Katie Byl

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Education

Ph.D.	Mechanical Engineering (2008),	Massachusetts Institute of Technology
S.M.	Mechanical Engineering (2003),	Massachusetts Institute of Technology
S.B.	Mechanical Engineering (1999),	Massachusetts Institute of Technology

Areas of Research and Teaching Expertise

Robotics / Dynamics / Locomotion / Control / Autonomous Systems / Learning

Ph.D. Dissertation

Metastable Legged-Robot Locomotion. (Prof. Russ Tedrake, advisor; CS and AI Lab) Legged robots in real-world environments are inherently subject to significant stochasticity and underactuation. This work focuses on the problems of evaluation and optimization of control algorithms to produce fast, dynamic motions which are highly reliable. "Metastability" (literally, "'beyond stability") refers to the fact that absolute guarantees of stability (continuous walking, forever) are instead replaced with mathematically-derived estimates of reliability (e.g., the expected distance traveled before falling) and of the regions most frequently visited in state space. The tools developed are applicable more generally to a broader class of highly dynamic robotic and mechatronic systems.

Teaching Experience

- Numerical Marine Hydrodynamics, (Prof. Jerry Milgram), *MIT course 2.29/13.024*, Spring 2005.
  Lecture TA.
- Analysis and Design of Feedback Control Systems, (Prof. Dave Hardt), *MIT course 2.14*, Fall 2004.
  Lecture TA and laboratory instructor.
- Modeling Dynamics and Control I, (Prof. David Trumper), *MIT course 2.003*, Fall 2003.
  Recitation instructor, lab instructor, head TA.
- Mechanical Engineering Tools, (Prof. Doug Hart), *MIT course 2.670*, IAP (January term) 2002.
  MATLAB laboratory instructor.
- Modeling Dynamics and Control I, (Prof. David Trumper), *MIT course 2.003*, Fall 2001.
  Lab instructor, head TA.
- Modeling Dynamics and Control III, (Prof. Steve Dubowsky), *MIT course 2.010*, Spring 2001.
  Lecture TA.
- Mechanical Engineering Tools, (Prof. Sanjay Sarma), *MIT course 2.670*, IAP (January term) 2001.
  MATLAB laboratory TA.
- Modeling Dynamics and Control III, (Prof. Neville Hogan), *MIT course 2.010*, Fall 2000.
  Lecture TA.
- "How Things Work", *The Winsor School, Boston*, January 2000.
  Organized and taught a short (high school) course where we took apart household appliances (toasters, food processors, etc.) to reverse engineer how they work (and sometimes to fix them).
- Lego/LOGO robotics, (Fred Martin), *Boston Museum of Science*, 1990-91.
  Taught weekend classes where elementary students built and controlled their own Lego/LOGO robots. (Similar to, but pre-dating, the MindStorms controllers for Lego.)

Research Experience

Postdoctoral Fellow — 2008–present
Rob Wood (Harvard, EECS) — Harvard Microrobotics Laboratory

- Dynamic characterization of and control development for a flapping-wing MAV (micro air vehicle).
- Design of automation techniques for fabrication of micro-scale robotics.

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Doctoral Research 2005–2008
Russ Tedrake (MIT, CSAIL) MIT, Comp. Sci. and Artif. Int. Lab.
• Motion planning and code development for an autonomous quadruped on rough terrain. (DARPA Learning Locomotion project.)
• Approximate optimal control solutions for (compass gait) biped simulations on rough terrain.
• Development of statistical tools for analyzing metastable (long-living) walking gaits.

Research Consultant 2004-2005
Markus Zahn (MIT, EECS) GE Global Research
• Analytic and numeric (FEM) models to relate magnetic flux leakage (MFL) field signatures to corresponding spheroidal defects in a pipeline wall.

