Wen-Loong (Wenlong) Ma

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Faculty Search Committee *December 2, 2019*

Department of Electrical and Computer Engineering
University of Texas at Austin
2501 Speedway, Austin, TX 78712

Dear committee members,

My name is Wen-Loong (Wenlong) Ma and I am writing to apply to the Department of Electrical and Computer Engineering at the University of Texas at Austin for a tenure-track faculty position in the field of robotics and control. I am currently a Ph.D. candidate in Mechanical Engineering from the California Institute of Technology under the advise of Dr. Aaron D. Ames, with a focus on robotics, dynamics, optimization and control. UT Austin has a high reputation in the field of engineering and I will be grateful to be considered as a candidate for this opportunity.

Robotics is an exciting field and I am proud to present my work on this subject. My research focuses on the dynamics and control of legged robots. In particular, I have been applying computational and nonlinear control methods to realize the robust locomotion of legged robots, including monopedal, bipedal and quadrupedal robots. My main effort lies in bridging the gap between provable theoretical methods and experimental implementation. For example, I have applied input-to-state stability analysis and direct collocation-based optimization to realize robotic running on a human-size bipedal robot and shown its viability and robustness. Through system design, dynamic modelling, theoretical analysis, optimization and experimental design, I have realized various dynamically stable behaviors such as human-like multi-contact walking, walking over a slippery surface, bipedal dancing, walking with compliance, hopping, running and quadrupedal ambling. Currently, I am working towards formulating a multi-leg system as a coupled control system of bipedal robots and showing its stability. This concept has shown a powerful computational advantage using a case study of quadrupedal robot, on which rough terrain ambling has been achieved. I believe the fruitful results using real-world platforms have served as a convincing demonstration of the scability of formal analysis and theoretical foundation and broadened the practical impact of robotics.

My ultimate target is to understand and realize the autonomy of robotic systems that resemble terrestrial animals' agile performance. The approach I will continue to take is an iterative process of formal mathematical analysis and rigorous experimental design. This means, more theoretical tools will be used to analyze experimental results and synthesize new ideas, while creative experiments can further inform the direction of theoretical studies. My future research will continue to be guided by real-world robotic applications that can perform daily tasks and fundamentally change our society.

I view the study of legged locomotion as a natural blend of theoretical and experimental research across multiple engineering fields. Hence I have been privileged to collaborate with multiple pioneers from different fields and universities in my years' research career. From this experience, it has became my belief that true progress in robotics research can only be achieved by interdisciplinary endeavours. Close cross-disciplinary collaborations from different perspectives can effectively maximize the outcome of research development. The multidisciplinary and collaborative environment of UT Austin has significantly promoted the progress of robotics research in the past decades. I believe my diverse background in legged locomotion, optimization, nonlinear control theory and experimental robotics would be a unique fit for the school's rigorous and creative atmosphere. Further, starting with my previous results of real-life robotic dynamic locomotion, I am thrilled to purse more innovations and impacts in the field of robotics.

I look forwards to working closely with the faculty members and students from all departments of the University of Texas at Austin . To detail my work and future plans, I have enclosed my curriculum vitae, research and teaching statements and other supporting documents. Thank you in advance for your time and consideration of my application.

Sincerely,

Wenlong Ma

Wen-Loong Ma (Wenlong Ma)

Research Statement

Wen-Loong (Wenlong) **Ma**

Bridging the gap between theory and experiment in Robotics

Almost all terrestrial creatures in nature are granted the capability to locomote with legs, from the simplest insects to the agile and intelligent biomachine — humankind. Yet, the mechanism of robust walking still remains a cutting edge research topic across the fields of science and engineering. The challenges are twofold: the design of machinery that resembles biological systems' dynamics, and the controller that realizes its autonomy. However, these two targets are often coupled: a carefully designed system might be impossible to model or control, a provably stabilizing controller might diverge from the physical system it was built from because of an ignored light weight linkage. Further, this coupled dilemma appears almost in every domain of robotics and engineering. Thus, the study of legged locomotion presents a unique fusion of multiple disciplines, and narrowing this gap between a theoretically justifiable method and experimental realization has became the center of my research interests.

My ultimate goal is to achieve the control and design of autonomous machines that encode human-level robustness and animalistic agility. Its applications are limited only by imagination: space exploration, hazardous environment operation, self-assembly robots, prosthesis, exoskeleton, etc. To achieve this target, my body of research centered on the dynamics and control of legged robots, spanning a variety of its branches: hybrid dynamics modelling, model reduction, trajectory optimization, optimal control, data-driven control, dynamic stability analysis, experimental and hardware design. Multiple dynamic behaviors such as bipedal walking, multi-contact walking, dancing, running, 3D rough terrain walking and multi-domain quadrupedal locomotion have been successfully demonstrated on a series of legged robots. Meanwhile, these realization are built upon theoretical foundations and well-posed computational methods. Moving forward, my future research directions will cover three major branches: robot design, computational methods for complex dynamical systems and robust feedback controller design.

