Patrick D. Holmes

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Education

University of Michigan — Ann Arbor, MI
PhD, MS in Mechanical Engineering; GPA: 3.74/4.00 — Aug. 2015 - Aug. 2021
Focus: *Robotics, Control, Biomechanics*

University of California, Berkeley — Berkeley, CA
BS in Mechanical Engineering, *High Honors;* GPA: 3.92/4.00 — Aug. 2011 - May 2015

Work Experience

University of Michigan Ford Center for Autonomous Vehicles, ROAHM Lab — Ann Arbor, MI
Senior Research Engineer — Oct. 2021 - Dec. 2022

Skills Summary

- **Programming/Software**: C++, MATLAB, Python, Git, LaTeX, SolidWorks, Simulink, LabVIEW
- **Technical**: Robot Kinematics and Dynamics, Linear/Nonlinear Systems and Control, Hybrid Systems, Motion Planning, Reachability Analysis, Real/Functional Analysis, Optimization, Machine Learning, Computer Vision

Selected Projects

- **Guaranteed-Safe Trajectory Planning and Control for Robotic Manipulators with Model Uncertainty**:
  - Developed a novel robust trajectory-tracking controller for robotic arms with uncertain inertial parameters.
  - Proved bounds on the maximum tracking error possible under this controller using control barrier functions.
  - Modified the Recursive Newton-Euler Algorithm (RNEA) to operate over sets described by polynomial zonotopes (PZs).
  - Utilized PZs with robot kinematics and RNEA to bound reachable workspace positions and torques for sets of trajectories.
  - Created a reachability-based receding horizon trajectory planner that guarantees satisfaction of collision avoidance and torque limit constraints in the presence of static and dynamic obstacles, inertial parameter uncertainty, and tracking error.
  - Leveraged parallelization on a GPU to perform real-time nonlinear optimization over sets of safe trajectories.
  - Demonstrated in simulation and on hardware in real time with Fetch Mobile Manipulator and Kinova Gen3 robots.
- **Planning Safe Trip Recoveries for Robotic Prostheses using Swing Hip Kinematic Predictions**:
  - Conducted a 16-subject tripping experiment to study three distinct able-bodied human trip recovery strategies.
  - Trained Gaussian Process Regression (GPR) models to accurately predict post-trip swing hip kinematics for each strategy.
  - Incorporated sets of GPR predictions within a trip-recovery trajectory planner for robotic prosthetic legs tripped in swing.
  - Showed in simulation that the prostheses avoided premature ground contact and were placed appropriately for recovery.
- **Characterizing Human Stability during Sit-to-Stand using Reachable Sets**:
  - Designed and conducted an 11-subject Sit-to-Stand (STS) experiment with motor-driven cable pull perturbations.
  - Constructed individualized dynamic models and controllers from observed trajectories crafted from motion capture data.
  - Computed sets of safe STS trajectories as the backwards reachable set of a subject's successful standing set.
  - Experimentally demonstrated that the method predicted STS failures caused by perturbation with over 90% accuracy.
- **Certifiably-optimal 3D Human Pose Estimation via Sums-of-Squares Programming**:
  - Developed sparse sums-of-squares optimization programs for reconstructing 3D human pose from multi-view 2D estimates.
  - Demonstrated state-of-the-art keypoint accuracy and computational efficiency on Human3.6m dataset.
  - Certified global optimality of solutions obtained via semidefinite programming with strict segment length constraints.

Selected Publications

- **Holmes**, Kousik, Zhang, Raz, Barbalata, Johnson-Roberson, Vasudevan. "Reachable sets for safe, real-time manipulator trajectory design". Robotics: Science and Systems (RSS), 2020. (Conference)
- **Holmes**, Danforth, Fu, Moore, Vasudevan. "Characterizing the limits of human stability during motion: perturbative experiment validates a model-based approach for the Sit-to-Stand task". Royal Society Open Science, 2020. (Journal)
- Kousik, **Holmes**, Vasudevan. "Safe, Aggressive Quadrotor Flight via Reachability-based Trajectory Design". ASME Dynamic Systems and Control Conference (DSCC), 2019. **Best Student Paper Award**. (Conference)
- Danforth, Liu, Ward, **Holmes**, Vasudevan. "Predicting Sagittal-Plane Swing Hip Kinematics in Response to Trips". IEEE Robotics and Automation Letters (RA-L), 2022. **Best RA-L Paper Award, BioRob 2022**. (Journal)
- **Holmes**, Kousik, Mohan*, Vasudevan. "Convex estimation of the α-confidence reachable set for systems with parametric uncertainty". IEEE Conference on Decision and Control (CDC), 2016. (Conference)

Honors, Awards, and Leadership

- Selected as RSS Pioneers participant (July 2020) and helped organize workshop (July 2021).
- Awarded Drake Scholarship to attend UC Berkeley (one of six ME students, full academic scholarship, 2011-2015).
- Reviewed submissions to prominent robotics and control venues including TRO, TCST, RA-L, IROS, and ICRA.
- Developed and led an introductory C++ summer course for my lab (2020, github.com/pdholmes/CppPrimerPrimer).