Research Assistant 2002-2003
Rich Mittleman (MIT) MIT, Kavli Inst. for Astr. & Space Research
• Modal analyses and vibration isolation work for the Laser Interferometer Gravitational-Wave Observatory (LIGO).

Masters Thesis 2001-2002
David Trumper (MIT, ME) MIT, Lab. for Manuf. and Prod.
• Design and control of a mobile inverted pendulum robot, similar to DEKA's Segway.
• Design and construction of modular laboratory equipment for the sophomore-level class Modeling Dynamics and Control I. Hardware are used to demonstrate near-ideal first- and second- and fourth-order dynamics, and to implement feedback control of a second-order system.

Research Consultant 1999
David Trumper (MIT, ME) Anorad
• Implementation and debugging of a control system for a magnetic bearing stage. Prototyped an initial controller for both single- and five-degree-of-freedom magnetic bearing systems with capacitive position sensing using the dSPACE (graphical block-diagram) environment and implemented a working design in assembly language.

Undergraduate Thesis 1999
David Trumper (MIT, ME) MIT, Dept. of Mech. Eng.
• Software implementation (low-level code and GUI) for a Dynamic Signal Analyzer (DSA) to run in Simulink/MATLAB. This software has been used throughout the last decade both in courses (Mechatronics, Dynamic Modeling and Control) and for in-lab research to obtain the empirical transfer function of a dynamic system within the dSPACE real-time controller board environment.

Undergraduate Research (UROP) 1997-1999
Michael Fripp and Nesbitt Hagood (MIT, AA) MIT, Active Materials and Structures Lab
• Developed FEM models in ANSYS for strutted aircraft bodies to calculate their acoustic modes and the corresponding stress distribution within the shells of these structures. The aim of the project was to determine the best placement for piezoelectric (PZT) actuators on the surface of an airframe body, for implementation of active control of the dominant acoustic modes.

Undergraduate Research (UROP) 1988
Robert Kelly (Harvard Dental School) MIT, Ceramics Processing Research Laboratory
• Manufactured and tested new ceramics for machineable (CAD/CAM) dental prosthetics. Materials testing (hardness, etc.), scanning electron micrographs (SEM) to document crystal structures.

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Honors and Awards

Meredith Kamm Award for **outstanding graduate student** for teaching, 2003

Dept. Service Award for **excellence in teaching**, 2002. (Mech. Eng. Dept. nominee and runner-up for institute-wide Goodwin medal for excellence in teaching.)

Whitelaw Award for "**originality in design**" in 2.70 (now 2.007) Introduction to Design, 1989, for design of a fast, telescoping robot arm.

Research Science Institute (RSI), 1986. One of approx. 75 HS juniors (US and abroad) selected and participating. (http://www.cee.org/rsi/)

Selected Coursework

2.737 Mechatronics
2.032 Dynamics
2.42 Thermodynamics
2.52 Mod. and Approx. of Thermal Proc.
2.51 Heat and Mass Transfer
2.96 Design Seminar
2.097J Optimization Methods
6.881 Underactuated Robotics
6.777 Design and Fab. of MEMS Devices
6.642 Continuum Electromechanics
6.641 Electromagnetic Fields, Forces and Motion
6.013 Electromagnetic Fields and Energy
6.431 Prob. Sys. Anal. and App. Prob.
15.076 Statistical Theory

Publications and Presentations for Katie Byl (nee Lilienkamp)

- **Journal and Magazine Publications**

- Nanayakkara T, T Villabona, K Byl and R Tedrake. "Experimental Metastability Analysis of a Rimless Wheel." To be submitted in *Journal of Experimental Mechanics* (Special Issue on Locomotion), June 2009.

- Byl K and R Tedrake. "Metastable Walking Machines." To appear in *International Journal of Robotics Research*, Aug 2009.

- Lundberg K H, K A Lilienkamp and G Marsden. "Low-cost magnetic levitation project kits." *IEEE Control Systems Magazine* 24(5): 65–69 Oct 2004.

