins for legged locomotion on obstacle terrains**, *International Conference on Intelligent Robotics and Systems (IROS)*, online
with Haodi Hu (presenter), Michelle Joyce, Simon Wilshin, Andrew Spence, and Feifei Qian
Workshop: Robotics-inspired biology

2019 **Principal Koopman eigenfunctions for nonlinear and nonsmooth systems**, *University of California, Los Angeles*, Los Angeles, CA
with Shai Revzen
Workshop: Operator theoretic methods in dynamic data analysis and control

2019 **Principal Koopman eigenfunctions for nonlinear and nonsmooth systems**, *University of California, Los Angeles*, Los Angeles, CA
with Shai Revzen
Workshop: Operator theoretic methods in dynamic data analysis and control

2018 **Global linearization and fiber bundle structure of invariant manifolds**, *AIMS Conference Series on Dynamical Systems and Differential Equations*, Taipei, Taiwan
with Jaap Eldering and Shai Revzen

2018 **Templates and Anchors: a review of notions of model reduction**, *Dynamic Walking*, Pensicola, FL
with Shai Revzen

2017 **Asymptotic phase, model reduction, and control of Templates & Anchors**, *Ohio State University, Mathematical Biosciences Institute*, Columbus, OH
with Shai Revzen
Workshop: Sensorimotor control of animals and robots

2017 **A dynamical systems perspective on Templates & Anchors: some general methods for anchoring templates**, *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Vancouver, BC
with Shai Revzen
Workshop: Robotics-inspired Biology

2014	**Phase-based algorithm for modeling time-rescaling distortion of rhythmic data**, *University of Michigan*, Ann Arbor, MI
	with Shai Revzen
	Engineering Graduate Symposium
2013	**A hybrid system provides a robust alternative to a linear regulator**, *University of Michigan*, Ann Arbor, MI
	with Shai Revzen
	Engineering Graduate Symposium
2013	**An indoor navigation device for use in GPS-denied environments**, *Ohio University*, Athens, OH, Award: 1st place, EECS division
	with Ryan Kollar, Christopher Moore, Jessica Belzer, and Matthew Miltner
	Ohio University Student Expo

Academic Service

Service to the Profession

2025	**Associate Editor and International Program Committee Member**, *IFAC Conference on Networked Systems (NecSys2025)*
2023–	**Associate Editor**, *Mathematics of Control, Signals, and Systems*
2023	**Co-organizer**, *IEEE International Conference on Robotics and Automation*
	Workshop: "Compositional Robotics: Mathematics and Tools"
2022	**Co-organizer**, *Festschrift in honor of Daniel E. Koditschek* ([link](#))
2022	**Co-organizer**, *IEEE International Conference on Robotics and Automation*
	Workshop: "Compositional Robotics: Mathematics and Tools"

Reviewer, *AFOSR Dynamical Systems and Control Theory Program; Annual Reviews in Control; ASME J. Biomechanical Engineering; Automatica; Biological Cybernetics; Chaos; IEEE Conference on Decision and Control; IEEE Control Systems Letters; IEEE International Conference on Robotics and Automation; IEEE Transactions on Automatic Control; International Symposium on Nonlinear Theory and Its Applications; Learning for Dynamics & Control; Machine Learning: Science and Technology, Mathematics of Control, Signals, and Systems; Robotics: Science and Systems; Scientific Reports; SIAM J. Control and Optimization; Stochastic Models*

Member, *American Mathematical Society, Institute of Electrical and Electronics Engineers, Society for Industrial and Applied Mathematics, SIAM Activity Groups on Dynamical Systems and on Control and Systems Theory, Pi Mu Epsilon, Tau Beta Pi*

University Service

2024–2025	**Co-organizer and volunteer**, *UMBC Invitational Science Olympiad Co-organizer and Volunteer*, University of Maryland, Baltimore County, MD
2024	**Volunteer, Faculty Meet-and-Greet, Admitted Student Sneak Peek**, *College of Natural and Mathematical Sciences*, University of Maryland, Baltimore County, MD
2023–2024	**Co-organizer and volunteer**, *UMBC Invitational Science Olympiad Co-organizer and Volunteer*, University of Maryland, Baltimore County, MD
2022	**Volunteer**, *Females Excelling More in Math, Engineering, and Science (F.E.M.M.E.S.)*, University of Michigan, Ann Arbor, MI