Past Research Overview

In retrospect, my existing work can be categorized by the robot platforms that I have worked on, some of which were partially created by myself and some were purchased but customized based on different research requirements. The gradual progress of my research career can then be summarized in three phases:

Phase I. *Experimental implementation of Walking.* Build upon the (Partial) Hybrid Zero Dynamics (HZD) theoretical framework [1][2], I have led the effort designing experiments of feedback controllers to realize walking on a series of AMBER robots that are constructed by AMBER lab (in Fig. 1). I have designed a real-time based hierarchical control architecture, to which motor driver, sensor feedback, low- and high-level control algorithm are integrated (see Fig. 1). A variety of theoretically proven methods, such as human-inspired control, data-driven control, formal methods and impedance control are successfully implemented on these physical platforms. Some representative results are the first stable HZD walking with feet [3]; the first bipedal walking with planned multi-contact, heel-lift and toe-impact behaviors [4] (featured by Discovery Channel Canada [5]) and the first bipedal walking with planned slippage [6].

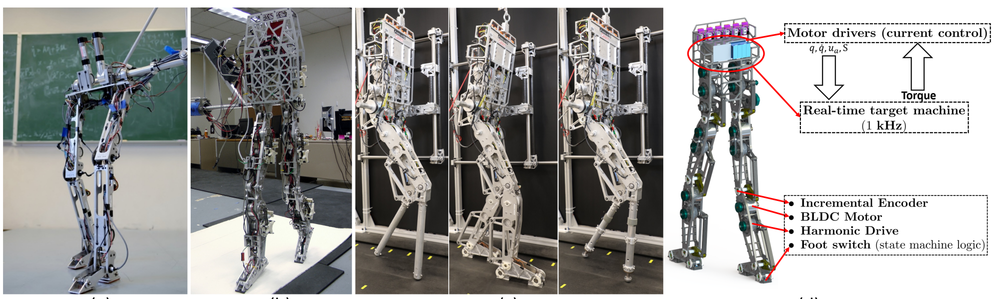


Figure 1: Three generations of AMBER robots (a) AMBER2 (height 0.82 m, weight 7.2 kg); (b) AMBER3 (height 1.45 m, weight 31 kg); (c) AMBER3M (M stands for modular) with rigid point feet, human-like feet, compliant point feet; (d) showing the layered control architecture of AMBER3 with feet contact logic.

(a) (b) (c) (d)

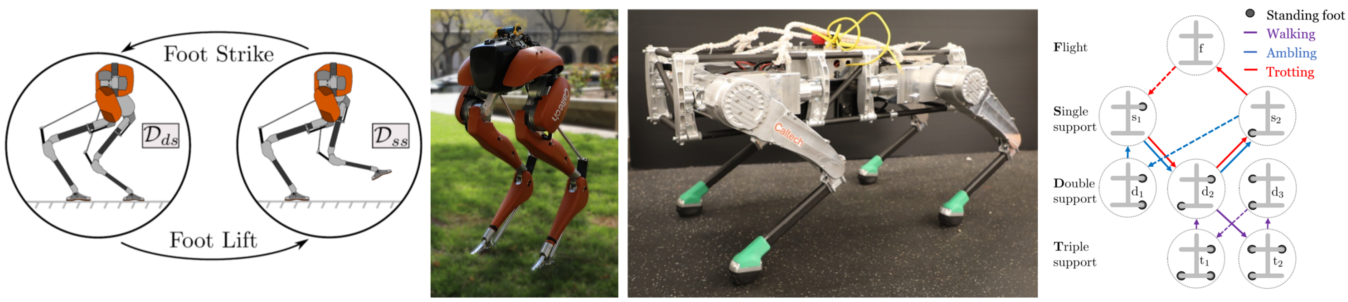
Figure 2: Two representative examples of running robots. In (a), utilizing ISS analysis, the bounded phase uncertainty (in the upper figure) results in bounded state stability (phase portraits are in the lower figure). The running can be stabilized by time+stable based control to realize DURUS-2D (b) running at 1.75 m/s; By direct collocation based optimization, DURUS (c) demonstrated 24 different stable 3D running gaits at different running speed. (d) shows the computational performance.

Phase II. *Bipedal robotic running.* As a benchmark problem of legged locomotion, limited methods [7] have demonstrate to efficiently and effectively produce bipedal robotic running on a physical robot. This is due to its complex dynamics that are intractable to computation, and its high nonlinearity can result in control fragility. To make a step towards pushing the boundary of the control of legged robots, I took the lead to apply various trajectory optimization methods such as single & multiple shooting methods, direct collocation, pseudospectral methods on the full-body hybrid dynamics of DURUS-2D and DURUS (see Fig. 2). During this process, input-to-state stability (ISS) analysis [9] was used to synthesis a new control structure: state feedback + time feedforward based phasing variable. The resultant phase-uncertainty-to-state stability was then formally justified. Its nature is a blend of the robustness of open-loop control and stabilizing effect of closed-loop control. The result is a robust and repeatable bipedal robotic running behavior realized on DURUS-2D [8], with a prominent flight phase foot clearance of 13 cm and running speed of 1.75 m/s. The optimization performance for computing a range of 3D running gaits for DURUS Fig. 2(c), which are *stable* periodic solutions to the closed-loop system, are shown in Fig. 2(d).