- Abbott R, et al. "Seismic isolation enhancements for initial and advanced LIGO." *Classical and Quantum Gravity* 21(5): 515–5921 Sp. Iss. SI Mar 7 2004.

- **Conference Publications**

- Byl K, A Shkolnik, S Prentice, N Roy and R Tedrake. "Reliable dynamic motions for a stiff quadruped." *Proc. of the 11th Int. Symposium of Experimental Robotics (ISER 2008)*, Springer Tracts in Advanced Robotics (STAR), 54:319–328, 2009. **Winner of IFRR Student Fellowship Award.**

- Byl K and R Tedrake. "Approximate optimal control of the compass gait on rough terrain." *Proc. of the IEEE Int. Conf. on Robotics and Automation (ICRA)*, pp. 1258–1263, 2008.

- Byl K and R Tedrake. "Metastable walking on stochastically rough terrain." *Proc. of Robotics: Science and Systems (RSS)*, 2008.

- Robertson N A, et al. "Seismic isolation and suspension systems for Advanced LIGO." *Proc. SPIE Conf. on Gravitational Wave and Particle Astrophysics Detectors*, 5500(1):81–91, Sep 2004.

- Lilienkamp K A and K H Lundberg. "Low-cost magnetic levitation project kits for teaching feedback system design." *Proc. of American Control Conference (ACC)*, 2::1308–1313, 2004.

- Rosales E, B Ito, K Lilienkamp and K Lundberg. "An open-ended ball-balancing laboratory for undergraduates." *Proc. of American Control Conference (ACC)*, 2:1314–1318, 2004.

- Trumper D L, S A Nayfeh, and K A Lilienkamp. "Projects for Teaching Mechatronics at MIT." *Proc. of the 8th Int. Conf. on Mechatronics.* Enschede, The Netherlands, 2002.

- Fripp M L, D Q O'Sullivan, S R Hall, N W Hagood and K Lilienkamp. "Testbed design and modeling for aircraft interior acoustic control." In *Proc. SPIE Conf. on Smart Structures and Materials 1997: Smart Structures and Integrated Systems*, 3041(1):88-99, Jun 1997.

• **Unpublished Conference Presentations**

- Byl K and R Tedrake. "Dynamically Diverse Legged Locomotion for Rough Terrain." Presented at *IEEE Int. Conf. on Robotics and Automation (ICRA)*, Kobe, Japan. May 2009. [video presentation]

- Byl K and R Tedrake. "Control of the compass gait on rough terrain." Presented at *Dynamic Walking*, Delft, The Netherlands. May 2008.

- Byl K and R Tedrake. "Stability of passive dynamic walking on uneven terrain." Presented at *Dynamic Walking*, University of Michigan. May 2006.

• **Invited Talks**

May 2009	University of Illinois at Urbana-Champaign, Dept. of Aerospace Engineering
May 2009	Stanford University, Dept. of Aeronautics and Astronautics
May 2009	Arizona State University, Dept. of Mechanical and Aerospace Engineering
April 2009	University of Massachusetts at Amherst, Dept. of Mech. and Ind. Eng.
April 2009	U. of Cal. at Santa Barbara, Center for Control, Dyn. Systems and Comp.
April 2009	San José State University, Dept. Mechanical and Aerospace Engineering
April 2009	Northeastern University, Dept. Mechanical and Industrial Engineering
April 2009	Massachusetts Institute of Technology, Dept. of Mechanical Engineering
March 2009	Worcester Polytechnic Institute, Dept. of Mechanical Engineering
March 2009	University of New Hampshire, Dept. of Mechanical Engineering
February 2009	Carnegie Mellon University, Dept. of Mechanical Engineering
October 2008	Cornell University, Dept. of Theoretical and Applied Mechanics (TAM)
August 2008	Harvard, Microrobotics Laboratory
June 2007	Boston Dynamics, Inc. (Waltham, MA)

Professional Experience

Programming Consultant 2005
Jerry Milgram, MIT MIT, Ocean Eng. Dept.
• Editing MATLAB code and creating stand-alone executable. Improved the user interface for and sped up (by a factor >100) MATLAB code to solve for pressure forces and resulting dynamic motions of sea vessels given a user-defined frequency spectrum of ocean waves.