Departmental Service

2024–2025 **Co-author and grader**, *Departmental PhD comprehensive exams*, University of Maryland, Baltimore County, MD

2023– **Co-adviser, Pi Mu Epsilon Chapter**, *University of Maryland, Baltimore County, MD*
Mathematics honor society

2019 **Volunteer, demonstrations to visiting K-12 students, Philly Robotics Expo (PRX)**, *University of Pennsylvania*, Philadelphia, PA
Robotics outreach

2019 **Volunteer, demonstrations to members of the National Society of Black Engineers**, *Detroit, MI*, Representing BIRDS Laboratory, University of Michigan; robotics outreach
45th Annual Convention of the National Society of Black Engineers (NSBE)

2015 **Volunteer, demonstrations to alumni and industry**, *Engineering Graduate Symposium*, Ann Arbor, MI
Representing BIRDS Laboratory, University of Michigan; robotics outreach

2015 **Volunteer, panel particpant**, *Graduate Student Council*, Ann Arbor, MI
Member of panel of University of Michigan graduate students; answering questions from prospective graduate students

2014 **Volunteer, demonstrations to elementary schoolers**, *Bryant Elementary School*, Ann Arbor, MI
Representing BIRDS Laboratory, University of Michigan; robotics outreach

Teaching Experience

2024 **Course Instructor**, *University of Maryland, Baltimore County*, MD
Instructor of record for Introduction to Smooth Manifolds (Math 499 and 699) in Fall 2024

2024 **Course Instructor**, *University of Maryland, Baltimore County*, MD
Instructor of record for Real Analysis (Math 600) in Fall 2024

2024 **Course Instructor**, *University of Maryland, Baltimore County*, MD
Instructor of record for Ordinary Differential Equations (Math 612) in Spring 2024

2023 **Course Instructor**, *University of Maryland, Baltimore County*, MD
Instructor of record for Introduction to Linear Algebra (Math 221) in Fall 2023

2023 **Course Instructor**, *University of Michigan*, Ann Arbor, MI
Instructor of record for two course sections of Differential Equations (Math 316) in Winter 2023

2022 **Course Instructor**, *University of Michigan*, Ann Arbor, MI
Instructor of record for two course sections of Calculus I (Math 115) in Fall 2022

2019 **Guest Lecturer**, *University of Pennsylvania*, Philadelphia, PA
Graduate course: Dynamical Systems for Engineering and Biological Applications (ESE 512)
Course instructor: Daniel E. Koditschek

2014 **Graduate Student Instructor**, *University of Michigan*, Ann Arbor, MI
Senior-level course: Discrete-Time Signal Processing (EECS 451)
Course instructor: Laura Balzano

2011–2012 **Supplemental Instruction Leader, Academic Achievement Center**, *Ohio University*, Athens, OH
Sophomore-level course: Statics (CE 220)

Mentoring

2022–2023 **Mentor of graduate student**, *University of Michigan*, Ann Arbor, MI
Mentored 1 graduate student in research

2019–2023 **Mentor of graduate students**, *University of Pennsylvania*, Philadelphia, PA
Mentored 2 graduate students in research

2013–2018 **Mentor of undergraduate and graduate students, BIRDS Laboratory**, *University of Michigan*
Mentored 2 undergraduate and 3 graduate students

Trainings and Certifications

2024 **Madrid Summer School on h-principle**, *Instituto de Ciencias Matemáticas*, Madrid, Spain
Instructors: M Bertelson, K Cieliebak, Y Eliashberg, A Kupers, O Lazarev, G Meigniez, R Cardona, D Álvarez-Gavela, Á del Pino Gómez, M Theillière

2024 **Spring Faculty Success Program**, *National Center for Faculty Development and Diversity (NCFDD)*, online
Nominated by the Office of the Provost at the University of Maryland, Baltimore County

2023 **Principal Investigator Research Administrative Training & Education**, *Office of the Vice President for Research, UMBC*, Baltimore, MD

2023 **Media and Communications Training for STEM Faculty**, *American Association for the Advancement of Sciences (AAAS)*, Baltimore, MD

Media Activities

2025 **In the world of math, the hunt for eloquent solutions excites these researchers**
Author: Sarah Hansen
Interviewee (article)