Phase III. *The control of full-body 3D dynamics of legged systems.* In the third phase, I further explored the complex and detailed dynamics of legged locomotion, in which the full-body dynamics with compliance, closed-chain structure, and multi-domain hybrid dynamics with impulse effect are constructed for two 3D robots. By using FROST, an open-source optimization software [12], numerical computation of the periodic solutions to the full-body dynamics are performed on robotic systems including a 22-DOF Cassie robot (Fig. 3(b), see [11]) that has nontrivial series compliant linkages and a quadrupedal robot, the 18-DOF Vision 60 (Fig. 3(c), see [10]). By Poincaré section analysis, the stability property of the controlled systems is posed as a bilinear matrix inequality (BMIs) problem. The stability of the closed-loop dynamics can be further guaranteed. The end results are robust walking over outdoor rough terrains with experiments.

Current Research

The results of phase III have led to a new thread of research, **Dynamics decomposition and network controlled**



(a) (b) (c) (d)

Figure 3: (a) the two-domain walking of Cassie induced by the series compliance in legs; (b) a 3D bipedal robot Cassie; (c) a quadrupedal robot, Vision 60; (d) the directed graph showing the quadruped's hybrid control dynamics, with three multi-domain gaits: walking, ambling, trotting.

system theory. The full-model based controller and trajectory design come with a high computational cost: it normally takes $2 \sim 4$ minutes to find a periodic solution to the quadrupedal dynamics. Thus, inspired by the widely used virtual leg principle [13], where two limbs are always paired to be controlled, I decomposed the full-body dynamics into two connected bipedal robots (see Fig. 4) and controlled each individually. As a result, in [14], the computational time dropped below 5 seconds to find a stable periodic solution (an ambling gait) to the full-body dynamics of the quadruped. Then in [15], this method is further generalized to and characterized by network controlled systems (NCS), where it was shown the periodic solution to the decomposed subsystems can be reconstructed to the solution to the original dynamic system. The initial results using this method are the outdoor rough terrain walking of the Vision 60 robot.

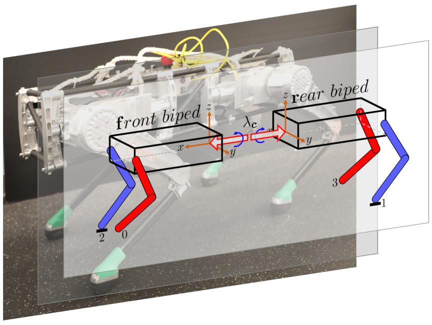


Figure 4: Dynamics Decomposition of a quadruped into two bipeds.

Instead of neglecting a certain level of modelling details (for example, limb masses) to reduce the computational cost, this manipulation accelerates the computational speed without inducing unnecessarily epistemic uncertainty (systematic uncertainty). It presents a new approach to design stabilizing controllers for multi-leg systems and legged systems with arms, without bearing the burden of full-body dynamics computation. That is, control each subsystem of a network controlled system. Hence I am currently working on designing control Lyapunov functions with quadratic programming (CLFQP) for the decoupled bipedal systems and proving the dynamic stability of the hybrid quadrupedal dynamics can be guaranteed. By further optimizing the hardware implementation and numerical algorithm, the results will be demonstrated through stable and robust quadrupedal trotting and galloping behaviors on Vision 60.

AMBER3M, an open source platform. The planar robot — AMBER3M (see Fig. 1 (d)) — has been developed in 8 years' research and demonstrated a wide variety of dynamic behaviors. This platform has reached a new level of consistency in terms of hardware robustness, optimization efficiency, simulation fidelity and ease of use. It is equipped with three pairs of modular legs (in Fig. 1(c)). Between the simplest linear invert pendulum and those complex 3D bipeds, AMBER3M acts as an articulation point for theoretical study and experimental validation. Because of these, opening source this platform to the research community becomes necessary. A good example using this platform is the study of energy economy of different leg configurations [17]. Especially for the reinforcement learning community, a platform that can produce experimental data consistently at low cost can mitigate the difficulty of the *sim2real* challenge. I am taking the lead sharing this platform, open sharing all of my post projects with tutorial examples that I used to produce those natural motions for all of the robots I have worked on.

