YAN GU

Assistant Professor, University of Massachusetts Lowell

CONTACT INFORMATION

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RESEARCH INTERESTS

My research investigates hybrid, physically-interactive mechanical systems under full actuation and/or underactuation. Particularly, I am interested in achieving stable, versatile, agile, and energy efficient bipedal robotic walking through the actual bipedal dynamics based nonlinear controls. Disaster response and rescue are potential applications of my research as well as rehabilitation. I also have a broad interest in biologically inspired energy minimization of robotic walking based on observations and analysis of human walking.

Topics: Robotic locomotion, nonlinear controls, hybrid dynamical systems, underactuation, motion stabilization, energy optimization

EDUCATION

Ph.D. in Mechanical Engineering — West Lafayette, IN, U.S.
Purdue University — Aug. 2011 - Aug. 2017
Co-Advisors: Dr. Bin Yao (ME) and
Dr. C. S. George Lee (ECE)

B.S. in Mechanical Engineering — Hangzhou, China
Zhejiang University — Aug. 2007 - June 2011

HONORS AND AWARDS

- **Frederick N. Andrews Fellowship,** Graduate School, Purdue University (2011-2015)
- **Estus H. and Vashti L. Magoon Award for Excellence in Teaching,** College of Engineering, Purdue University (2014)
- **Women in Engineering Program Conference Travel Grant,** Purdue University (2015)
- **IEEE ICRA Travel Grant,** (2015)
- **Graduate Student Travel Grant,** College of Engineering, Purdue University (2016)
- **Summer Research Grant,** Purdue Research Foundation, Purdue University (2014, 2015)
- **Chu Kochen Award,** Zhejiang University (highest university honor) (2010)
- **National Scholarship,** Ministry of Education of China (top 1%) (2009)
- **First-Class Scholarship for Outstanding Merits,** Zhejiang University (top 3%) (2009, 2010)

PUBLICATIONS

Published and Accepted:

1. **Y. Gu,** B. Yao, C. S. G. Lee, "Exponential Stabilization of Fully Actuated Bipedal Robotic Walking," *ASME Journal of Dynamic Systems, Measurements, and Control*, 140(5): 051008, May 2018.
2. **Y. Gu,** B. Yao, C. S. G. Lee, "Straight-Line Contouring Control of Fully Actuated 3-D Bipedal Robotic Walking," in Proc. of *American Control Conference (ACC)*, to appear.
3. W. K. Chan, **Y. Gu,** B. Yao, "Optimization of Output Function with Nonholonomic Virtual Constraints in Underactuated Bipedal Walking Control," in Proc. of *American Control Conference (ACC)*, to appear.
4. **Y. Gu,** B. Yao, C. S. G. Lee, "Time-dependent Orbital Stabilization of Underactuated Bipedal Walking," in Proc. of *American Control Conference (ACC)*, 2017, pp. 4858-4863.
5. **Y. Gu,** B. Yao, C. S. G. Lee, "Bipedal Gait Recharacterization and Walking Encoding Generalization for Stable Bipedal walking," in *Proc. of the IEEE International Conference on Robotics and Automation (ICRA)*, 2016, pp. 1788-1793.
6. **Y. Gu,** C. S. G. Lee, B. Yao, "Feasible Center of Mass Dynamic Manipulability of Humanoid Robots," in *Proc. of the IEEE International Conference on Robotics and Automation (ICRA)*, 2015, pp. 5082-5087.

Under Review:

7. **Y. Gu,** B. Yao, C. S. G. Lee, "Orbitally Exponential Stabilization of Underactuated Bipedal Robotic Walking," submitted to *Automatica* for publication.
8. **Y. Gu,** B. Yao, C. S. G. Lee, "Exponential Stabilization of Underactuated Bipedal Walking," submitted to *IEEE Control Systems Letters* for publication.
9. Y. Zhao, **Y. Gu**, "An Integrated Non-periodic Planning and Exponential Stabilization Framework of Dynamic Legged Locomotion," submitted to *Conference on Decision and Control (CDC)* for publication.

RESEARCH EXPERIENCE

Integrated Non-periodic Planning and Exponential Stabilization Framework of Dynamic Legged Locomotion

June. 2017 - Mar. 2018

- Proposed an integrated planning and control framework for achieving high-performance bipedal robotic walking.
- Constructed a trajectory generation strategy that provides a smooth interface between the reduced-order model based planner and the full-order model based controller.
- Established the closed-loop stability conditions of the hybrid walking control system based on the construction of Multiple Lyapunov functions.

  (Submitted: *CDC*)

Global Contouring Control of Fully Actuated 3-D Bipedal Robotic Walking over Uneven Terrains

Oct. 2017 - present

- Generalized our previous study on flat-terrain straight-line contouring control to contouring

tracking of an arbitrary, feasible contours on an uneven walking surface.

- Greatly improved the walking versatility of the Hybrid-Zero-Dynamics framework.

Straight-Line Contouring Control of Fully Actuated 3-D Bipedal Robotic Walking

Nov. 2016 - June 2017

- Extended our previous study on exponential stabilization of fully actuated walking to a more complicated biped model.
- Realized exponential tracking of the desired travel path on the walking surface as well as the desired motion along the travel path.
- Further improved the walking versatility as compared with previous studies.

