Alexander Elias

Ph.D. in Robotics (Pending Conferral) · John Wen Research Group @ RPI · Graduate Student Member, IEEE

🌐 alexanderelias.com · ✉ alex@alexanderelias.com · in alexander-elias · ⓞ aelias36 · ▶ AlexEliasRobotics

- Creator of IK-Geo, an open-source high-performance geometric inverse kinematics solver used by NASA and universities worldwide and cited on Wikipedia's Paden–Kahan subproblems page for extending the classical framework
- Versatile robotics researcher: From robot arms to mobile robots, from theoretical foundations to practical implementations, and from collaborations with fellow academics to NASA and industry
- Skilled communicator and mentor with an eye for design and a knack for simplifying tough concepts

Education

Rensselaer Polytechnic Institute, Troy, NY

Ph.D. in Electrical, Computer, and Systems Engineering   Fall 2019–Expected Summer 2025
Specialization: Control, Robotics, and Automation
Dissertation: *Efficient Singularity-Robust Inverse Kinematics and Redundancy Management for Robotic Systems*
Advisor: John Wen
GPA: 3.97/4.00

Dual B.S. in Electrical Engineering and Computer & Systems Engineering, Minor in Economics   Fall 2015–Spring 2019
Summa Cum Laude; Dean's Honors List; Rensselaer Leadership Award
GPA: 3.97/4.00

Research Experience

Ph.D. Research on Cuspidality, Redundancy, and Parallel Mechanisms (TA-funded)   Spring 2025–Present

- Developed novel algorithms for cuspidal robots, which can change IK solutions without passing through a singularity: Identified the ABB GoFa as cuspidal for the first time and proposed graph-based path planning and pose optimization methods
- Analyzed the complete kinematics of the ABB YuMi, including validated shoulder-elbow-wrist (SEW) angle redundancy parameterization matching the ABB controllers/simulators, classification of algorithmic singularities, and inverse kinematics using IK-Geo
- Proved that the ABB YuMi exhibits cuspidality for any joint angle parameterization and for ABB's SEW angle definition, establishing the first results for cuspidality in redundant manipulators
- Extended IK-Geo to support efficient inverse and forward kinematics for parallel robots, including those with prismatic joints

NASA Goddard On-Orbit Satellite Servicing (OSAM-1)   Fall 2021–Fall 2024

- Designed and analyzed control algorithms for elastic-joint 7-DOF manipulators carrying massive payloads on orbit: compliance control, trajectory tracking, stability analysis of low-level control loops, optimal control, and dynamics modeling and simulation
- Developed IK-Geo, a highly efficient 6-DOF and 7-DOF inverse kinematics solver for any robot using subproblem decomposition: finds all IK solutions including singular solutions and the fastest solver in our testing achieving >40x faster IK for UR5 than IKFast
- Proposed the stereographic SEW angle to enlarge the singularity-free workspace of 7R arms (especially useful during teleoperation), proved all redundancy parameterizations exhibit algorithmic singularities, and classified 7R arms based on joint geometry

Multi-Robot Systems for Tent Manufacturing (ARM-TEC-20-02-F-15)   Summer 2020–Spring 2022

- Led development of five mobile robots for collaborative manipulation of heavy fabrics in emergency medical tent construction
- Designed/built two omnidirectional robots: low-level PID control, ROS drivers/integration, wireless teach pendant teleoperation
- Developed constraint-aware formation control via QP optimization, enabling rigid-body formations with obstacle avoidance
- Implemented UWB localization and EKF sensor fusion with ±5 cm accuracy, including antenna calibration and height constraints
- Demonstrated safe and reliable coordinated multi-robot fabric transport, collaborative RF welding, and caging of large carts

Robotic Deep Rolling (ARM-TEC-18-01-F-03)   Summer 2019–Spring 2020

- Designed and implemented GUI-based hybrid motion-force controller for deep rolling using ABB IRB 6640 robot: custom parametric toolpath generation and execution, ±5% force accuracy, and experimentally validated compressive residual stress in aluminum
- Designed and validated robot simulation models from data: open-loop physical dynamics, inner closed-loop controller behavior (delay + low-pass filter), and outer-loop compliance models (joint and environment stiffness), enabling offline controller tuning
- Conducted finite element analysis (FEA) of the deep rolling process using Abaqus to evaluate residual stress profiles

PUBLICATIONS

Journal Articles

A. J. Elias and J. T. Wen, "IK-Geo: Unified robot inverse kinematics using subproblem decomposition,"
Mech. Mach. Theory, vol. 209, Jul. 2025, Art. no. 105971.

