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.

Employment

2023– **Assistant Professor**, *University of Maryland, Baltimore County*, Department of Mathematics and Statistics.

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

Peer-Reviewed Journal Publications

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

11 **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)

10 **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)

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

6 **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)

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 **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)

3 **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)

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

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

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

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

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

3 **Phase response curves and the role of coordinates**.
Simon Wilshin, Matthew D. Kvalheim, and Shai Revzen
(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

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

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*.

University Service

2024 **Volunteer, Faculty Meet-and-Greet, Admitted Student Sneak Peek**, *College of Natural and Mathematical Sciences, University of Maryland, Baltimore County*.

2023–2024 **Co-organizer and Volunteer**, *UMBC Science Olympiad Co-organizer and Volunteer*, University of Maryland, Baltimore County, MI.

2022 **Volunteer**, *Females Excelling More in Math, Engineering, and Science (F.E.M.M.E.S.)*, University of Michigan, Ann Arbor, MI.

Departmental Service

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

Honors and Awards

2013 **Rackham Engineering Award**, *University of Michigan*.
A graduate research fellowship awarded by Rackham Graduate School

2013 **Outstanding Senior in Electrical Engineering**, *Ohio University*.
Awarded by a faculty panel

2013 **First place, Undergraduate Student Expo**, *Ohio University*.
Senior design team awarded first place in the EECS division

2012 **Undergraduate Research Award, College of Engineering**, *Ohio University*.
My proposal was funded for a semester of undergraduate research

2012 **Outstanding Junior in Electrical Engineering**, *Ohio University*.
Awarded by a faculty panel

2009–2013 **Gateway Excellence Scholarship**, *Ohio University*.
Academic merit-based scholarship (full tuition)

2011 **Dean's Scholarship**, *Ohio University*.
Academic merit-based scholarship

2011 **Fritz/Dolores Russ Scholarship**, *Ohio University*.
Academic merit-based scholarship

Teaching Experience

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