Jake Welde

PhD Candidate | Researcher in Robotics, Dynamics, and Control

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RESEARCH FOCUS

My work addresses the control of complex mechanical systems. I'm interested in rigorous geometric approaches which leverage strong properties of these control systems and scale gracefully with system complexity, tackling challenges associated with underactuation and non-Euclidean geometry. Such structural properties can inform mechanism and controller design for real-world systems and enable the deployment of robots that more closely parallel the incredible examples found in Nature.

EDUCATION

PhD Candidate in Mechanical Engineering and Applied Mechanics   2019 - present

University of Pennsylvania, GRASP Laboratory   *Philadelphia, PA*

Advisor: Dr. Vijay Kumar

My ongoing work exploits symmetry, Riemannian geometry, and dynamical systems theory to develop a constructive approach to geometric control for a broad class of underactuated mechanical systems, such as aerial and space robots.

Master of Science in Engineering, Robotics   2020

University of Pennsylvania   *Philadelphia, PA*

Bachelor of Science in Engineering, Mechanical Engineering and Applied Mechanics   2019

University of Pennsylvania   *Philadelphia, PA*

Minor in French and Francophone Studies

PUBLICATIONS

JOURNAL ARTICLES

1. **"A Compositional Approach to Certifying Almost Global Asymptotic Stability of Cascade Systems"**,
   Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.
   IEEE Control Systems Letters, 2023.

2. **"Dynamically Feasible Task Space Planning for Underactuated Aerial Manipulators"**,
   Jake Welde, James Paulos, and Vijay Kumar.
   IEEE Robotics and Automation Letters, 2021.
   Finalist for "Best Paper in Unmanned Aerial Vehicles" at ICRA 2021.

3. **"Autonomous Flight for Detection, Localization, and Tracking of Moving Targets With a Small Quadrotor"**,
   Justin Thomas, Jake Welde, Giuseppe Loianno, Kostas Daniilidis, and Vijay Kumar.
   IEEE Robotics and Automation Letters, 2017.

REFEREED CONFERENCE PROCEEDINGS

1. **"The Role of Symmetry in Constructing Geometric Flat Outputs for Free-Flying Robotic Systems"**,
   Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.
   IEEE International Conference on Robotics and Automation, 2023.

2. **"Trajectory Planning for the Bidirectional Quadrotor as a Differentially Flat Hybrid System"**,
   Katherine Mao, Jake Welde, M. Ani Hsieh, and Vijay Kumar.
   IEEE International Conference on Robotics and Automation, 2023.

3. **"Coordinate-Free Dynamics and Differential Flatness of a Class of 6DOF Aerial Manipulators"**,
   Jake Welde and Vijay Kumar.
   IEEE International Conference on Robotics and Automation, 2020.

PRESENTATIONS

TALKS

1. **"Differential Flatness and Geometric Hierarchy in Underactuated Mechanical Systems with Symmetry"**,
   Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.
   Invited Talk, Joint Mathematics Meetings, 2024.

2. **"A Compositional Approach to Certifying Almost Global Asymptotic Stability of Cascade Systems"**,
   Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.
   Contributed Talk, *Compositional Robotics Workshop*, International Conference on Robotics and Automation, 2023.

3. **"A Geometric Perspective on Differential Flatness of Mechanical Systems with Symmetry"**,
   Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.
   Contributed Lecture, SIAM Conference on Control and Its Applications, 2023.

4. **"A Principal Bundle Perspective on Differential Flatness in Complex Robotic and Biological Systems"**,
   Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.
   Contributed Talk, *Robophysics Focus Session*, APS March Meeting, 2023.

5. **"Geometric Control of Underactuated Robotic Systems: Flatness, Hierarchy, and Control-Aware Design"**,
   Jake Welde.
   Invited Talk, *Nikolai Matni Group*, University of Pennsylvania, 2023.

6. **"Hierarchical Methods for Geometric Control of Underactuated, Free-Flying Robotic Systems"**,
   Jake Welde.
   Departmental Research Seminar, Mechanical Engineering and Applied Mechanics, University of Pennsylvania, 2023.