Future Work

As my ultimate goal is to make robots automated and deliver daily-tasks for human, my future work shall be oriented by real-world applications, which includes *extreme environment exploration, mobile manipulation, home service robots, aerial-bipedal robots, construction robotics and advanced manufacturing.* Thus my future lab will focus on the following three major research topics:

- **Robot platform design.** Design different hardware platforms that integrate available actuators (inputs) and sensors (feedback) according to systematic case studies of dynamics and control theory.
- **Ultra fast computational methods.** Tailor the existing numerical optimization and machine learning methods according to the special structure of a robotic platform to realize real-time optimal control.
- **Feedback controller design.** Design feedback controllers that guarantee the stability of the assumed mathematical model, and admits some level of robustness to bear uncertainty from reality.

Therefore, in the initial phase of my career, three projects will be conducted:

1. Formally justify the control composition of simple and full-body dynamics.
One effective heuristic that has partially yielded the robust walking of Cassie [11] is the blending use of Raibert-type regulator [13] and the stable periodic solution to the assumed full-body dynamics. The nature of Raibert regulator is a stabilizing controller for a linear invert pendulum (LIP) model. Because the simplicity of this model, its dynamic stability and robustness can be then enforced. My hypothetical interpretation of this robust phenomenon is that,

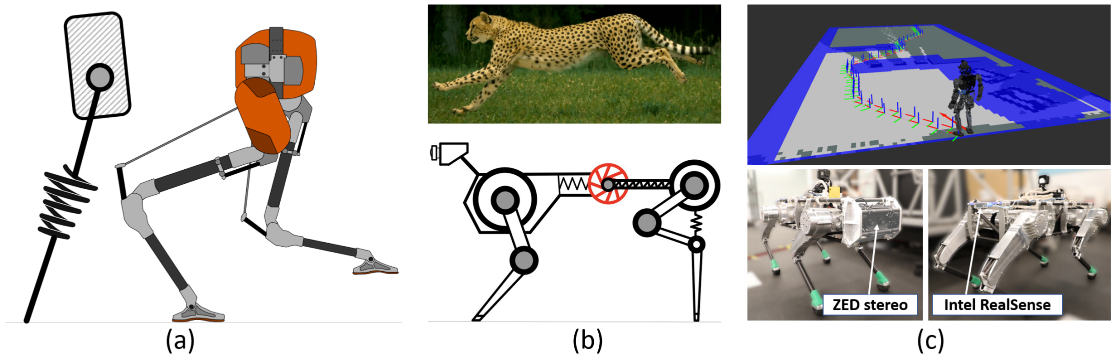


Figure 5: (a) Simple model (A-SLIP) embedding; (b) Control decomposition of a quadruped with compliant torso, the upper photo is from [19]. The compliance can be a flexure joint (in red); (c) Navigation with a quadrupedal robot.

since the simple LIP model locally captures the evolution of the full-body dynamics, we can combine its robustness with the original stabilizing controller that were carefully crafted based on the detailed full-body dynamics in an offline process. I believe how the simplified model interacts with the full-body dynamics can be formulated as uncertainty using *input-to-state stability* (ISS) analysis. From this formulation, an ISS-type constraint can be added to the offline optimization problem, I expect this research to result in: 1) formal simple model synthesis such as the Asymmetric-SLIP model in Fig. 5(a), instead of the popular but over-simplified LIP model; 2) a method to design robust controllers that systematically encode the computational advantage of simple models and the optimally of full-body dynamics based control; 3) More robust dynamic behaviors such as hopping, running and flipping realized on a physical system.

2. Control decomposition of a compliant quadrupedal platform.
Largely inspired by *quadruped pair gaits* from [13], a wide range of the quadrupedal robots are designed with identical legs and a rigid torso. This design has led to many successful implementations of the *virtual bipedal* methods. However, biomechanics [18] have shown the importance of torso compliance to quadrupedal animals' motions. And the methods in the dynamics decomposition [14] and full-body motion planning [10] do not rely on the traditional table-like design. Hence it will be a unique research topic to integrate the compliant components such as *flexure* in the major linkage — torso, and coordinate with some asymmetric leg configurations. The concept is shown in Fig. 5 (b). An extension of the coupled control system research is that, the multi-domain fashion of quadrupedal dynamics could be the result of the asynchronization of the two connected bipedal systems' phasing variable. Instead of planning such multi-domain motions in the first place, we could potentially design robust controllers using ISS-CLF [16] to reject the phasing uncertainty of such two bipedal robots. By further exploring the coupled control system methods in [15], I believe a range of agile motions can be realized on this new quadrupedal platform, with largely improved energy efficiency. In addition, we can potentially understand more fundamental science of this biomorphic mechanism found on animals by designing different compliant machinery.

3. Navigation and manipulation on legs.
With the fruitful results of legged locomotion in recent years, one of the major future directions is to integrate low-level feedback controllers with high-level decision making. The areas of applications that I am particular interested is the *space exploration* and *construction robotics*, where navigation and manipulation will be fully engaged to the control of legs. My early experience in the control and dynamics of legged robots can play a new role in this type of projects, in the sense that more dynamical and behavioral tasks can be achieved, providing more available options for the decision making process. Fig. 5(c) shows a preliminary result on navigation with Atlas in `Drake` (a simulation environment), where the high-level navigation algorithm is running a *D* lite* method to chose stepping location and navigate itself through obstacles, while the low-level HZD controller is utilized to stabilize walking and execute path following commands. A conceptual illustration of navigation and manipulation on a commercial available quadrupedal robot, Vision 60 is also shown, where vision sensors are integrated and fused to the low-level feedback controllers and high-level decision making algorithm. My target is to by mixing my expertise in dynamics and controls with the exciting results from localization, navigation and vision, legged system can make more impacts improving our daily life.

