

# Caroline Hills

**OBJECTIVE:** Seeking opportunities that will sharpen mathematical, analytical, and research skills through the use of mathematical research in projects focused on national defense and security.

## ACCOMPLISHMENTS

**Practical Understanding of Applied Mathematical Principles:** My current doctoral research in robotic kinematic systems has resulted in conference presentations and publications. I have enriched my studies with research experiences sponsored by Department of Defense, Department of Energy, and University Affiliated Research Center labs. In Spring 2024 I taught an undergraduate course on differential equations and helped my students learn the course material with exposure to variety of real-world applications.

**Leadership and Organizational Skills:** I have been involved in Notre Dame's graduate organizations including the SIAM Chapter as Treasurer (2022-23) and President (2023-24) and the Graduate Student Union as a department representative (2022-23). I co-organized a mini-symposium for the SIAM Algebraic Geometry 2023 Conference and co-revived the Notre Dame Association for Women in Mathematics chapter for the 2023-24 academic year.

**Personal Development:** As a varsity student-athlete on the women's rowing team, I balanced a full academic course schedule with 20-hour training weeks and travel to competitions. I learned to set short and long-term goals with discipline and teamwork, and was a member of the 2<sup>nd</sup> Varsity Four boat that finished 2<sup>nd</sup> at the 2019 Atlantic Coast Conference Women's Rowing Championships. Post-athletics, I helped my team as a volunteer coach, I learned new skills through the sailing team, and I volunteered at a local South Bend community center, St. Margaret's House.

## EDUCATION

**University of Notre Dame**, Notre Dame, IN

PhD: Applied and Computational Mathematics and Statistics  
Anticipated January 2025, current GPA: 3.8

MS: Applied and Computational Mathematics and Statistics  
May 2021, GPA: 3.7

BS: Applied and Computational Mathematics and Statistics, Minor in Computational Engineering  
May 2020, GPA: 3.5

## PROFESSIONAL EXPERIENCE

**University of Notre Dame**, Graduate Research Assistant Present

- Advised by Jonathan Hauenstein, PhD (Department of Applied and Computational Math and Statistics) and co-advised by Mark Plecnik, PhD (Department of Aerospace and Mechanical Engineering)
- Research is focused on solving polynomial systems that arise in robotic kinematic systems using homotopy continuation methods.
- Current projects include a study of the geometry of dynamical system separatrices and an analysis of branch point distributions for select homotopy start and end systems.

**Johns Hopkins Applied Physics Laboratory**, Technical Aide 2024

- Interned in the Strategic Deterrence Mission Area within the Force Projection Sector (FPS).
- Successfully implemented into APL software an alternative method of matrix exponentiation for error propagation and validated the method for accuracy and speed with regards to current algorithms. Learned the physical conditions and nuances of the system that the Python code needed to be robust in handling.
- Collaborated with other groups within FPS to address a special study experiment. Was often tasked with leading weekly meetings including sharing progress, proposing ideas, and delegating action items for future goals. Presented findings to program managers and branch and group supervisors.

**Naval Air Warfare Center Weapons Division**, Intern 2023

Naval Research Enterprise Internship Program (NREIP)

- Interned with the Autonomy Research group in China Lake, CA in research projects focused on exploring data dimensionality reduction techniques in dynamic mode decomposition and the successful implementation of an optimal control algorithm for drone testing.
- Assisted in preparing lab demonstrations to base visitors, including representatives from other DoD labs.

**UCLA Institute for Pure and Applied Mathematics (IPAM)**, Undergraduate Researcher

2020

### Research in Industrial Projects for Students (RIPS)

- Experienced the lifecycle of a project from ideation, timeline planning, and execution for a project supported by LLNL to improve speed and accuracy of their parallelized multigrid integration solver.
- Code improvements were cataloged into LLNL's open-sourced C++ parallel multigrid software library and findings were presented at Southern California Math REU Conference in August 2020 and at the Joint Mathematics Meeting in January 2021 and April 2022.