7. **"Trajectory Planning"**,
   Jake Welde.
   Guest Lecture in MEAM 6200: Advanced Robotics, University of Pennsylvania, 2023.

8. **"The Role of Symmetry in Constructing Geometric Flat Outputs for Free-Flying Robotic Systems"**,
   Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.
   Invited Talk, *Kostas Daniilidis Group*, University of Pennsylvania, 2022.

9. **"Planning and Control for Multirotor Aerial Vehicles and Manipulators"**,
   Jake Welde and Vijay Kumar.
   Guest Lecture, *MEAM 543: Performance, Stability, and Control of UAVs*, University of Pennsylvania, 2019.

POSTERS

1. **"Towards Automatic Identification of Globally Valid Geometric Flat Outputs via Numerical Optimization"**,
   Jake Welde and Vijay Kumar.
   Geometric Representations Workshop, International Conference on Robotics and Automation, 2023.

2. **"Some Aerial Manipulators Can Exactly Track Arbitrary Smooth End-Effector Trajectories in 6 Degrees of Freedom"**,
    Jake Welde and Vijay Kumar.
    Northeast Robotics Colloquium, University of Pennsylvania, 2019.

HONORS AND AWARDS

Outstanding Teaching Assistant Award, Mechanical Engineering, University of Pennsylvania	Fall 2021
Finalist for Best Paper in Unmanned Aerial Vehicles, International Conference on Robotics and Automation	2021
National Science Foundation Graduate Research Fellowship	2019
Couloucoundis Prize for Best Presentation, Mechanical Engineering Senior Design, University of Pennsylvania	2019
Second Place, School of Engineering Senior Design Competition, University of Pennsylvania	2019
Student Travel Grant Award, IEEE International Conference on Intelligent Robots and Systems	2017

TEACHING

PEDAGOGICAL TRAINING

Certificate in College and University Teaching, Center for Teaching and Learning — 2023
Multipart teaching preparation and credential for university instruction — *University of Pennsylvania*
Preparation consists of participation in teaching seminars held by current faculty, expert observation of a teaching demonstration, and exploration and development of personal teaching philosophy through interaction with expert teachers and scholars.

Course in College Teaching, Center for Teaching and Learning — Fall 2022
Semester-long seminar covering course design, active learning, and engaging teaching practices — *University of Pennsylvania*

Inclusive and Equitable Teaching Mini-Course, Center for Teaching and Learning — Spring 2023
One-month seminar on scholarly research and primary sources on inclusive and equitable instruction — *University of Pennsylvania*

INSTRUCTIONAL EXPERIENCE

MEAM 520 / CIT 520: Introduction to Robotics — Fall 2020 / Spring 2021 / Fall 2021
Teaching Assistant for Professors Cynthia Sung, Vijay Kumar, and M. Ani Hsieh — *University of Pennsylvania*
Led development of written and laboratory assignments to achieve key pedagogical objectives across theory and practice, covering forward and inverse kinematics, motion planning, rigorous testing, and simulation-to-reality workflow. Worked closely with students in office hours, recitations, and hands-on lab sessions. Led the creation and introduction of a final capstone competition in which students implement a complete manipulation solution on industrial robot hardware. Recognized with the **Outstanding TA Award**.

MEAM 211: Engineering Mechanics, Dynamics — Spring 2021
Teaching Assistant for Professor Michael Posa — *University of Pennsylvania*
Conducted interactive problem-solving recitations with undergraduates. Developed new computational assignments for the course, in which students implement a multibody dynamics simulator via step-by-step weekly modules, putting concepts into practice.

EXPERIENCE

ACADEMIA

Research in Aerial Robotics, Dynamics, and Control — *GRASP Laboratory, University of Pennsylvania*
Undergraduate Research Assistant — 2015 - 2019
Graduate Research Fellow — 2019 - present

- Contributed to onboard sensing, estimation, and motion planning pipeline enabling a quadrotor to autonomously track dynamically moving targets without violating the vehicle's coupled sensor and actuation constraints
- Advanced fundamental theory underpinning practical control implementation to generalize flatness-based planning and cascaded control approaches to other robot morphologies while adhering to stringent onboard computational budget