References

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[2] A. D. Ames, *Human-Inspired Control of Bipedal Walking Robots*, IEEE Transactions on Automatic Control, 2014.

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[11] J. Reher, W. Ma and A. D. Ames, *Dynamic Walking with Compliance on a Cassie Bipedal Robot*. In: 18th European Control Conference 2019, page 2589-2595.

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Wen-Loong (Wenlong) Ma

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Education

Ph.D.	Mechanical Engineering - Advisor: Aaron D. Ames	California Institute of Technology, United States	2020
M.S.	Mechanical Engineering - Thesis: Flat-foot dynamic walking via human-inspired controller design	Texas A&M University, United States	2014
B.S.	Mechanical Engineering	China University of Petroleum, China	2011

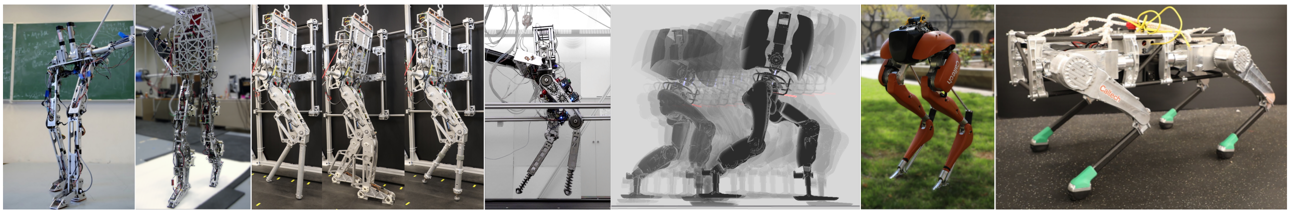
Area of Interests

Robotics Legged locomotion; Networked control systems; Mobile manipulation

Control+Dynamics Optimal control of multi-body dynamics and hybrid dynamics; Data-driven control

Optimization Trajectory optimization for complex dynamic systems; Numerical optimization

Academic Experience



Robots I developed and worked with: **AMBER2**, **AMBER3**, **AMBER3M**, **DURUS-2D**, **DURUS**, **Cassie**, **Vision60**.

Software and hardware development. 2012-2015

Design and implement a software + hardware framework for AMBER2, AMBER3, AMBER3M robots, including Real-time operating system, motor control, sensor fusion and experimental design, detailed in [C_{15}] [C_{14}], [B_1], [C_8].

Nonlinear control of bipedal locomotion. 2013-2018

Design the feedback control laws and experimental realization of Legged robots and autonomous driving using nonlinear control. This includes control barrier function based optimal control, full-body dynamics and compliant dynamics, data-driven control, abstraction-based control, input-to-state stability analysis, bilinear matrix inequality analysis, networked control systems, detailed in [C_{12}][C_6][C_7][C_{13}][J_3][J_3][C_9][C_4][C_3][C_1][J_1].

Multi-body hybrid dynamics + optimization 2015-2019

Design nonlinear programming algorithms for legged locomotion, including shooting methods, direct and indirect collocation methods to solve for the full-body, nonlinear and hybrid dynamics of legged locomotion. The results are robust and repeatable bipedal walking, multi-contact walking, dancing and running that are built on provable theoretical foundation, detailed in [C_{15}][C_{14}][B_1] [C_{11}][C_9][C_{10}][C_8][C_6][C_5][C_3][J_1].

Teaching Experience

2016-2019 **Graduate Study Mentor** Texas A&M University, California Institute of Technology
- Mentor the graduate research of Akarr Mehra, Noel V. Csomay-Shanklin and Eric Ambrose.

Fall 2018 **Guest Lecturer** California Institute of Technology
- CDS-233 Nonlinear Control
- Lecture: Trajectory optimization for legged robots, a tutorial on hybrid zero dynamics optimization, In: *Lectures on Nonlinear Dynamics and Control*, by A. D. Ames and P. Tabuada.

Spring 2017 **Teaching Assistant** California Institute of Technology
- CDS-270 Dynamics and Control of Walking Robots
- Prepare exams, project software and experimental practice on bipedal robots.

Honor and Awards

Best Paper Award Finalist, International Conference on Cyber Physical Systems, Germany, 2014
Third prize, In: 2^{nd} Higher Education Cup National Graphics Skill and Innovation Competition, China, 2009.