A. J. Elias and J. T. Wen, "Redundancy parameterization and inverse kinematics of 7-DOF revolute manipulators,"
Mech. Mach. Theory, vol. 204, Dec. 2024, Art. no. 105824.

A. J. Elias and J. T. Wen, "Path planning and optimization for cuspidal 6R manipulators," 2025, arXiv:2501.18505.
Accepted for publication in *ASME J. Mech. Robot.*

Preprints

A. J. Elias and J. T. Wen, "Redundancy parameterization of the ABB YuMi robot arm," 2025, arXiv:2505.23111.
Submitted to *IEEE Robot. Autom. Lett.*

In Preparation

A. J. Elias and J. T. Wen, "Cuspidal redundant manipulators."

A. J. Elias and J. T. Wen, "Kinematic analysis and applications of subproblem decomposition in 6R, 7R, and parallel manipulators."

B. Aksoy, A. J. Elias, C. O. Ike, A. A. Julius, G. Saunders, and J. T. Wen, "Distributed and coordinated multi-robot assembly and task planning in large structure manufacturing."

WORK EXPERIENCE

Draper   January–August 2018
Instrumentation Electronics 8-Month Co-op   *Cambridge, MA*

- Modeled gyroscope quadrature loop in Simulink (FPGA/ASIC/MEMS) and proposed control improvements to leadership
- Authored 20-page technical report on accelerometer front-end mixed-signal dynamics
- Contributed to atomic magnetometer design, implemented SPI test code, and debugged hardware
- Created test plan and equipment requirements for new A/D converter, acquired and validated test equipment
- Developed solar-powered drone: designed test hardware/code, co-developed drone hardware and autonomous flight code
- Designed and built ultra-low-current picoamp-precision test jig, requiring clean room fabrication

OPEN-SOURCE SOFTWARE CONTRIBUTIONS

rpiRobotics / **ik-geo**
Unified inverse kinematics solver for 6R manipulators using geometric subproblem decomposition

rpiRobotics / **subproblem-polynomial**
Symbolic generation of tangent half-angle polynomials for converting search-based inverse kinematics to closed form

rpiRobotics / **stereo-sew**
Redundancy parameterization and inverse kinematics of 7-DOF arms using stereographic and conventional SEW angles

rpiRobotics / **yumi-ik**
Forward and inverse kinematics for ABB YuMi with SEW angle computation and Jacobians

rpiRobotics / **cuspidal-path-planning**
Graph-based planner and optimizer for cuspidal 6R arms such as FANUC CRX and ABB GoFa

rpiRobotics / **subproblem-parallel-robots**
Forward and inverse kinematics of parallel robots using subproblem decomposition

rpiRobotics / **ARM-20-02-C-15-Swarm-Robotics**
Mobile multi-robot control and localization for collaborative manipulation of flexible materials

aelias36 / **robotic-deep-rolling-gui**
GUI for automated robotic deep rolling of metal surfaces using force feedback

aelias36 / **matlab-diagrams**
Custom MATLAB plotting utilities for publication-quality visuals

hehonglu123 / **MARS_Sample_Return**
Hybrid motion/force control for ABB IRB 1200 performing high-force planar lid insertion for Mars Sample Return demo

Research Interests

Kinematics	Inverse kinematics, redundant robots, cuspidal robots, singularity analysis, serial & parallel manipulators
Path Planning	Non-singular & singular paths, planning for cuspidal robots, pose optimization
Control	Impedance & force control, flexible-joint arms, contact dynamics, modeling & simulation
Mobile Robots	Multi-robot systems, formation control, teleoperation, UWB localization, sensor fusion

Selected Coursework

AI/ML & Autonomy	Machine Learning, Computer Vision, Adaptive Systems, Safe Autonomy, Distributed Systems
Robotics & Control	Robotics I/II/Dynamics & Control, Optimal/Multivariable/Nonlinear/Digital Control, Mechatronics
Other Topics	Quantum Programming, RF & Microwave Engineering, Analog IC Design, Microprocessor Systems