- Leveraged theoretical control insights in the mechanical design of an aerial manipulator intended for agile, precise operation and integrated a diverse range of sensors and actuators in a flexible and unified control infrastructure

SharpShooter: an Invisible Tripod via Reaction Wheels 2018 - 2019

Senior Design Project, Mechanical Engineering at the University of Pennsylvania *Philadelphia, PA*

Development of a novel reaction wheel stabilizer for ergonomic, handheld long-exposure still photography with team of five peers
- Developed motor system identification pipeline to enable precise application of corrective torques
- Implemented gyroscope bias observer to enable accurate and precise attitude estimation during exposures
- Quantitative stabilization performance exceeded all other commercially available handheld stabilizers

INDUSTRY

Exyn Technologies Summer 2018

Robotics: Software and Algorithms Intern *Philadelphia, PA*

Software engineering at aerial robotics startup delivering trustworthy autonomy in challenging environments
- Evaluated and integrated range of technologies for barcode decoding and localization for autonomous warehouse inventory
- Contributed mission-critical modules to integrate low-level sensors with high-level flight software stack
- Developed and implemented novel algorithm for extrinsic calibration of any number of rigidly connected inertial measurement units, cameras, and LIDARs using only a single physical calibration target accomodating all sensing modalities

MEDIA

GRASP Lab Presents: "MEAM 520 Class Breakdown" 2022

Penn Engineering Today: "Virtual Robots: Taking Risks in an Online Classroom" 2021

National Geographic's Breakthrough: "Game of Drones" 2017

34th Street Magazine: "Penn Students Create Gingerbread Replica of Fisher Fine Arts Library" 2017

SERVICE

PUBLIC OUTREACH

Science Olympiad at the University of Pennsylvania 2017 - present
- **Event Supervisor**, *Penn Invitational Tournament*. Coordinating a team of student volunteers to run a yearly engineering challenge for high school students, with over 100 students competing.
- **Placement Leader**, *Urban Initiative*. Site supervisor for several student volunteers in affiliated outreach and mentoring program. Making weekly visits to a Philadelphia public high school to work directly with students exploring science and engineering topics.

MENTORING STUDENT RESEARCHERS

Undergraduate and masters student(s) I have supervised directly and doctoral student(s) with whom I have worked closely as a mentor.

Doctoral Students
- Katie Mao, University of Pennsylvania (Mechanical Engineering) 2022
  "Trajectory Planning for the Bidirectional Quadrotor as a Differentially Flat Hybrid System"

Masters Students
- Saibernard Yogendran, University of Pennsylvania (Robotics) Fall 2022 - present
  "Brushless Motor Dynamic Response Characterization and Aerial Vehicle Design"
- Jack Campanella, University of Pennsylvania (Robotics) Summer 2023 - present
  "Electronics Design and Integration for Dynamic Aerial Robots"

Undergraduate Students

- Nicole Luna, Cal Poly Pomona (Mechanical Engineering and Physics)   Summer 2021
  "Aerial Manipulator Mechanical Design"
- Natasha Dilamani, University of Pennsylvania (Mechanical Engineering)   Summer 2020
  "Dynamic Modeling of the Sphero, a Highly Nonholonomic System"

ACADEMIC AND PROFESSIONAL

Mechanical Engineering Graduate Association, Treasurer   2020 - 2021

Managed finances while planning and executing programming to support the professional, social, engagement, and inclusion needs of the graduate student community in our department.

GRASP "Student, Faculty, and Industry" Seminar, Organizing Committee Member   2023 - present

Curated, solicited, and hosted speakers from peer institutions and industry connections to visit the GRASP research community.

Review Activities for International Journals and Conferences

- Springer Autonomous Robots   2023
- IEEE Robotics and Automation Letters   2021 - 2023
- ASME Journal of Dynamic Systems, Measurement and Control   2022 - 2023
- IEEE International Conference on Robotics and Automation   2022 - 2023
- IEEE Transactions on Robotics   2021 - 2023
- Robotics: Science and Systems   2022
- IEEE Transactions on Automatic Control   2022
- IEEE International Conference on Intelligent Robots and Systems   2020 - 2021
- IEEE International Conference on Automation Science and Engineering   2020