### **Deloitte and Touche, LLP**, Regulatory and Operational Risk Intern 2019

- Assigned to a client project to establish a new company-wide risk management framework plan compliant with regulatory banking standards.
- By taking detailed and thorough notes, the project partners were able to review action items and issues and promptly address the clients to expedite existing project work and establish new developments to the project's goal framework.

### **Department of Applied and Computational Math and Statistics**, Undergraduate Researcher 2018

- Tested Dr. Jonathan Hauenstein's proposed theory for a novel computational method to identify high-degree polynomial coefficients using Bertini software and self-written C++ code.

## **TEACHING EXPERIENCE**

### **Department of Applied and Computational Mathematics**, Graduate Instructor Spring 2024

#### ACMS 20750: Introduction to Mathematical Methods II (Course Chair)

- Held 50-minute lectures three times per week in addition to 2 hours of office hours per week. Wrote and administered exams and their respective exam concept sheets and practice problems. Provided students with extra credit opportunities that introduced them to real-world math applications.
- Met with students to discuss experiences within ACMS and Notre Dame and mentored two students through a grant proposal.
- Designated TA and grader duties and communicated with the graduate and undergraduate aides to incorporate student feedback and address questions and issues.
- From an 82.9% student response rate, Course Instructor Feedback ratings were a composite median of 5.0/5.0, 83.8% V Good or Excellent, 0% V Poor or Poor.
- Feedback includes:

*"1. with exam study guides and notes outlines and homework hints, provides us with every resource needed to succeed, genuine concern for students and their success and made sure that no one fell behind 2. very thorough, clear, and slow in explanations to ensure everyone conceptualizes and grasps the material"*

*"She really listened to her students and went at a really good pace during lecture, making sure we all understood everything before moving on. She was also there for us, and I could tell she wanted us to succeed in her class."*

## **PUBLICATIONS and PREPRINTS**

Jonathan D. Hauenstein, **Caroline Hills**, Hoon Hong, and Francisco Ponce-Carrion. "Geometry of Continuous Adjoint Newton's Method for Bivariate Quadratics". *In Progress*.

Jonathan D. Hauenstein, **Caroline Hills**, Andrew J. Sommese, Charles W. Wampler. "Singularities of Homotopies Part I: Distribution and Probability of Failure". *In Progress*.

Andrew J. Sommese, Jonathan D. Hauenstein, **Caroline Hills**, Charles W. Wampler. "Branch Points of Homotopies Part II: Enumeration and General Theory". *In Progress*.

**Caroline Hills**, Aravind Baskar, Mark Plecnik, and Jonathan D. Hauenstein, "Computing complete solution sets for approximate four-bar path synthesis". *Mechanism and Machine Theory*, 196, 105628, 2024. <https://doi.org/10.1016/j.mechmachtheory.2024.105628>.

Taylor Brysiewicz, Jonathan D. Hauenstein, and **Caroline Hills**, Max-convolution through numerics and tropical geometry. *Numer Algor* **96**, 845–877 (2024). <https://doi.org/10.1007/s11075-023-01668-w>

Hauenstein, J. D., Huebner, A., Wagle, J. P., Cobian, E. R., Cummings, J., **Hills, C.**, McGinty, M., Merritt, M., Rosengarten, S., Skinner, K., Szemborski, M., & Wojtkiewicz, L. "Reliability of Markerless Motion Capture Systems for Assessing Movement Screenings." *Orthopaedic journal of sports medicine*, 12(3),

23259671241234339. <https://doi.org/10.1177/23259671241234339>

P. B. Edwards, A. Baskar, C. Hills, M. Plecnik and J. D. Hauenstein, "Output Mode Switching for Parallel Five-bar Manipulators Using a Graph-based Path Planner," *2023 IEEE International Conference on Robotics and Automation (ICRA)*, London, United Kingdom, 2023, pp. 9735-9741, doi: 10.1109/ICRA48891.2023.10160891.