Professional Experience

Peer Reviewer

American Control Conference	2018, 2020
IEEE Robotics and Automation Letters	2019
IEEE-RAS International Conference on Humanoid Robots	2017
IEEE International Conference on Robotics and Automation	2015, 2019, 2020
IEEE Conference on Decision and Control	2017, 2018, 2019
IEEE Conference on Control Technology and Applications	2017
IEEE Access	2018, 2019
IEEE Control Systems Letters	2019
IEEE Transactions on Robotics	2019
Nonlinear Analysis: Hybrid Systems	2017
International Journals of Control, Automation and Systems	2017, 2018

Invited Demonstration & Presentations

- *Walking with Cassie and Quadrupeds*, Southern California Robotics Symposium, LA, 2019
- *How to Make a Bipedal Robot Run Like Us?* Disney TechTalk, Disney Research LA, 2018
- *The Control of Bipedal Running*, 32^{nd} Southern California Control Workshop, Pasadena, CA, 2017
- *AMBER2 walking with Voltage Inputs*, NIWeek, Austin, TX, 2012

Publications

Journals

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From Bipedal Walking to Quadrupedal Locomotion: Full-Body Dynamics Decomposition for Rapid Gait Generation, submitted to IEEE Robotics and Automation Letters with 2020 International Conference on Robotics and Automation (ICRA) option.

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[J3] A. D. Ames, P. Tabuada, A. Jones, W. Ma, M. Rungger, B. Schürmann, S. Kolathaya and J. Grizzle ,
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Coupled Control Systems on Graphs: Periodic Orbit Generation with Application to Quadrupedal Locomotion. Submitted to: 23rd International Conference on Hybrid Systems: Computation and Control (HSCC 2020).

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Distributed feedback controllers for stable cooperative locomotion of quadrupedal robots: A virtual constraint approach. American Control Conference (ACC), Under Review, September 2019.

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First steps towards full model based motion planning and control of quadrupeds: A hybrid zero dynamics approach. In: 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).

[C_4] K. Akbari Hamed, W. Ma and A. D. Ames,
Dynamically Stable 3D Quadrupedal Walking with Multi-Domain Hybrid System Models and Virtual Constraint Controllers. In: 2019 American Control Conference (ACC), page 4588-4595.

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Dynamic Walking on Slippery Surfaces: Demonstrating Stable Bipedal Gaits with Planned Ground Slippage. In: 2019 International Conference on Robotics and Automation (ICRA), page 3705-3711.

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Dynamic Walking with Compliance on a Cassie Bipedal Robot. In: 18th European Control Conference 2019, page 2589-2595.

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Toward benchmarking locomotion economy across design configurations on the modular robot: AMBER-3M. In: 2017 IEEE Conference on Control Technology and Applications (CCTA), 1270-1276.

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[C_{10}] M. J. Powell, W. Ma, E. R. Ambrose and A. D. Ames,
Mechanics-based design of underactuated robotic walking gaits: Initial experimental realization. In: 2016 IEEE-RAS 16th International Conference on Humanoid Robots (Humanoids).

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[C_{14}] H. Zhao, W. Ma, A. D. Ames, M. Zeagler,
Human-inspired multi-contact locomotion with AMBER2. In: 2014 ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS).

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Peer-reviewed Book Chapters

[B_1] S. Kolathaya, W. Ma, and A. D. Ames,
Composing Dynamical Systems to Realize Dynamic Robotic Dancing. In: Algorithmic Foundations of Robotics XI: Selected Contributions of the Eleventh International Workshop on the Algo-

rithmic Foundations of Robotics. Ed. by H. L. Akin et al. Cham: Springer International Publishing, 2015, pp. 425–442. ISBN 978-3-319-16595-0.

Non Peer-reviewed Articles

[N_1] K. Akbari Hamed, W. Ma, V. Kamidi and A. D. Ames, **Hierarchical Feedback Control for Complex Hybrid Models of Multiagent Legged Robotic Systems**. In: arXiv preprint arXiv:1902.03690

[N_2] S. Kolathay, H. Zhao, W. Ma and A. D. Ames, **Human-Inspired Walking in Amber 1.0 and Amber 2.0**. In: Dynamic Walking 2013.

Selected Media Report

[M_1] Engadget: **AMBER Lab robot jogs just like a human**, 03.18.2016

[M_2] DailyMail: **Watch the robot that can run like a human: Researchers say Durus-2D could lead to radical new prosthetic limbs** 03.18.2016

[M_3] Gizmodo: **Robots Are Getting Really Good at Running**, 03.20.2016

[M_4] Discovery Channel Canada: **Daily Planet Feature on AMBER Lab**, featuring the *Multi-Contact AMBER2 Walking* in [C_{14}]. Available at: `youtu.be/gaOpUvWCHU4`.

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Teaching Statement

Wen-Loong (Wenlong) **Ma**

I believe education is the most essential driving force for our civilization. Thus teaching is one of the major duties of academic community. Through my academic career, I have received countless advices in this journey and gained abundant knowledge to fulfill my curiosity. In this statement, I present my teaching philosophy, teaching principle, teaching interests, curriculum development plan and how I will advise my future laboratory students.