  (Accepted: *ACC 2018*)

Systematic Optimization for Orbitally Exponential Stabilization of Underactuated Bipedal Robotic Walking

Oct. 2016 - Nov. 2016

- Introduced a more general definition of output functions as compared with our previous work.
- Optimized the definition of output functions to guarantee the orbitally exponential stability of underactuated bipedal robotic walking under time-dependent output feedback control.
- Reduced the computational burden for finding a stable bipedal gait with desired features.

Orbitally Exponential Stabilization of Underactuated Bipedal Robotic Walking Based on Time-dependent Output Feedback Control

Apr. 2016 - Sep. 2016

- Used time to encode the desired gait to avoid implementation issues caused by sensor noise.
- Introduced a phase variable to construct an augmented autonomous system that is equivalent to the original hybrid, aperiodically varying closed-loop system.
- Constructed the first sufficient conditions for orbitally exponential stabilization based on time-dependent output feedback control.

  (Accepted: *ACC 2017*.)

Exponential Stabilization of Fully Actuated Bipedal Walking

June 2015 - Sept. 2015

- Established the exponential stability conditions for the closed-loop control system based on the construction of multiple Lyapunov functions.
- Realized exponential tracking of the desired position trajectory in the Cartesian space as well as the desired walking pattern, both symmetric and asymmetric, in the configuration space.
- Improved the walking versatility as compared with previous studies on orbital stabilization.

  (Publication: *ICRA 2016*. Submitted: *ASME*)

Bipedal Gait Recharacterization and Walking Encoding Generalization

Mar. 2015 - June 2015

- Recharacterized bipedal gait by differentiating the roles of the left and the right legs.
- Integrated the walking pattern encoding with a biped's global position in the Cartesian space.
- Proposed a novel method of walking pattern design to decouple the high-level planning of global position and the low-level planning of walking pattern.

(Publications: *ICRA 2016*. Submitted: *ASME*)

Feasible Center of Mass Dynamic Manipulability of Humanoid Robots

Sept. 2013 - Sept. 2014

- Analyzed the achievable Center of Mass accelerations at a given posture under three common ground-contact constraints.
- Evaluated the effects of postures, joint velocities, and joint torques on the torque-bounded CoM dynamic manipulability ellipsoid.
- Developed an optimization method to select the best walking posture for achieving maximum CoM acceleration in a given direction.

(Publication: *ICRA 2015)*

TEACHING EXPERIENCE

Instructor UMass Lowell

MECH 5315: Modern Control Systems Spring 2018

Instructor UMass Lowell

MECH 3220: Control of Mechanical Systems Fall 2017

Head Teaching Assistant, Graduate Teaching Assistant Purdue University

ME 475: Automatic Control Systems Fall 2015, Spring 2016

- Head Teaching Assistant of a senior-level undergraduate control course.
- Responsible for managing five graduate teaching assistants per semester.
- Designed the final project on an underactuated mechanical system with modeling, system identification, control design, and hardware implementations on LabVIEW per semester.
- Developed and organized the course competition.

Lab Instructor, Graduate Teaching Assistant Purdue University

ME 475: Automatic Control Systems Fall 2013 - Fall 2016

- Delivered laboratory lectures, 3 - 6 hours per week.
- Graded weekly assignments.
- Developed laboratory quizzes.

Teaching Assistant Ratings by Students

- 4.8/5.0 (Spring 2016, 28 students).
- 4.9/5.0 (Fall 2015, 11 students).
- 4.9/5.0 (Spring 2015, 27 students).
- 4.7/5.0 (Fall 2014, 22 students).
- 4.8/5.0 (Spring 2014, 26 students).
- 4.7/5.0 (Fall 2013, 26 students).

Guest Lecturer Purdue University

- *ME 365: Measurement Systems* Fall 2016
- *ME 475: Automatic Control Systems* Fall 2015

PROFESSIONAL SERVICE

- Reviewer – IEEE Transactions on Robotics.
- Reviewer - International Journal of Humanoid Robotics.
- Reviewer - Journal of Sports Engineering and Technology.
- Reviewer - IEEE-RAS International Conference on Robotics and Automation.
- Reviewer - IEEE/RSJ International Conference on Intelligent Robots and Systems.
- Reviewer - IEEE-RAS International Conference on Humanoid Robots.
- Reviewer - IEEE International Conference on Advanced Intelligent Mechatronics.
- Reviewer - IFAC Symposium on Mechatronic Systems.
- Reviewer - ASME Dynamic Systems and Control Conference.

INVITED TALKS

1. "Time-dependent Nonlinear Control of Bipedal Robotic Walking," *robotics seminar*, University of Michigan, Ann Arbor, MI, April 2017.
2. "Time-dependent Nonlinear Control of Bipedal Robotic Walking," Department of Mechanical Engineering, University of Massachusetts Lowell, Lowell, MA, April 2016.
3. "Modeling, Motion Planning, and Control of Bipedal Robotic Walking," *graduate seminar*, Department of Automation, Shanghai Jiao Tong University, Shanghai, China, June 2016.