Programming Consultant 2005
Mark Brown, MIT MIT, Academic Media Prod. Services (AMPS)
• Created a stand-alone executable application from existing MATLAB code to analyze airline passenger disruption due to flight delays. Software for an Operations Research textbook.

Research Consultant 2003
David Trumper (MIT, ME) Hale and Dorr LLP
• Patent/literature search relating to vibration isolation of photolithography stages. Research involved finding and documenting a wide range of electro-mechanical systems in which a reaction mass is used to reduce vibration.

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Other Experience

Professional Gambler 1992–1999
Strat. Inv. / Amphib. Inv. / Omega Inv. "MIT Blackjack Team"

• Member of several limited liability corporations, popularly called the MIT Blackjack Team. We invested in team play of blackjack, using card counting and other strategies (e.g., shuffle tracking) to produce average annual returns of about 100% (doubling the money invested before taxes). I wrote software to calculate such things as: look-up tables for estimating profitability, given particular playing conditions (e.g., how crowded a table is, number of decks remaining unplayed, count, etc.); derivation of basic strategy for Spanish 21; analysis of card-spacings in a typical multi-pass Las Vegas casino shuffle; and calculating the value of and optimal play for various special rules offered as casino promotions.

Other positions include:
- CAD Illustrator (Product Genesis, Cambridge, MA)
- Glassblower's Asst. (Penrose Glass, Waltham, MA)
- Mechanical Engineering Intern (TRW, Washington, DC)
- Laboratory Aide (US Geological Survey, Natl Hdqrs, Reston, VA)

Technical Skills

- MATLAB (very high proficiency)
- C,C++ (several yrs exp.; grader at MIT)
- SolidWorks (basic familiarity)
- AutoCAD (professional exp.)
- Machine shop proficiency (basic)
- CNC machine code (gcode)
- Assembly and machine code experience
- Circuit design (basic)
- Real-time controller design experience with: PC104, dSPACE, LabView
- FEM (Finite element modeling): ANSYS, Ansoft (for E&M, in particular), ADINA

Abstract of Doctoral Dissertation: "Metastable Legged-Robot Locomotion"

A variety of impressive approaches to legged locomotion exist; however, the science of legged robotics is still far from demonstrating a solution which performs with a level of flexibility, reliability and careful foot placement that would enable practical locomotion on the types of rough and intermittent terrain humans negotiate with ease on a regular basis. In this thesis, we strive toward this particular goal by developing a methodology for designing control algorithms for moving a legged robot across such terrain in a qualitatively satisfying manner, without falling down very often. We feel the definition of a meaningful metric in locomotion is a useful goal in and of itself: specifically, the mean first-passage time (MFPT), also called the mean time to failure (MTTF), is an intuitively practical cost function to optimize for legged robots. We propose that the nature of walking generally results in dynamics with a fast mixing time, where initial conditions are largely "forgotten" within 1 to 3 steps, and that as a result, one may approach a near-optimal solution for motion planning using only a short time-horizon look-ahead. Our method involves planning one "motion" (which may consist of a single leap or of a small number of simple steps) at a time, such that the end-state of one motion has a high level of repeatability and accuracy and can be mated to future actions as an initial state for one or more possible motion types. Although we openly recognize that there are important classes of optimization problems for which long-term planning is required to avoid "running into a dead end" (or off of a cliff!), we demonstrate that a large class of terrains can in fact be successfully negotiated with a surprisingly high level of long-term reliability by selecting the short-sighted motion with the greatest probability of success.