Baskar, A, Hills, C, Plecnik, M, and Hauenstein, JD. "Estimating the Complete Solution Set of the Approximate Path Synthesis Problem for Four-Bar Linkages Using Random Monodromy Loops." *Proceedings of the ASME 2022 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. Volume 7: 46th Mechanisms and Robotics Conference (MR)*. St. Louis, Missouri, USA. August 14–17, 2022. V007T07A026. ASME. <https://doi.org/10.1115/DETC2022-90402>

**Caroline Hills**, Michael Kielstra, Dylan King, and Matt Torrence. "Multigrid Methods in Time for Constrained Optimization". Research in Industrial Projects for Students Technical Report, August 2020.

### **PRESENTATIONS**

*Estimation Techniques and Applications of Computing Maximum Values*. AMS Spring Sectional Meeting Special Session on Applications of Numerical Algebraic Geometry. Milwaukee, WI, 20 Apr 2024

*Robotic Kinematic Optimization Applications*. Joint Mathematics Meetings AMS Special Session on Topological and Algebraic Approaches for Optimization. San Francisco, CA, 3 Jan 2024.

*Theoretical and Applied Naval Research in Mathematics*. Applied Math Seminar. The United States Naval Academy, Annapolis, MD, 2 Nov 2023.

*Computing optimal designs for the approximate synthesis of four-bar mechanisms*. SIAM Conference on Computational Science and Engineering. Amsterdam, The Netherlands, 2 Mar 2023.

*Solving optimal path synthesis of four-bar mechanisms via homotopy continuation*. Joint Mathematics Meetings AMS Special Session on Polynomial Systems, Homotopy Continuation, and Applications, Boston, MA, 4 Jan 2023.

*Parallel Time Integration for Constrained Optimization*. Joint Mathematics Meetings MAA Student Poster Session on Mathematics Education, Numerical Analysis & Other Topics. Virtual, 8 Jan 2021.

*Multigrid Methods in Time for Constrained Optimization*. Southern California Math REU Conference 2020. Virtual, 12 Aug 2020.

### **MINI-SYMPOSIUMS**

*Numerical Methods in Algebraic Geometry*. Co-organized with Paul Brieding, Emma Cobian, and Jose Rodriguez. SIAM Conference on Applied Algebraic Geometry, Eindhoven, The Netherlands. 11-14 July 2023.

### **NCAA DIVISION I ATHLETICS**

**University of Notre Dame Women's Varsity Rowing Team** Fall 2016-Spring 2021

- 3-time Notre Dame Monogram recipient and Monogram Club Member
- Atlantic Coast Conference Academic Honor Roll member (2017, 2018, 2019, 2020, 2021)
- 2<sup>nd</sup> Varsity 4, 2<sup>nd</sup> place finisher, 2019 Atlantic Coast Conference Women's Rowing Championship

### **SCHOOL EMPLOYMENT**

Notre Dame Graduate School, MS-Data Science Tech Teaching Assistant Fall 2020-Spring 2021  
Rolf's Aquatic Center, Lifeguard Fall 2018-Spring 2021

### **EXTRACURRICULAR ACTIVITIES**

St. Margaret's House Volunteer Winter 2023-Spring 2024  
Notre Dame SIAM Student Chapter  
• President Fall 2023-Spring 2024  
• Received 2024 SIAM Student Chapter Certificate of Recognition Award

- Treasurer

Notre Dame AWM Student Chapter, Vice President  
 ND Club Sailing Team  
 Graduate Student Union, ACMS Representative  
 ND Athletics, Varsity Women's Rowing Volunteer Coach

Fall 2022-Spring 2023  
 Fall 2023-Spring 2024  
 Fall 2022-Fall 2023  
 Fall 2022-Spring 2023  
 Fall 2021-Spring 2022

### **TECHNICAL SKILLS**

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Currently programming in Mathematica and MATLAB.

Experience in Python (250 hours), R (200 hours), C++ (150 hours) mainly through academic courses and internships. New experience in Maple (<20 hours) through research projects.

### **AWARDS**

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SIAM Travel Award

February-March 2023

- Up to \$800 to attend SIAM Conference on Computational Science and Engineering and SIAM Student Days in Amsterdam, The Netherlands.