Teaching Philosophy. There is a Chinese proverb —*Give a man a fish and he will eat for a day. Teach a man how to fish and you feed him for a lifetime.*— emphasising the significance of teaching the method over directly giving away the knowledge. While teaching knowledge will be a daily task of my teaching practice as a faculty member, my "how to fish" is the *interest*. Hence my ultimate target is to **excite students' intrinsic interests** to achieve *autonomy in learning*. Through my years researching robotics, the most powerful driving force is the passion for robotics, which helps me overcome difficulties, challenges and leads me to new findings in research. Intriguing and fostering this passion will be the guideline of my teaching Philosophy. The approach I plan to take to intrigue students' interests is to carefully craft the teaching process using available software to visualize the applications of knowledge, involve more research topic along the course of teaching, prepare the most straightforward illustrating examples and always take advantages of counterexamples. However, interest can be fragile when it comes to cumbersome theoretical derivation and principles of physics. To foster the interest to grow deeper and become an "intrinsic interest", I will organize the class materials in an layered structure and gradual level of details, promote new ideas, encourage more questions and patiently understand student's misconceptions.

Teaching Principles. My commitment to teaching is governed by two major principles: **the dedication to open sharing of knowledge**; **the freedom of communication and discussion**. I am a strong proponent of popularization of knowledge and I believe there is always a way to guide the students to understand the knowledge in a enjoyable way. It is my intrinsic passion to reveal the fun and easy angle of knowledge. When I was a guest lecturer for the class *Nonlinear Control* at California Institute of Technology, I presented the materials with many animations and visual effects, and carefully introduce the concepts in a gradual level of details step by step. According to the students' feedback, the complex concepts of numerical optimization have been easily understood. In my another experience as a teaching assistant for the class *Dynamics and Control of Walking Robots*, I used my a robot platform AMBER3M to illustrate a series of theoretical and experimental studies on the control and dynamics of legged locomotion. In addition, I have conducted research tours and explained how control and computation reinvented robotics for business professionals, children and underrepresented groups, engineers and academic researchers on a monthly basis. Searching for the easiest way to transfer knowledge will continue to be my teaching principle as a faculty member.

In addition, organizing office hours and keeping a door open to students who wants to share their confuse is crucial to my approach. This provides an important feedback to help me correct and develop my teaching skills. The principle I value heavily is the *freedom of communication and discussion*. As a senior Ph.D. student, I have mentored the study of multiple undergraduate and graduate students. This experience has helped my communication skills to grow both broader and deeper. In my faculty career, not only will I open myself to well-defined questions from any student, I will pursue the capability to help the students to recondition an ill-posed question and together we shall find a better answer.

Teaching interests. The multidisciplinary nature of robotics has prepared me with knowledge from a wide range of engineering and mathematical subjects. The foundation of my knowledge is centered on rigid body dynamics, linear system theory, nonlinear control and convex optimization. I am particularly passionate about paving a way for connecting rigorous theorems and physical applications for the students in these classes. This way, a strong correlation of the knowledge from class and their uses in real world can better motivate students' interests. I am also interested in revealing state-of-the-art challenges in the field of robotics — the gap between theory and applications — by conducting projects on simple platforms. The situations where experiments evolve differently from theorems can serve as an inspiration to the students' creativity and potentially the future directions for the next generation of scientists and engineers. From my experience as a researcher, teaching assistant and lecturer, I am open to teach any related course in the area of rigid body dynamics, nonlinear control, robotics and optimization.

Curriculum Development. In addition, I plan to develop a project-based course, *Robotic Optimization* for engineering students. The course will focus on introducing the most advanced techniques in trajectory optimization and optimal control to rigid body dynamics, autonomous driving, hybrid dynamics and underactuated mechanical systems. The target is to show means of posing a control problem of dynamical systems into optimization problems. In the course, a variety of third party software for optimization and dynamics modelling will be introduced. And the course will be evaluated by experimentally implementing these optimal controllers on different simple platforms such as 2D walking robot, 1D hopper, segway, quadcopter, manipulation arms and model cars. This idea is inspired by my teaching experience when I was helping organize the class *Dynamics and Control of Walking Robots*, where I observed joyful moments when the students were surprised by the alignment of experiments and a mathematical equation. This could help the students to better develop interests in both math and engineering.

Advising Laboratory Students. I plan to build a robotics laboratory with passionate students from different backgrounds. Together we will bring robotics from science fiction to real life. Based on my years' working experience inside a remarkable laboratory, I will emphasize advising my future group of students to develop the following two qualities for our laboratory atmosphere:

1) *Developing experiments with rigor.* As a whole group, the research flow is an iterative process of designing experiments, observing patterns, deriving the math, synthesising new methods, and then again, experimental validation. Therefore, for each project the initial motivation and the final validation should both be through proper design of a robotic experiment. A systematic way of designing experiments and rigorous justification of each step in this process is an essential philosophy for the laboratory. This involves detailed documentation, rigorous comparison between experimental data and theoretical prediction, mathematical justification and interpretation, and transparent presentation of the results in scientific reports. It was through robotic experiments in my own academic journey, I obtained insights and satisfaction for my curiosity. And through rigorous justification, fruitful results and new research directions merged. Hence I am thrilled to formally propagate this research philosophy.

