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

Matthew D. Kvalheim

Research Interests

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

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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

Employment

- 2023- **Assistant Professor of Mathematics**, *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 samplingbased 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

9 Differential topology of the spaces of asymptotically stable vector fields and Lyapunov functions

Matthew D. Kvalheim (2025). (arXiv)

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
- 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 $Z\ddot{u}rich$, 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; NSF Division of Mathematical Sciences Computational and Data-Enabled Science and Engineering 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
 - 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
 - **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
 - 2024 Adviser, Pi Mu Epsilon Chapter, University of Maryland, Baltimore County, MD Mathematics honor society
- 2023–2024 **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
 - 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

- 2025 **Mentor of graduate student**, *University of Michigan*, Ann Arbor, MI Mentoring 1 graduate student in research
- 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)