Technical Skills

Programming	MATLAB, Simulink, Python, C, C++, Rust, LaTeX, Mathematica, Maple, Git/GitHub, AWS, Docker
Robotics Software	ROS/ROS2, ABB RobotStudio, FANUC ROBOGUIDE, YASKAWA MotoSim, KUKA.Sim
EDA, CAD, & CAE	Xpedition, EAGLE, DipTrace, PCB Artist, Virtuoso, LTspice, PSpice, ADS, NX, Abaqus, SketchUp
OS & Virtualization	Windows, Linux, macOS, WSL, VirtualBox, VMWare, Hyper-V
Media & Design	Photoshop, Illustrator, After Effects, Premiere, Audition, Canva, DaVinci Resolve, Audacity
Web Development	HTML, CSS, JavaScript, SQL (PostgreSQL, MySQL)

Awards and Honors

2nd Place Best Poster Award — October 2023
IROS 2023 Workshop on Assembling Large Infrastructures in Space using Intelligent Robots
"Efficient and Singularity-Aware Inverse Kinematics for 6-DOF and 7-DOF Revolute Manipulators"

The Professor Howard Kaufman '62 Memorial Fellowship — October 2019

Presentations

Poster presentation, ICRA late-breaking result — May 2025
"Path Planning and Optimization for Cuspidal 6R Manipulators"

Invited talk, University at Albany, Applied Topology in Albany (ATiA) Seminar — November 2024
"Robotics and Topology: Kinematics, Redundancy, and Cuspidality"

Poster presentation, RPI Space, Science, and Technology Day (RPI Bicentennial) — September 2024
"Efficient and Singularity-Aware Inverse Kinematics for 6-DOF and 7-DOF Revolute Manipulators"

Invited talk, RPI Robotics Club — October 2023
"Efficient and Singularity-Aware Inverse Kinematics for 6-DOF and 7-DOF Revolute Manipulators"

Poster presentation and lightning talk — October 2023
IROS Workshop on Assembling Large Infrastructures in Space using Intelligent Robots
"Efficient and Singularity-Aware Inverse Kinematics for 6-DOF and 7-DOF Revolute Manipulators"

Poster presentation, In-Space Servicing, Assembly, and Manufacturing (ISAM) Workshop — October 2022
NASA Goddard Space Flight Center
"Robotic Servicing of Orbital Space Assets"

Review Activities

IEEE Transactions on Robotics (T-RO)

IEEE Robotics and Automation Letters (RA-L)

IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)

Advances in Space Research (ASR)

Teaching and Mentoring

Teaching Assistant
Robotics II (ECSE 4490/6490, CSCI 4969/6969, MANE 4963/6963)   Spring 2025
Introduction to Electrical, Computer, and Systems Engineering (ECSE 1010)   Spring 2025

Undergraduate Research Program Supervisor   Fall 2022–Spring 2024
Supervised 4 students on porting IK-Geo from MATLAB to C++, Rust, and Python

Undergraduate Research Program Mentor   Fall 2023
Guided 2 students on robotic deep rolling experiments using my open-source GUI-based hybrid motion-force control software

ECSE Mentorship Program   Fall 2020
Mentored 4 undergraduate students on academic and professional development

Hackathons and Other Competitions

HackUMass VII, "Country Roads"   October 2020

5th Annual HackRPI, "HiveMap"   March 2019
3rd Place Overall, Best Education Hack, Wolfram Alpha award

HooHacks @ University of Virginia, "DuckWeb"   March 2019

HackPSU Fall 2018, "Duckie Rodeo"   October 2018
Runner-up HackPSU Overall - Tech

The Greatest International Scavenger Hunt the World Has Ever Seen (GISHWHES)
Stratosphere Paper Airplane Launcher, *Runner Up*   August 2017
Rotary Phone Robot, *First Place*   August 2016

2014 Hackaday Prize, "Low-Cost Solid-State Cosmic Ray Observatory"   August 2014
Semifinalist (Top 50)

Other Interests

Professional bassist, opened for Kevin Bacon, classically trained violinist, proficient in piano, guitar, drums, and melodica

Freelance graphic designer with 40+ posters and album covers for concerts and music releases

Freelance lighting designer with 30+ paid and volunteer productions, driven by a passion for combining technology and art

Passionate home cook who enjoys mastering dishes from around the world