2) *Collaboration and Open Discussion.* The multidisciplinary nature of robotics dictates that collaboration across multiple fields, such as mechanical, aerospace, electrical, biology engineering, applied math, computer science, etc, is crucial to its success. Moreover, robotics is still a young discipline, despite its prosperity. Over reliance on one particular direction or tool can be risky. Throughout my own research, I have worked closely with experts in control theory, mechanical design, machine learning, dynamic simulation, optimization, etc. It has become my belief that collaboration is a key to bring robots to reality. I will also strongly encourage the students to take diverse courses from different departments over the course of research. In addition, mutual reliance of group members is an essential task for my advise in the group. In my future laboratory, I plan to take the responsibility to reach out to experts from other fields and establish multiple threads of collaboration, both internally and externally. Brain storm and open discussions on research will be conduced in a weekly group meeting and more frequent sub-group meetings.

Diversity Statement

Wen-Loong (Wenlong) **Ma**

Just as important as discovery and innovation, promoting equality and diversity is a major duty of academic society, which is also a fundamental characterization of civilization. I am excited to see that the University of Texas at Austin emphasizes the importance of diversity, equality and inclusion. I personally am dedicated to pushing for the *popularization of knowledge* and *science without borders* and make our academic community a fair and progressive place for all students, teachers, staff and faculty members.

I am from a rural, tight-knit village of 1500 people spanning eight generations in northern China. Most people, like my parents, barely finished the *nine-year compulsory education* (middle school graduate). I was the first in my family that went to college, and I am the only Ph.D. graduate in my village's entire history since 1900s. Therefore, not in a single moment of my life do I believe who you were, where you were from, or your race, social class, gender, sexual orientation, religion can stop you from being who you desire to be. I went through many difficulties growing up, both in terms of finance and lack of guidance. Ever since second grade, no one in my family have talked with me about my coursework. I am neither the smartest nor the most hard working member in my village, but I was lucky enough to meet many kind and open-minded friends, teachers, colleagues and advisors. I deeply believe many more people could get to where I am now, if only they were treated with an open-mind of fairness and patience. Now it is my job to return to society what I was privileged to receive. As a future faculty member, I will dedicate my career to protect, inspire and foster any student's dream, despite his or her background. I will especially aim to reduce inequality against students from marginalized groups and poverty.

My commitment to promoting the diversity, inclusion and belonging in academia and education is grounded in my experience working with people from diverse backgrounds and groups. As an international student, overcoming the barrier of language, culture and financial difficulties was a challenging experience for me. But through these experience, I become sensitive to the difficulties many underrepresented groups faced. I have worked and studied with people from diverse race, social classes, sexual orientations and genders, some of whom are my closest friends. I witness how can an open-minded fairness can make them truly peaceful and fully wake their potential. In the countless conversations and story sharing between us, I am always encouraging them to embrace the true self and break the barriers. Over the years, I realized that a lot of people still carry unconscious biases towards some group, which is largely due to misunderstanding and ignorance. I have never hesitated to openly support people from any marginalized groups such as the LGBT and speak for their situations. It has became my belief that these biases can be effectively dissipated through open-minded discussion and patient listening. Therefore, I will continue to support every individual to become whoever he/she desires to be in my future career, and provide help along their way. I also plan to actively engage myself in the diversity initiatives such as the The Division of Diversity and Community Engagement (DDCE) at University of Texas at Austin .

When I was a teaching assistant and guest lecturer at the California Institute of Technology, I spent many hours making sure students from underrepresented groups, such as women and African Americans, are heard and understand the knowledge. In my future teaching career, I plan to develop an inclusive, equal and friendly environment. I will continue to observe the learning progress of marginalized groups while making sure their privacy is respected and list my diversity statements and honor code on my course website. In addition, my research topic —robotics— is a unique area for its distinct appearance and broad attractiveness. During my Ph.D. study, I have put efforts in leading laboratory tours for various groups of people such as women, children, high school students to explain how robots can be utilized to improve daily life on a monthly basis. In my future research career, I will continue to promote more people's interests into robotics, control and dynamics, by reaching out to students from underrepresented groups and organizing workshops and laboratory visits. My own passion to study robotics and engineering was ignited by watching the documentary "Hey Mars" in 2004 when the Spirit Mars rover landed. Hence I strongly believe no matter what group they are from, through carefully prepared research demonstrations, inspirations and new ideas will disseminate through the next generation of students.

In summary, I am committed to pursuing efforts in contributing to equity, diversity and inclusion at UT Austin and promote students from every group into STEM education, through my daily tasks of teaching, research and service.